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Electrical conductivity from 200 to 1000°C for 264 rocks  
and minerals from data in Parkhomenko and Bondarenko, 1972

by

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EARTH SCIENCE LAB.**

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This report summarizes and plots the data from a book (in Russian) that is not generally available. The data are for 264 rock and mineral measurements of electrical conductivity from 200 to 1000°C as tabulated in the appendices 1 through 14 of:

Пархоменко, Э.И., Бондаренко, А.Т., 1972, Электрорпроводность Горных Порода при Высоких Давлениях и Температурах, Москва: Издательство Наука

Parkhomenko, E.I. and Bondarenko, A.T., 1972, Electroconductivity of rocks at high pressures and temperatures, Moscow: Nauka Press, 279p.

The tables from the above appendices were entered into the U.S.G.S. Petrophysics Laboratory computer. Plots (all on the same scale) were produced of conductivity versus reciprocal temperature for each measurement. Statistical summaries were compiled for the activation energy as histograms over 100°C temperature intervals. Summary plots were produced for conductivity versus reciprocal temperature for measurements of common rock or mineral types.

There is no indication in the original Russian text as to the measurement procedure for each sample. The following are assumed: all measurements were performed in the same manner, samples were dry in air, and the measurements were at or below 1 kHz in a two-terminal sample holder. Measurements under other conditions are also tabulated elsewhere in the book, but are not amenable to ready comparison with the data from the appendices.

Therefore, the measurements herein from the appendices tables are useful for comparative purposes within the context of this dataset. However, the reliability of the measurements is unknown and therefore extreme care must be taken when comparing these data with other measurements.

Figures 1 through 9

Figures 1 through 8 illustrate the histograms compiled from all tabulated data of the activation energies from the temperature dependence of the electrical conductivity over 100°C intervals assuming

$$\sigma = \sigma_0 e^{-E/kT}$$

where  $k$  is Boltzmann's constant,  $T$  is temperature in Kelvin,  $E$  is activation energy in eV,  $\sigma$  is the electrical conductivity at  $T$ , and  $\sigma_0$  is the electrical conductivity at infinite temperature. Anomalous values of activation energy (greater than 0 eV or less than -3 eV) were excluded.

Figures 1 through 8 are all on the same horizontal scale (-3 to +1 eV) with the main plot showing the histogram. The main histogram has a vertical scale in percent samples in a given bin versus the total number of samples. Underneath the peak (mode) is given the histogram activation energy and percentage. Across the top of the histogram is given the temperature interval, the division ("div.") in eV of the bins in the histogram for counting purposes, the total number of samples ("no."), the skewness of the distribution, the median, mode, mean, and standard deviation (for definitions of these terms, see any statistics text or Meyer, 1975). The histogram is plotted with bar graphs for each bin count and also a smooth curve that is the running average over nearest neighbor bins.

The inset plot in the upper right corner of the histogram is the cumulative percentage of samples (vertical) that fall between the mode plus  $x$  and the mode minus  $x$  where  $x$  is the horizontal scale. Several points on the resultant curve are also labelled in these terms; thus in Figure 1, 71 percent of all activation energies in the 200 to 300°C interval lie between  $-0.58+0.26$  and  $-0.58-0.26$  eV.

Figure 9 summarizes the histogram results in a plot of the mean and modal activation energies versus temperature. The solid line is the mean with the box outlining the temperature interval and plus or minus one standard deviation. The dashed line is the mode.

Figure 1

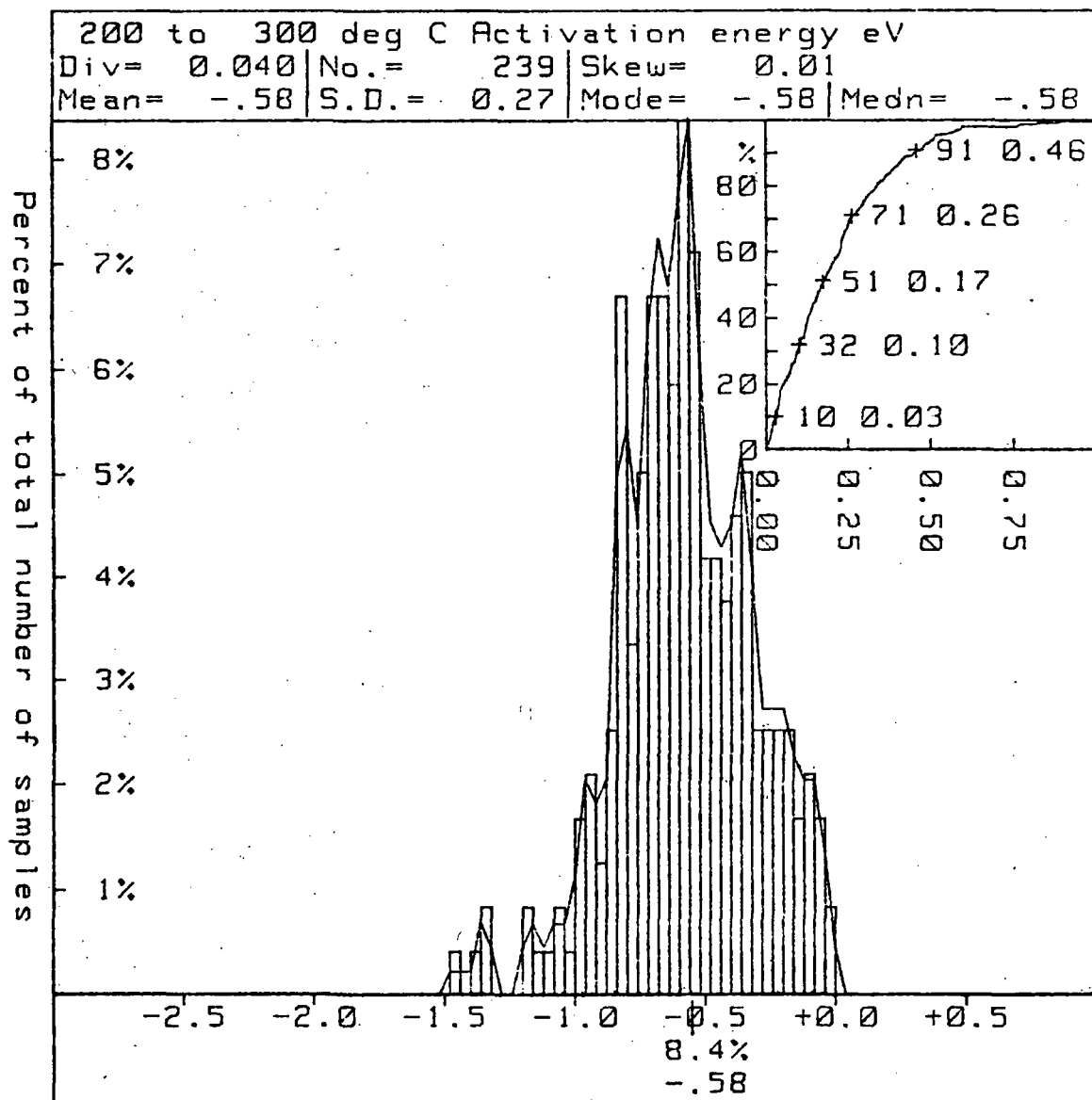


Figure 2

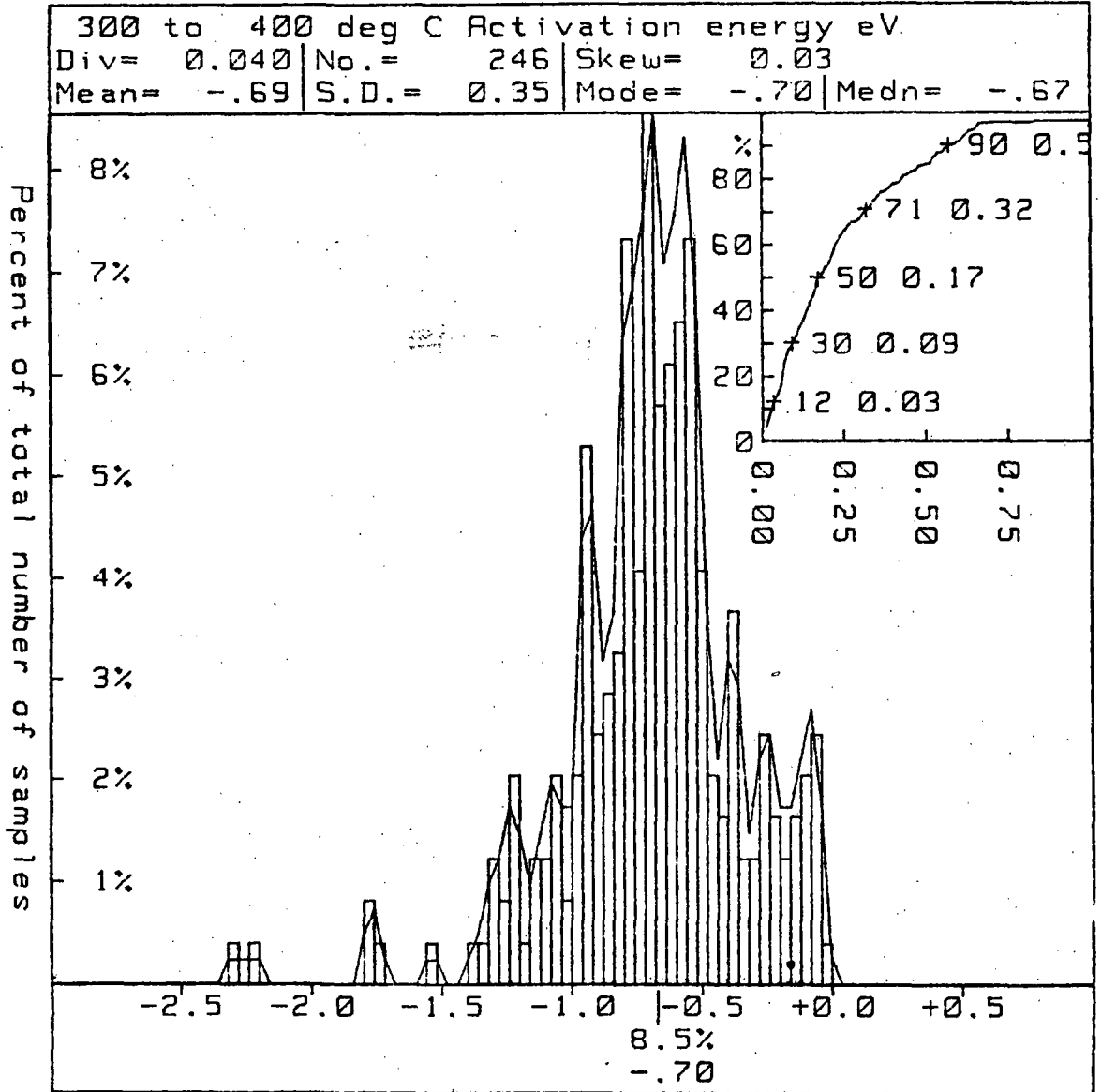


Figure 3

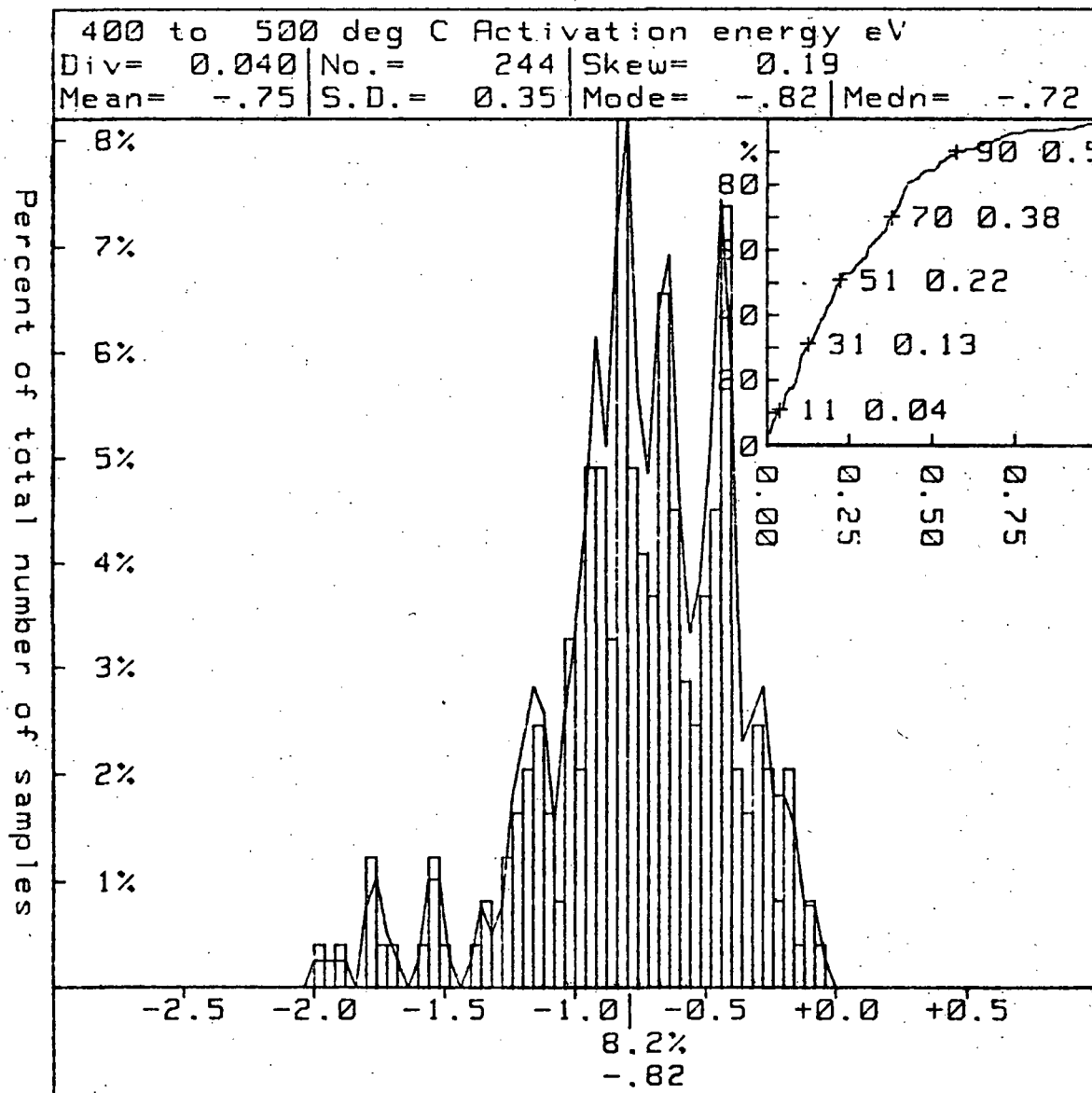


Figure 4

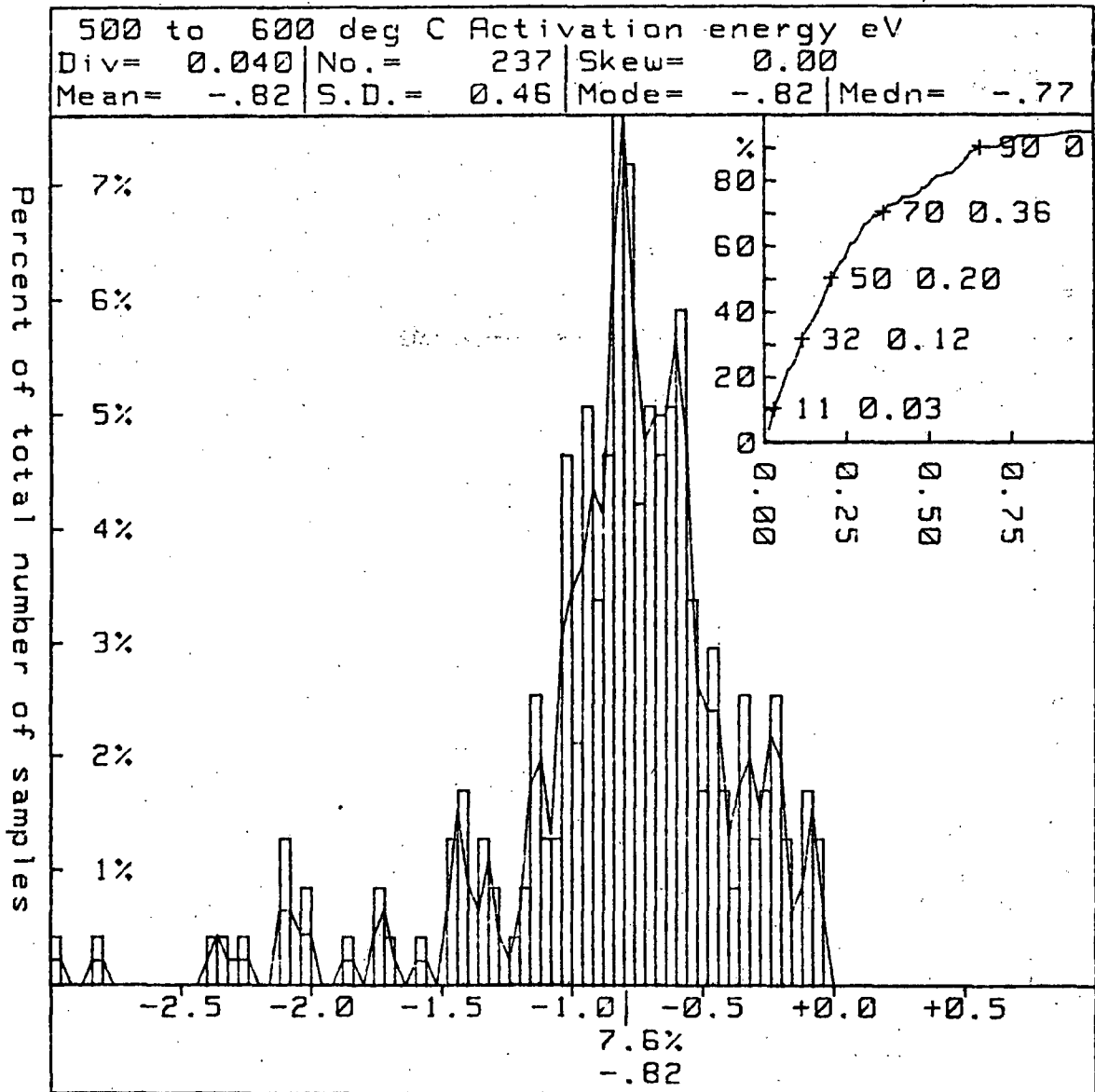


Figure 5

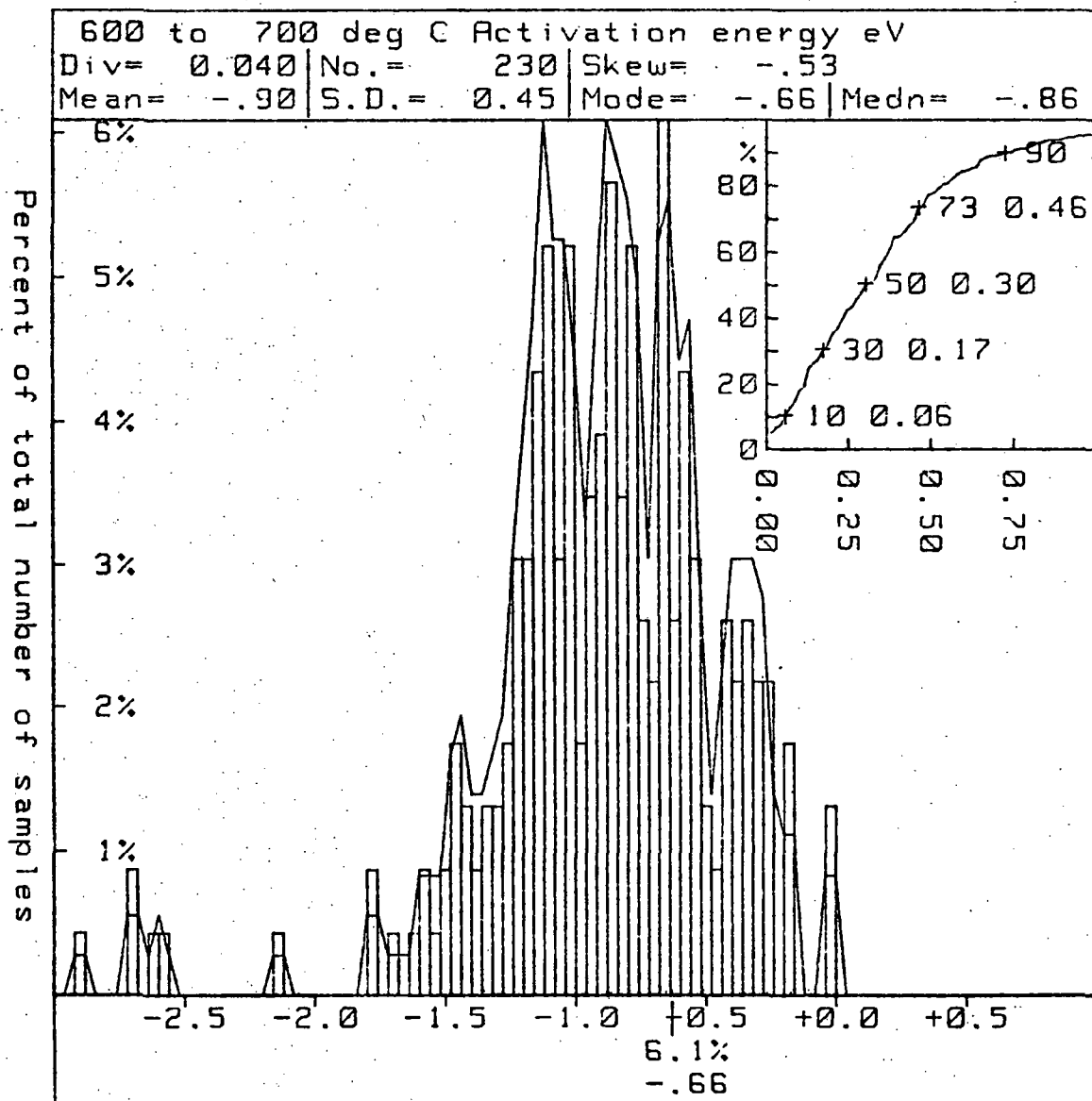




Figure 6

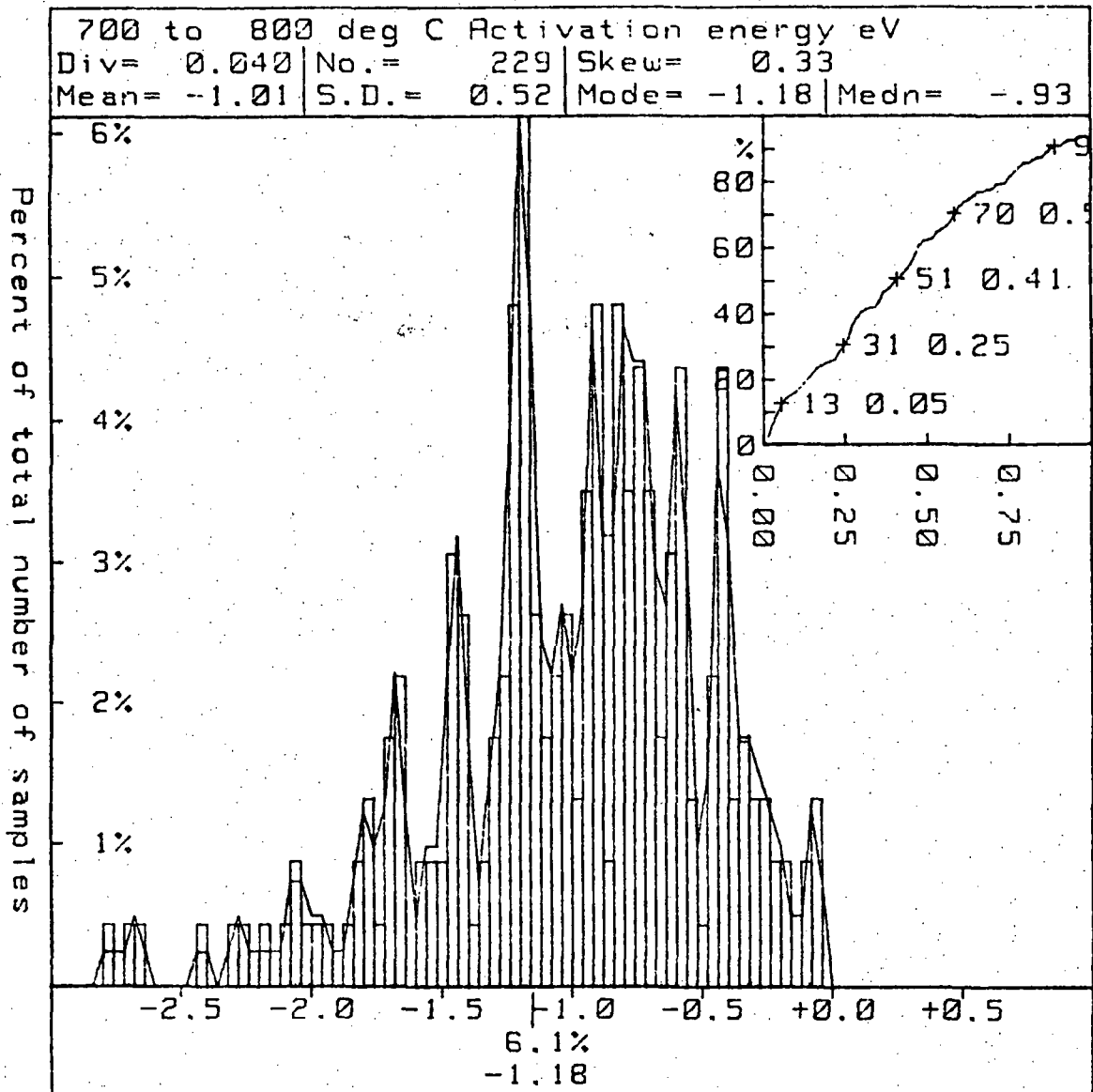


Figure 7

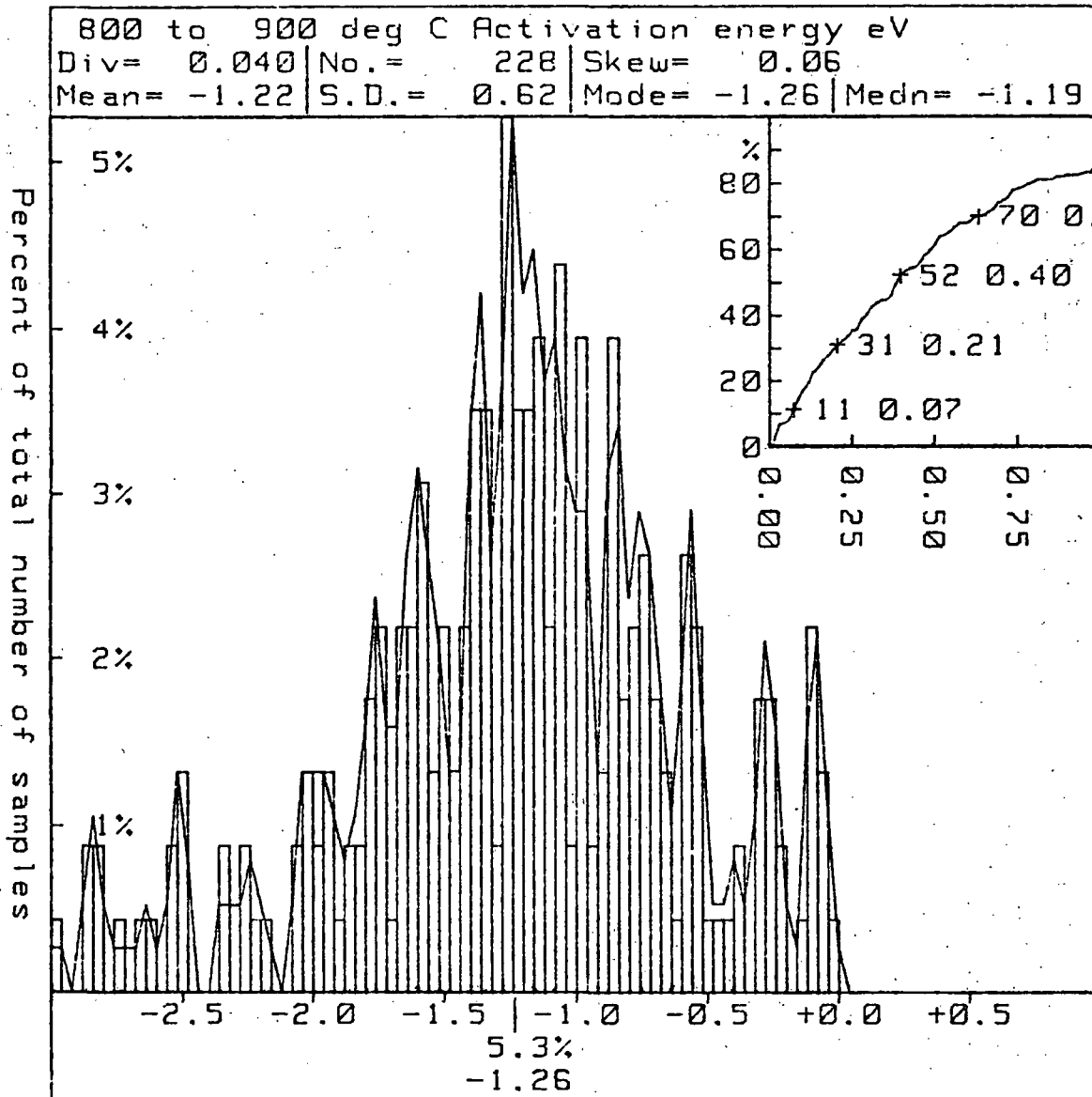


Figure 8

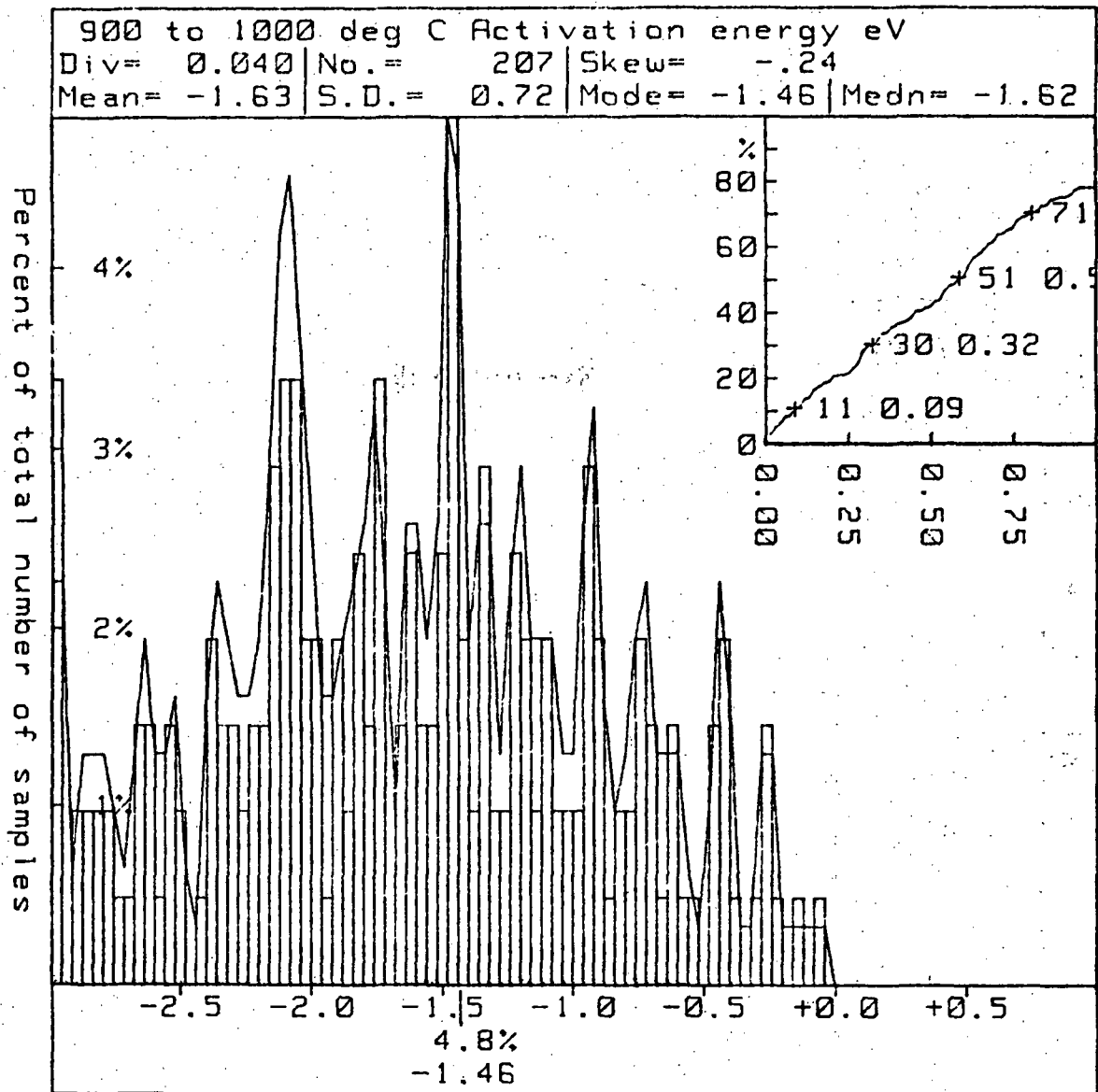
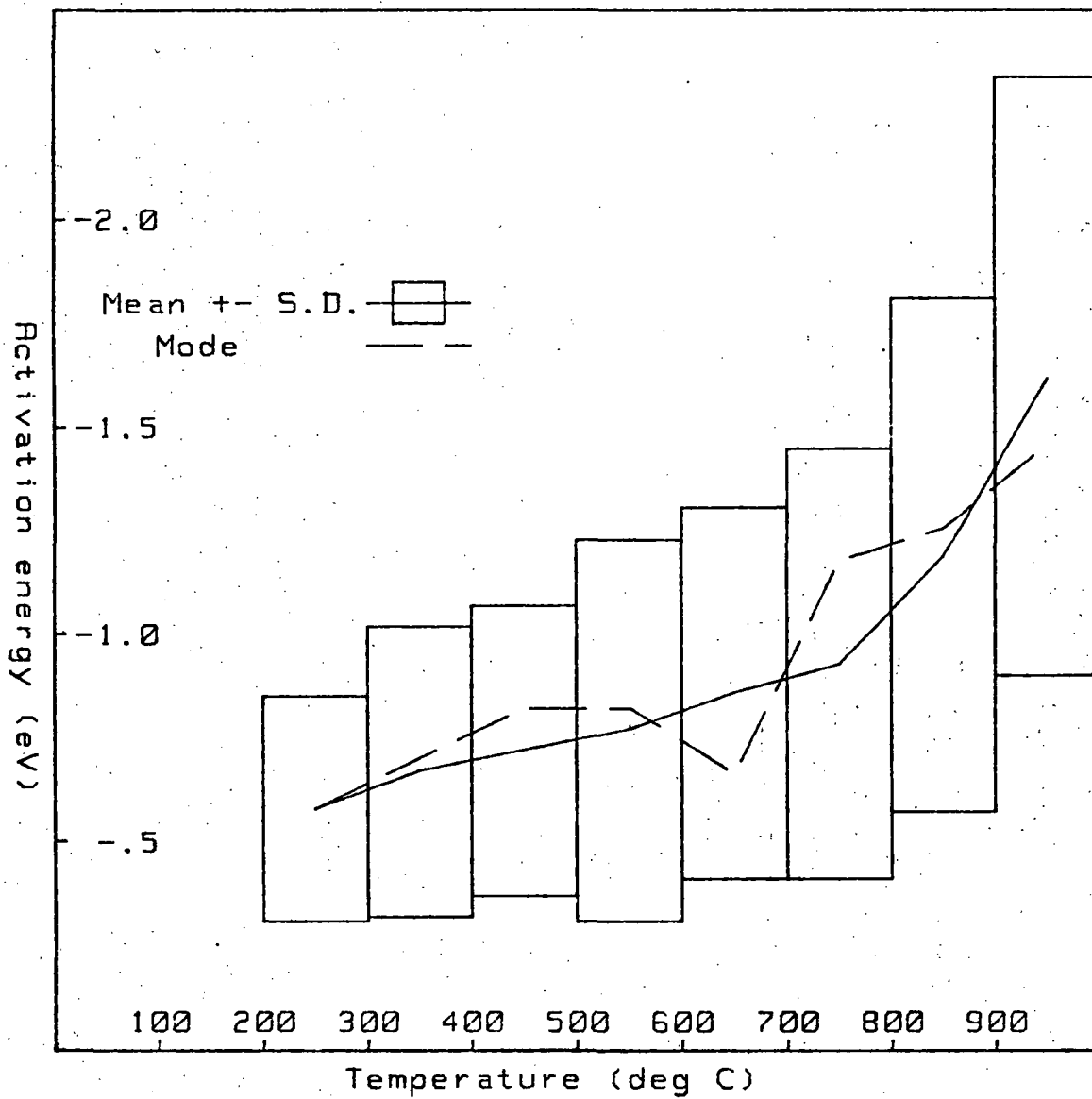


Figure 9



Figures 10 through 26

Figures 10 through 26 combine onto summary plots the electrical conductivity versus reciprocal temperature for rocks and minerals of a common type. In each figure, the vertical scale is  $\log_{10}$  electrical conductivity (mho/m) while the horizontal scale is  $1000/T$  where  $T$  is in Kelvin. Across the top of the figure is an alternate temperature scale in degrees Celsius.

Figure 10 Albite

Figure 11 Amphibole

Figure 12 Andesite

Figure 13 Basalt

Figure 14 Diabase

Figure 15 Diorite

Figure 16 Dolerite

Figure 17 Dunite

Figure 18 Gabbro

Figure 19 Gneiss

Figure 20 Granite

Figure 21 Nepheline

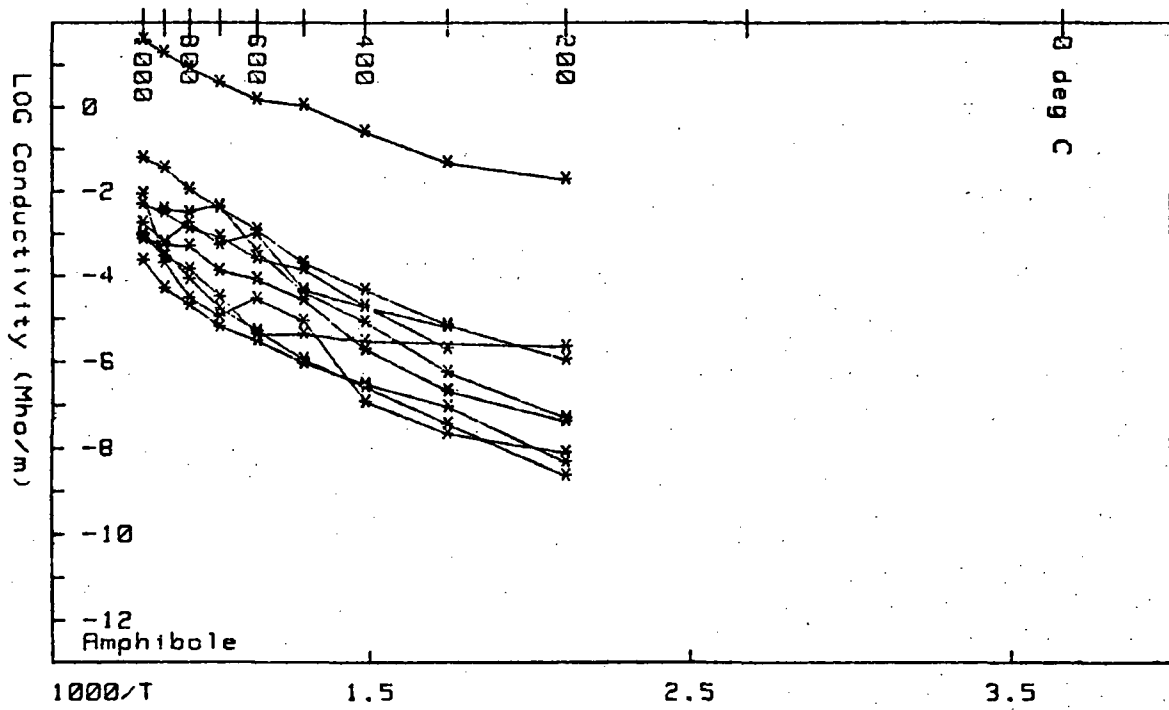
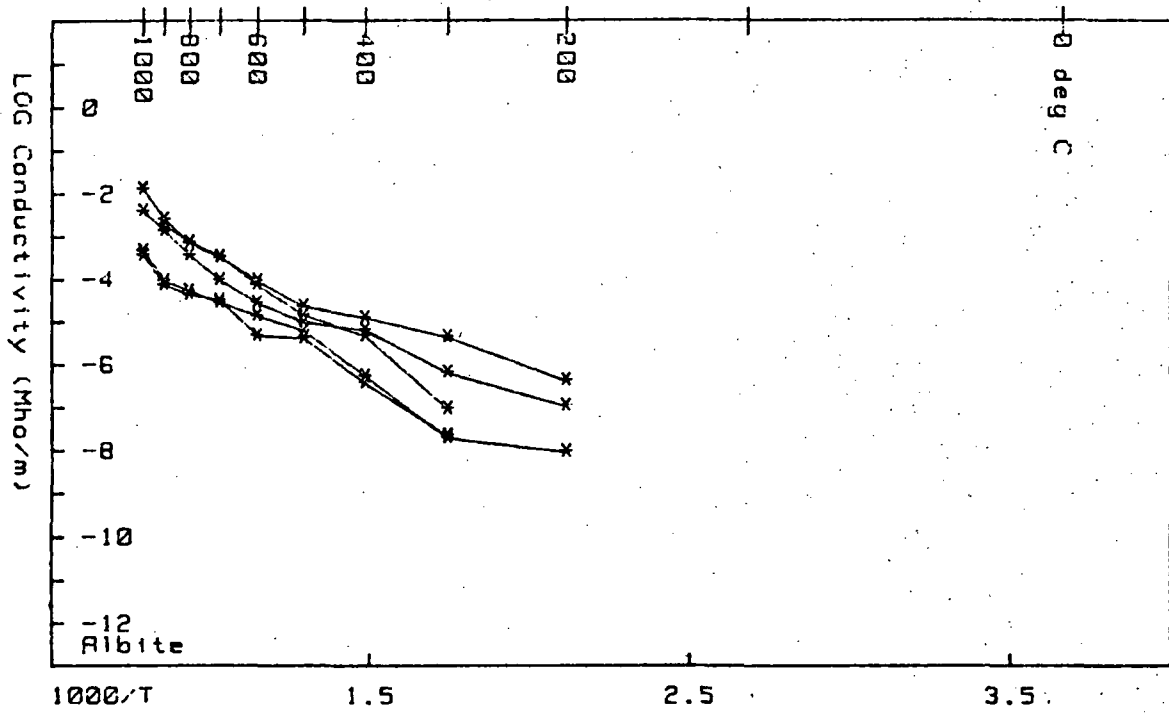
Figure 22 Olivine

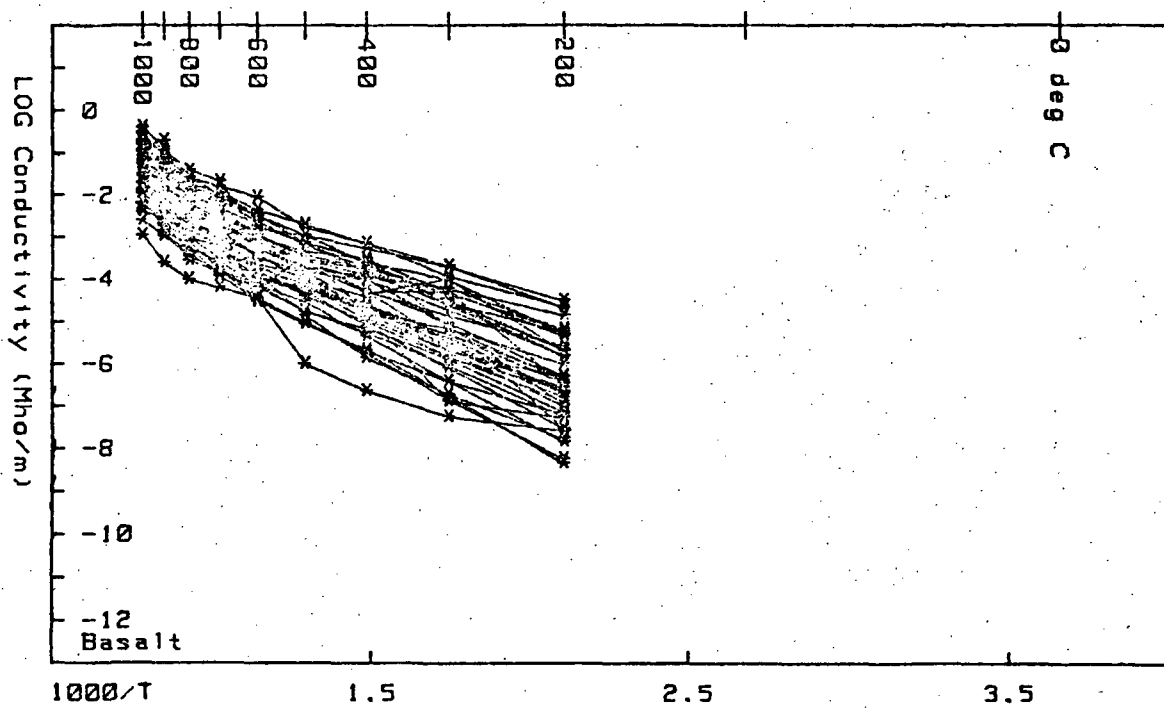
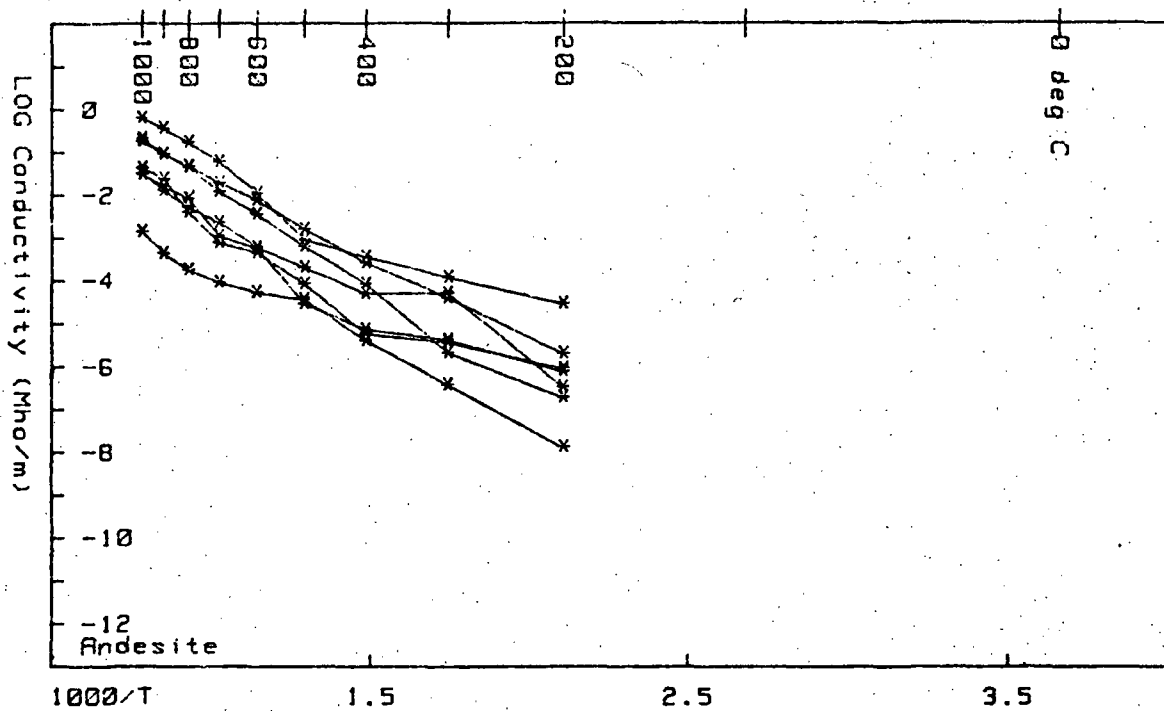
Figure 23 Peridotite

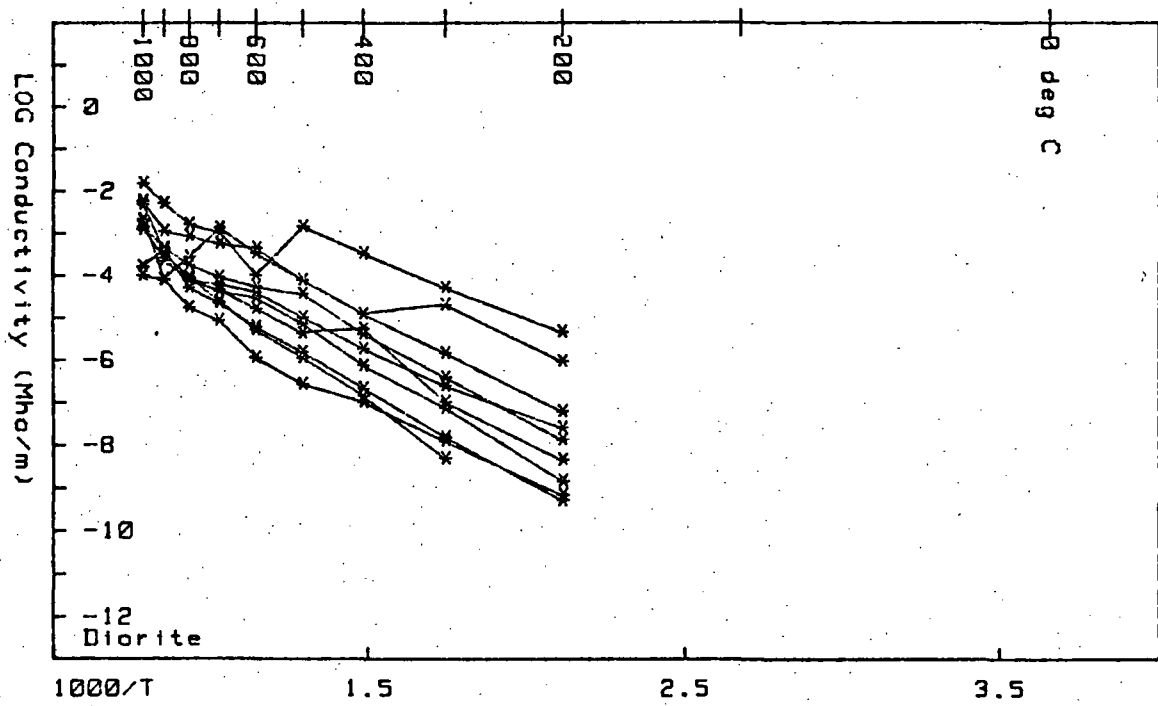
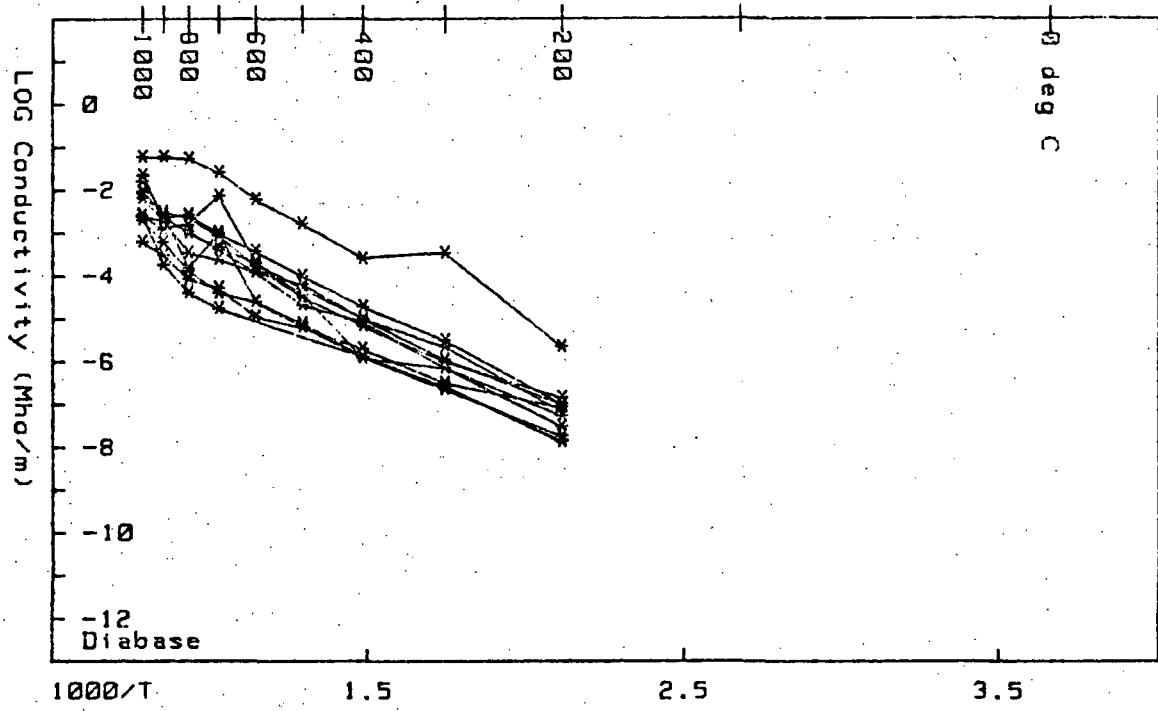
Figure 24 Plagioclase

Figure 25 Pyroxene

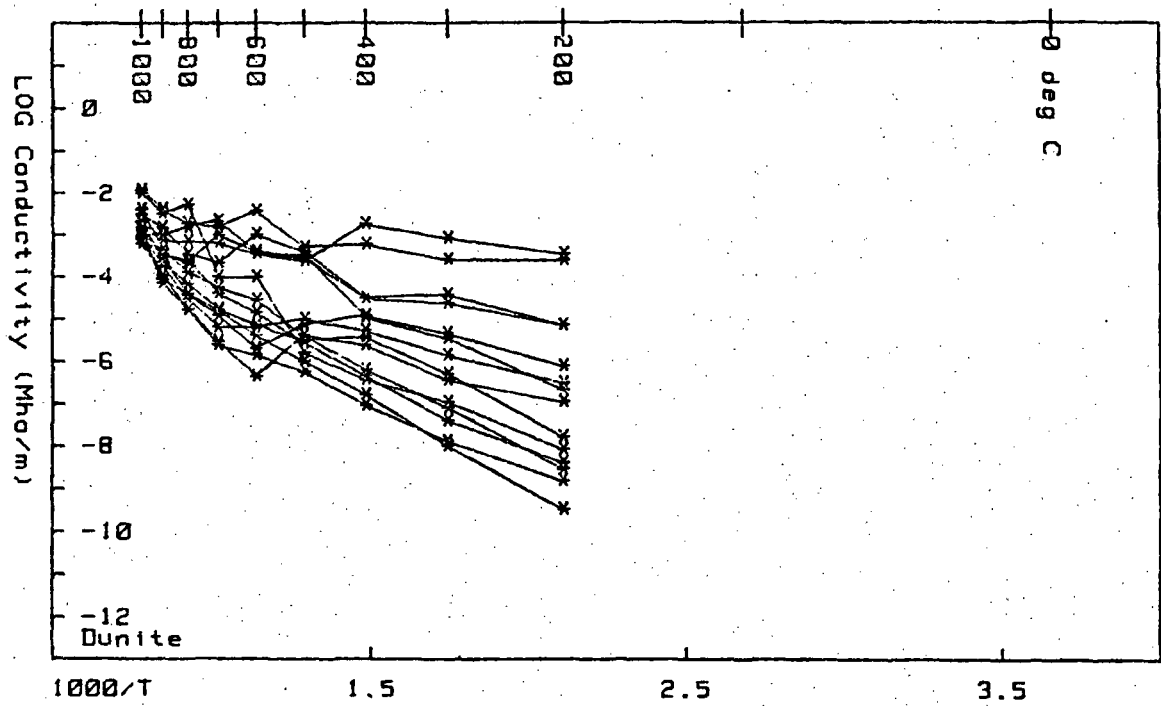
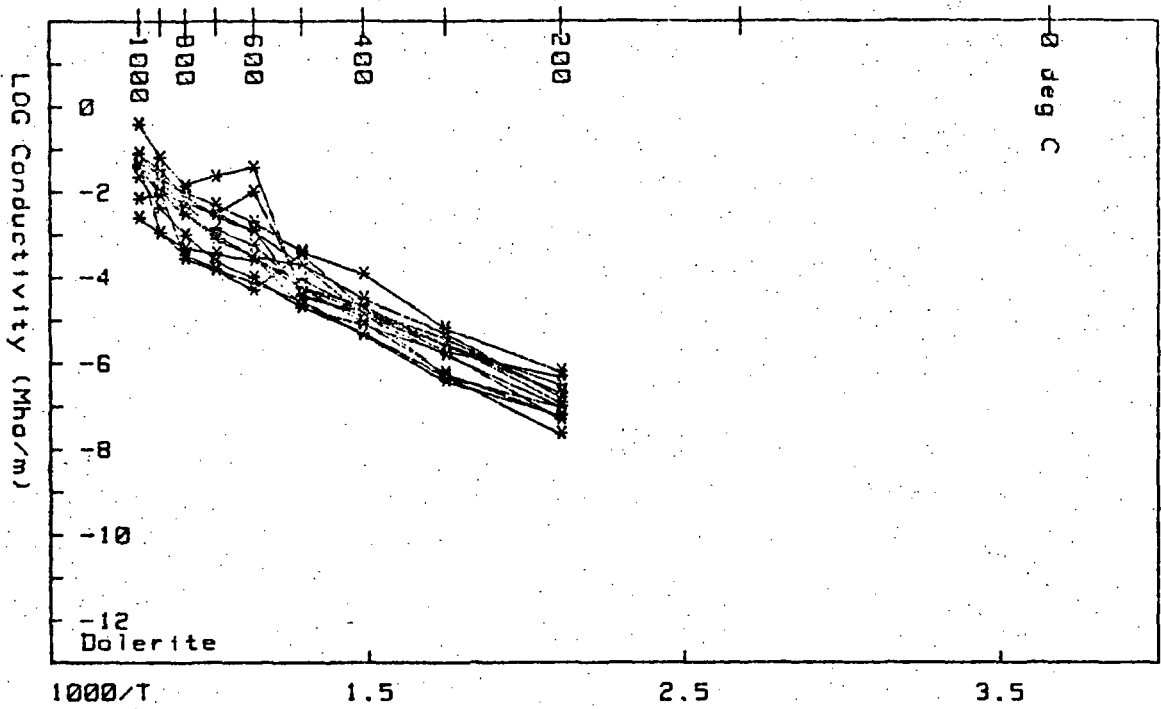
Figure 26 Serpentine



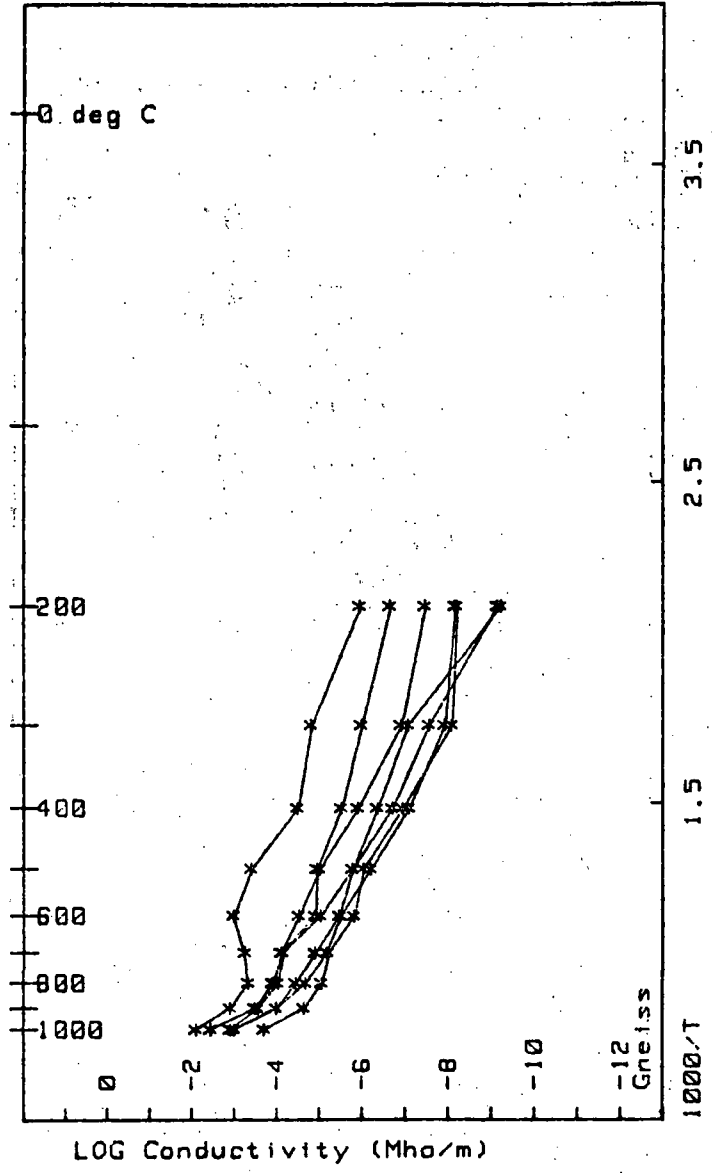
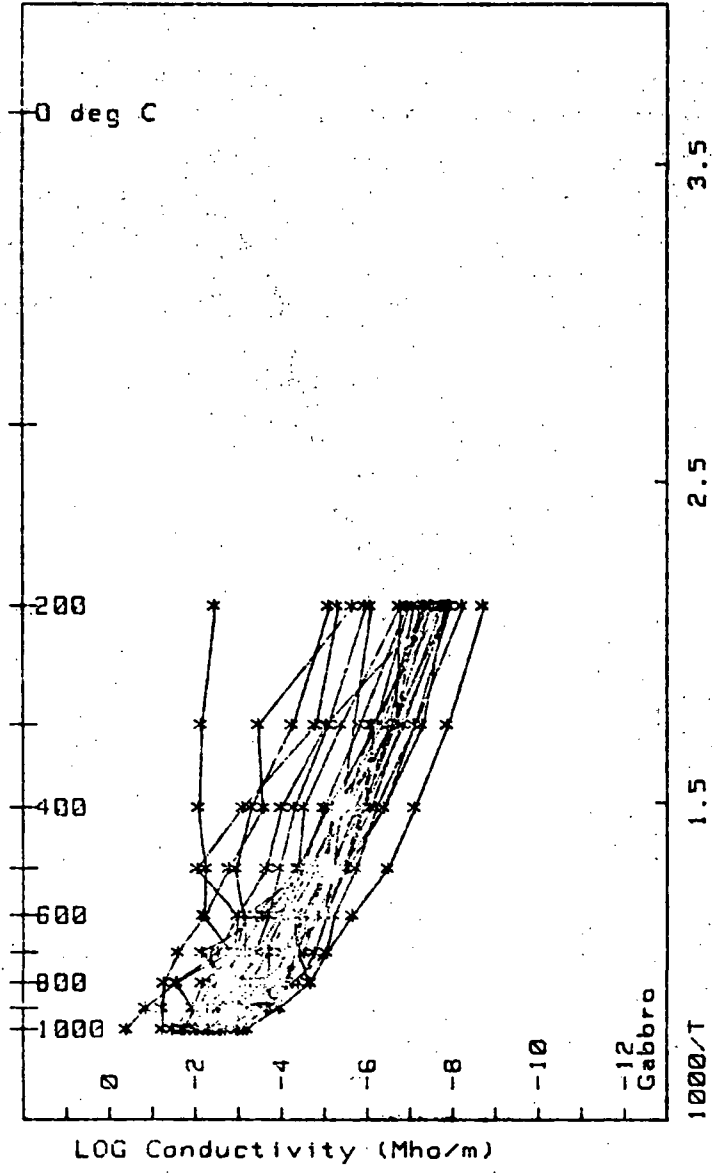


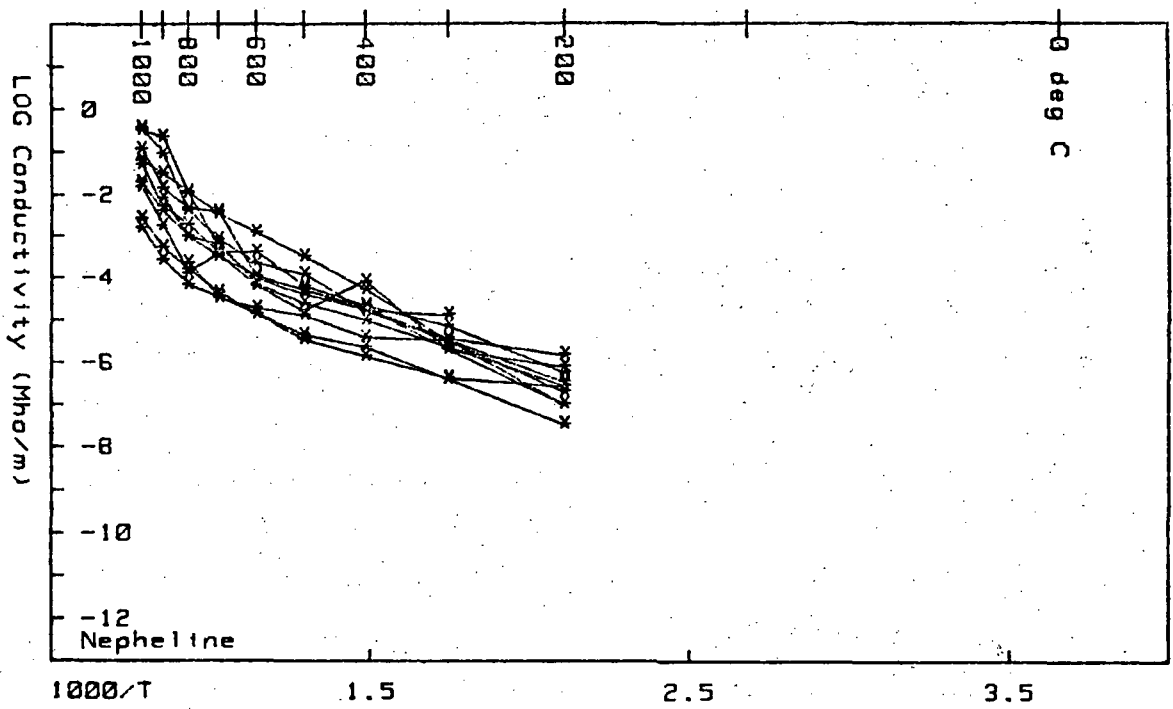
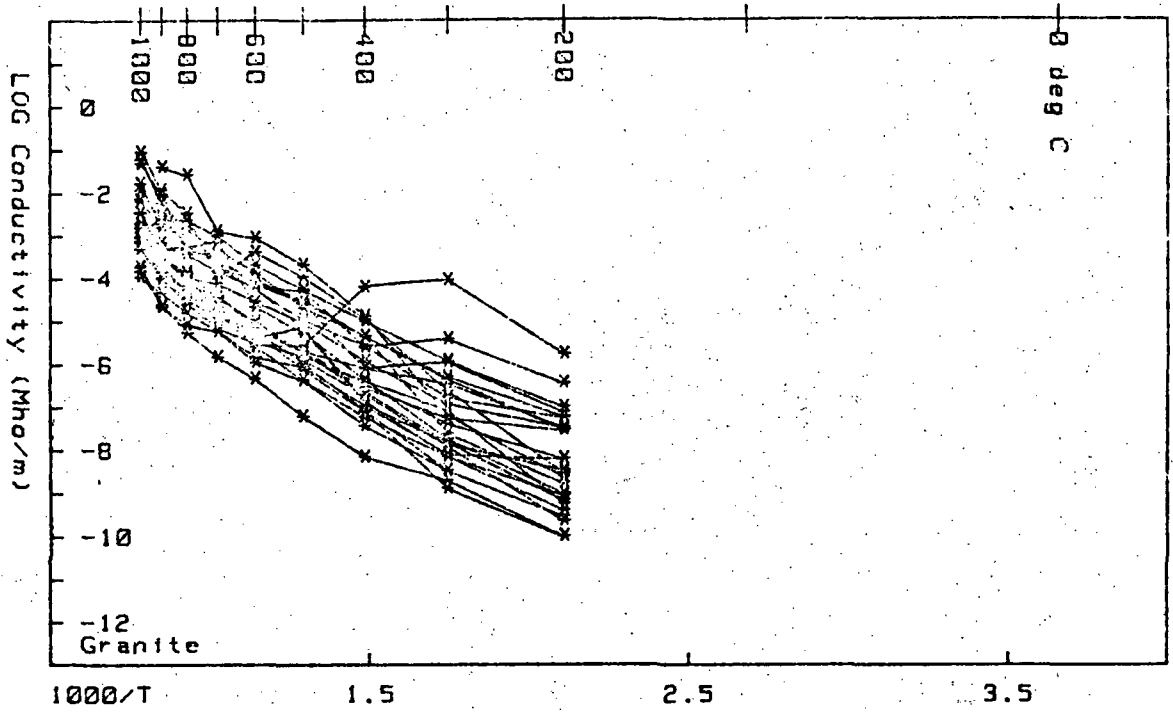


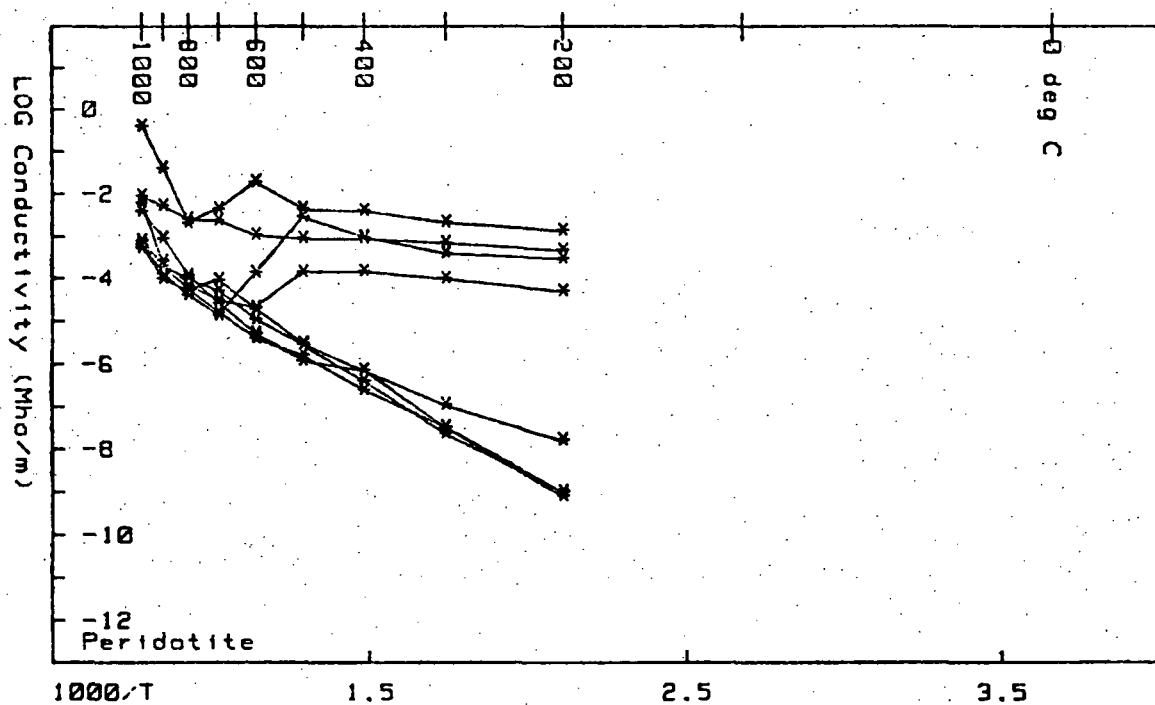
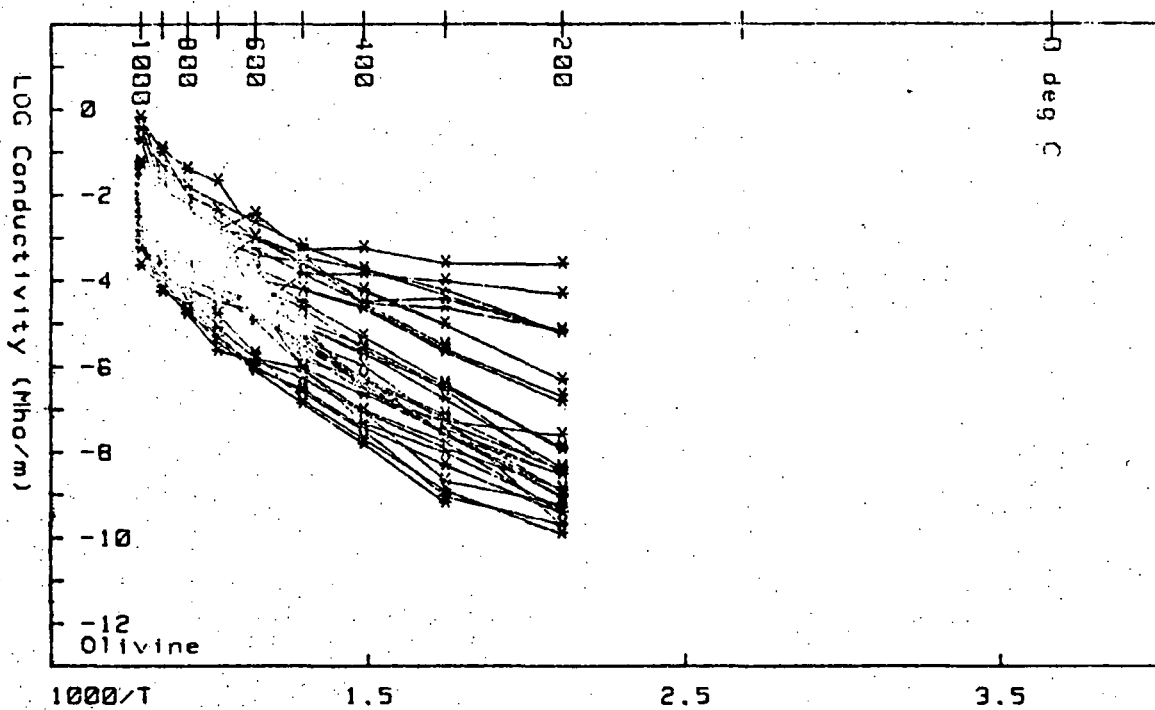




Figures 18 and 19







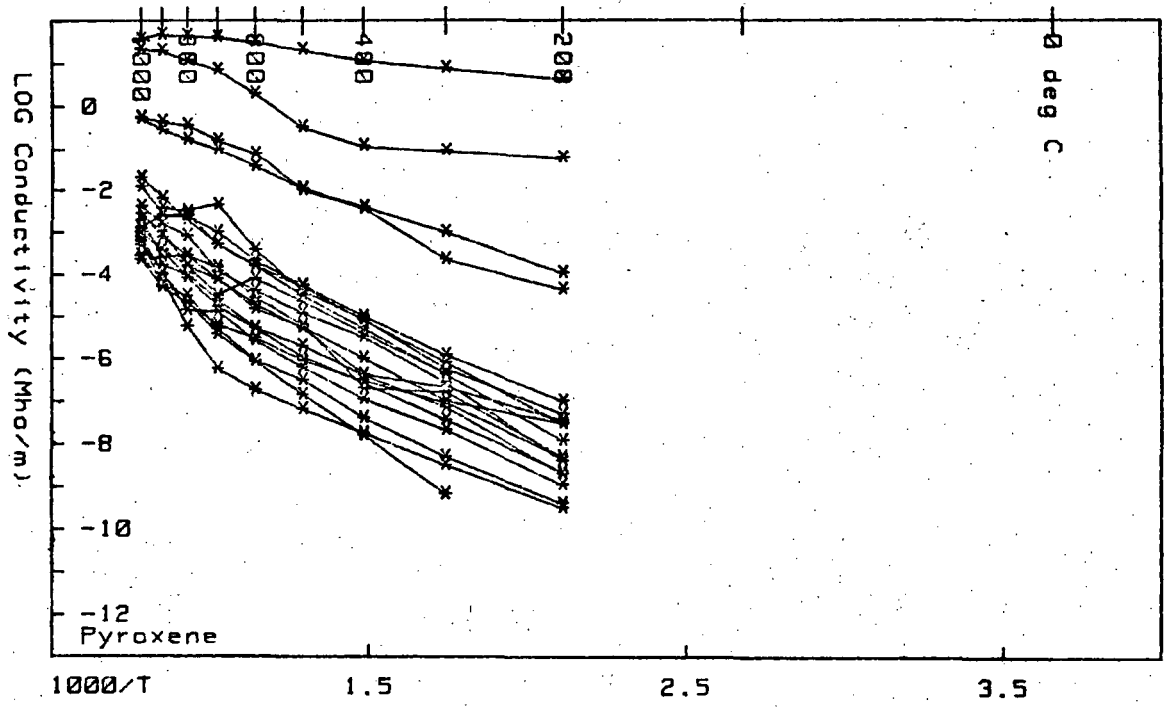
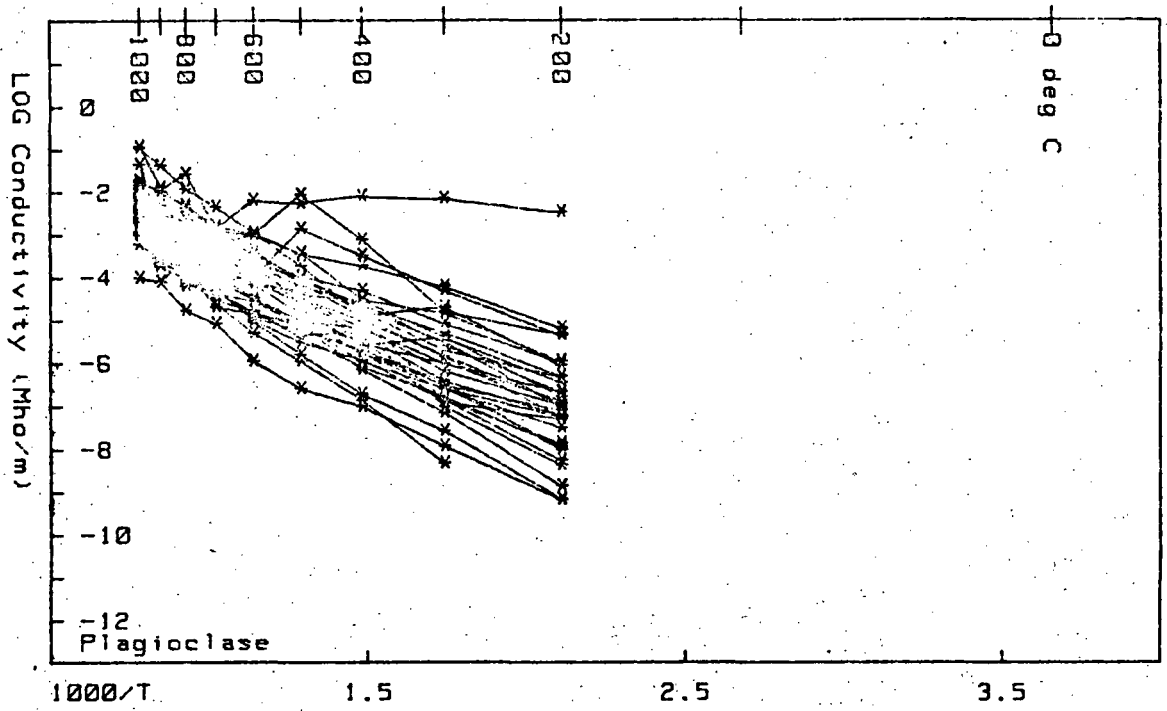
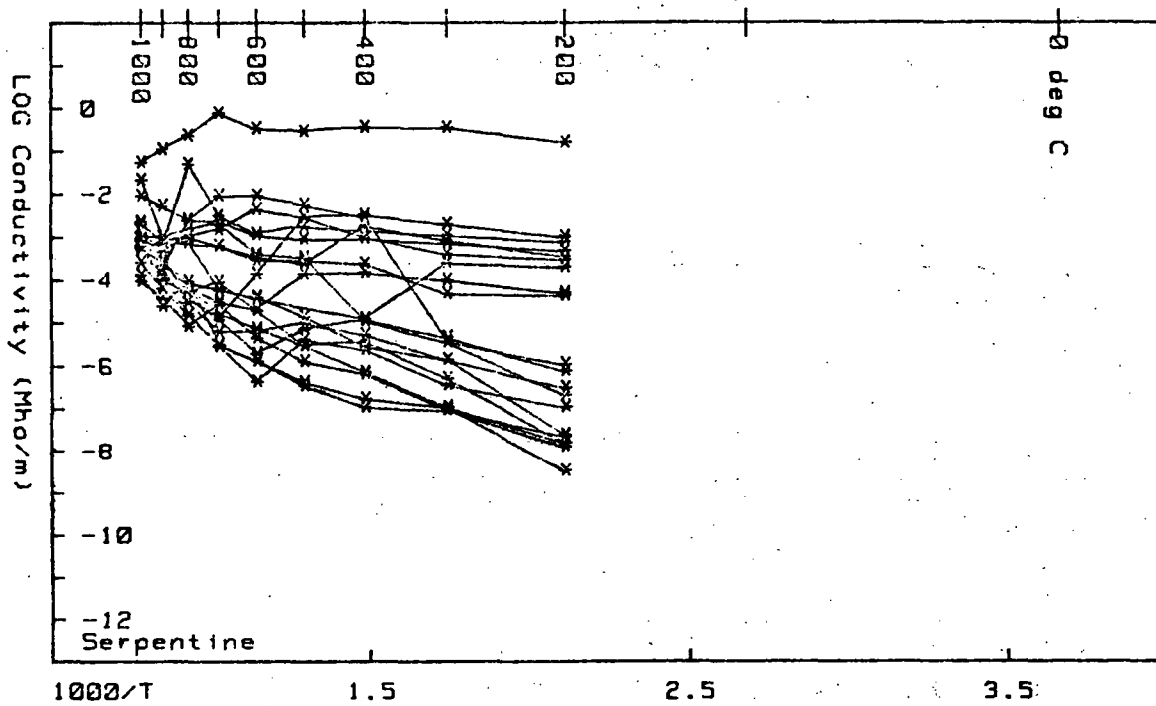


Figure 26



Reference

Meyer, S.L., 1975, Data Analysis for Scientists and Engineers:  
Wiley: New York, 513 p.

Appendix

The following pages contain individual plots of the separate rock and mineral measurements. The plots are in alphabetical order with a list of the rocks and minerals on the next page. The figure numbers appear in each plot in the lower left corner.

FIGURE 1	Actinolite
FIGURE 2	Aegirine
FIGURE 3	Aegirine nepheline 739
FIGURE 4	Albite
FIGURE 5	Albite
FIGURE 6	Albite
FIGURE 7	Albite (gabbroic) 2865 Cataclastic Plagioclase
FIGURE 8	Albite Foiyait 1441
FIGURE 9	Amphibole (pyroxenite) 2482
FIGURE 10	Amphibole (pyroxenite) 2500
FIGURE 11	Amphibole 1603
FIGURE 12	Amphibolite (chloritic) 2490
FIGURE 13	Amphibolite (gabbroic pyroxene) 2621
FIGURE 14	Amphibolite 2034
FIGURE 15	Amphibolite 861
FIGURE 16	Anamesit 237-21
FIGURE 17	Andesite 1010
FIGURE 18	Andesite 1011
FIGURE 19	Andesite 1374
FIGURE 20	Andesite 1694
FIGURE 21	Basalt (andesitic) 1373
FIGURE 22	Basalt (doleritic) 1295 Plagioclase
FIGURE 23	Basalt (doleritic) 1312 Plagioclase
FIGURE 24	Basalt (doleritic) 1319
FIGURE 25	Basalt (gabbroic) 5/166
FIGURE 26	Basalt (nepheline) 7
FIGURE 27	Basalt (nepheline) 969
FIGURE 28	Basalt (olivine plagio-porphyritic) 271
FIGURE 29	Basalt (olivine) 1104
FIGURE 30	Basalt (olivine) 14
FIGURE 31	Basalt (olivine) 1483
FIGURE 32	Basalt (olivine) 3-11
FIGURE 33	Basalt (olivine) 625/4
FIGURE 34	Basalt (olivine) 7-1 Plagioclase
FIGURE 35	Basalt (olivine) 780/1b
FIGURE 36	Basalt (pyroxene) 651e
FIGURE 37	Basalt (trachyte) 1103
FIGURE 38	Basalt 1109 Plagioclase
FIGURE 39	Basalt 1131
FIGURE 40	Basalt 161
FIGURE 41	Basalt 175-5
FIGURE 42	Basalt 19-3
FIGURE 43	Basalt 19-5
FIGURE 44	Basalt 2/1
FIGURE 45	Basalt 3-3
FIGURE 46	Basalt 3/2
FIGURE 47	Basalt 313
FIGURE 48	Basalt 4/1
FIGURE 49	Basalt 5/22
FIGURE 50	Basalt 506
FIGURE 51	Basalt 517
FIGURE 52	Basalt 518
FIGURE 53	Basalt 520

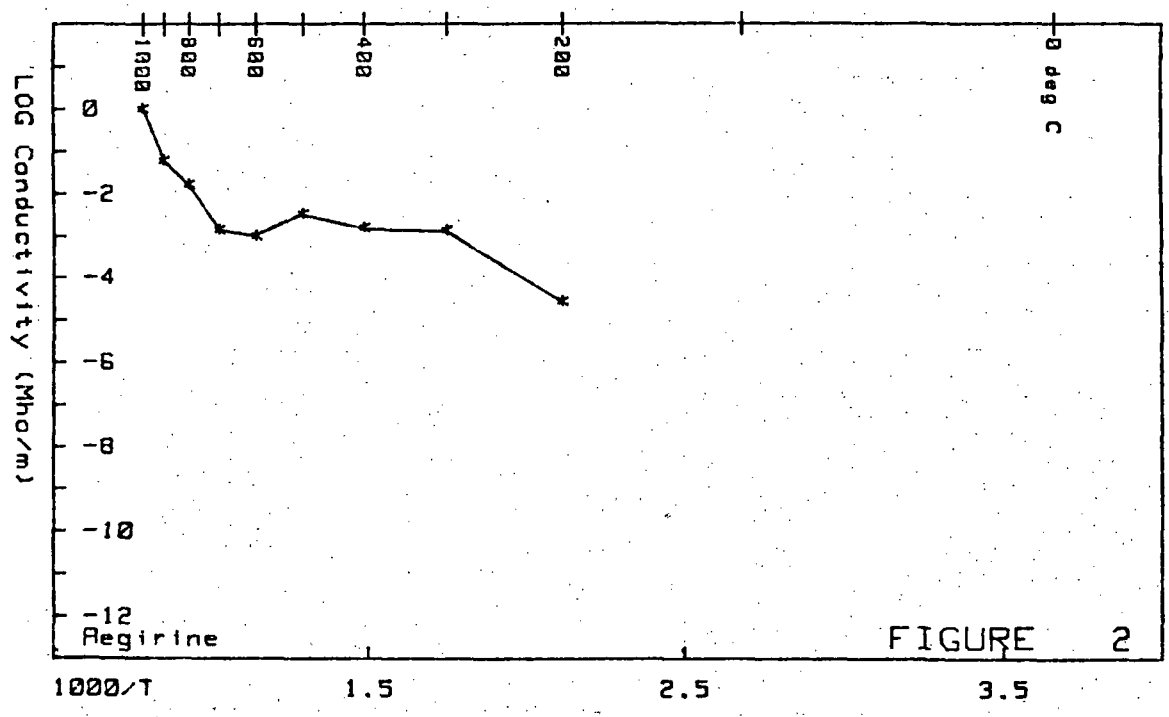
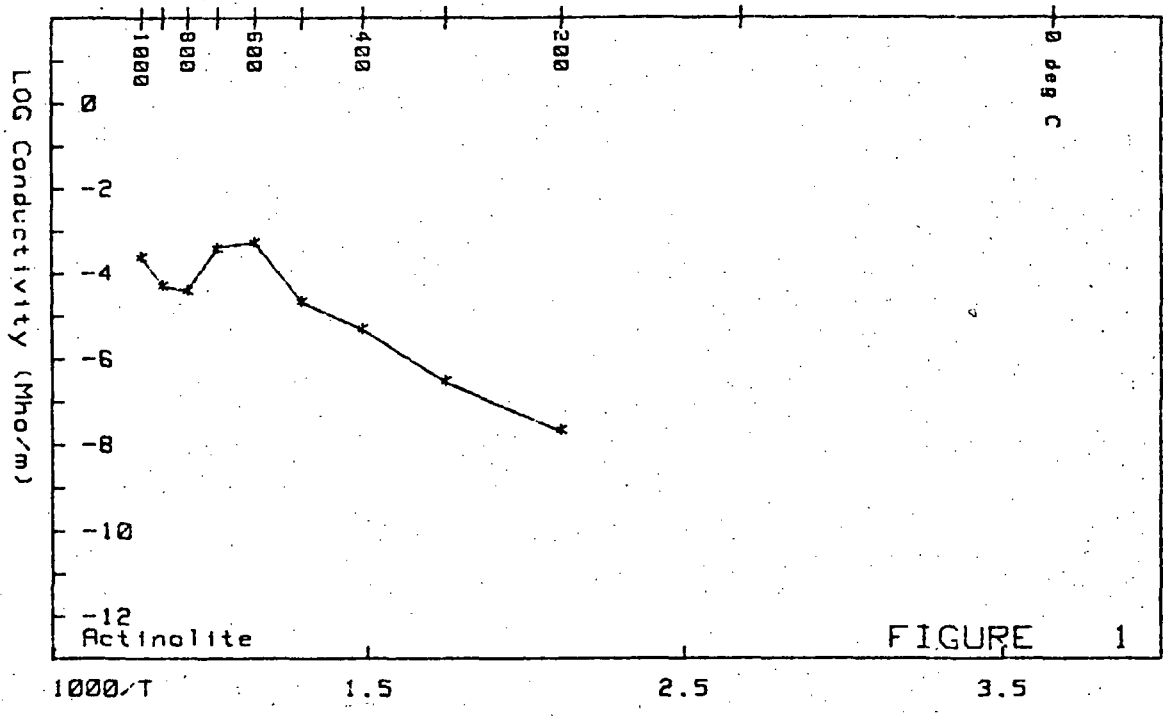


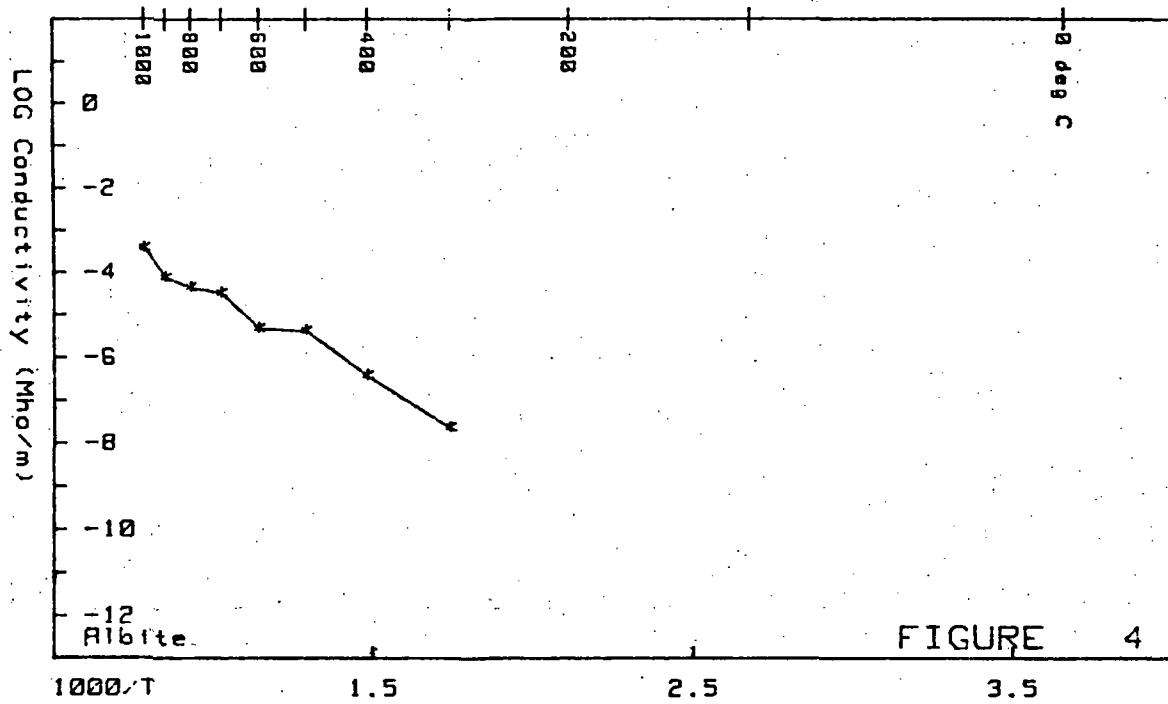
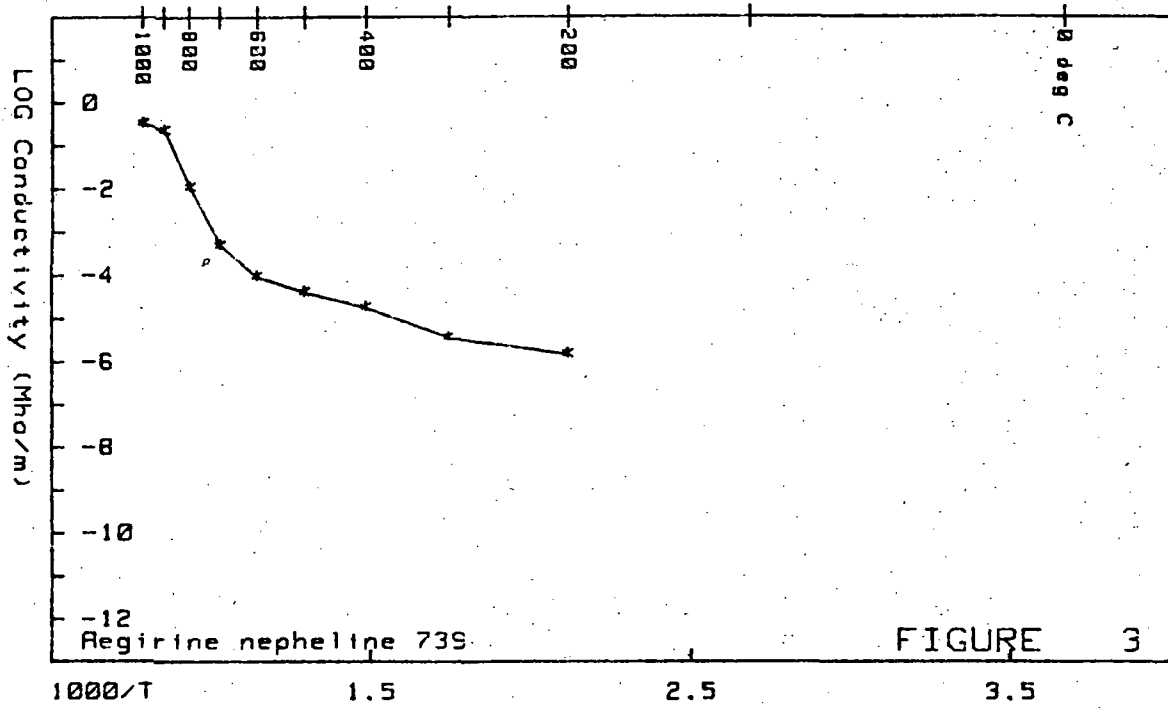
FIGURE 54	Basalt 522
FIGURE 55	Basalt 523 Plagioclase
FIGURE 56	Basalt 525
FIGURE 57	Basalt 528a
FIGURE 58	Basalt 531 Plagioclase
FIGURE 59	Basalt 54
FIGURE 60	Basalt 54a
FIGURE 61	Basalt 5d
FIGURE 62	Basalt 5e
FIGURE 63	Basalt 51
FIGURE 64	Basalt 602
FIGURE 65	Beryl
FIGURE 66	Beryl
FIGURE 67	Biotite
FIGURE 68	biotite (gabbroic) 2861 Plagioclase
FIGURE 69	Dacite (andesitic) 1379
FIGURE 70	Danburite
FIGURE 71	Danburite
FIGURE 72	Danburite
FIGURE 73	Diabase (gabbroic) 173-11
FIGURE 74	Diabase (gabbroic) 2617
FIGURE 75	Diabase (gabbroic) 2618
FIGURE 76	Diabase (gabbroic) 2863 Plagioclase
FIGURE 77	Diabase (gabbroic) 42b
FIGURE 78	Diabase 1102
FIGURE 79	Diabase 21a Plagioclase
FIGURE 80	Diabase 4a Plagioclase
FIGURE 81	Diabase 5a
FIGURE 82	Diabase porphyry 650
FIGURE 83	Diopside
FIGURE 84	Diopside
FIGURE 85	Diorite 166 Plagioclase
FIGURE 86	Diorite 2600 Plagioclase
FIGURE 87	Diorite 2619
FIGURE 88	Diorite Plagioclase
FIGURE 89	Diorite porphyry 80-160 Plagioclase
FIGURE 90	Dolerite
FIGURE 91	Dolerite
FIGURE 92	Dolerite (trachyte) 9
FIGURE 93	Dolerite 1052
FIGURE 94	Dolerite 108
FIGURE 95	Dolerite 29
FIGURE 96	Dolerite 60
FIGURE 97	Dolerite 60p
FIGURE 98	Dolerite 61b
FIGURE 99	Dolerite 83
FIGURE 100	Dunite (pirod-spinel) 1497
FIGURE 101	Dunite (pirod-spinel) 1498
FIGURE 102	Dunite (serpentinized) 2606
FIGURE 103	Dunite 2614 Serpentine
FIGURE 104	Dunite 5556 Olivine
FIGURE 105	Dunite 5577 Olivine
FIGURE 106	Dunite 6669 Serpentine

FIGURE 107 Dunite 6671 Serpentine  
FIGURE 108 Dunite 6672 Serpentine  
FIGURE 109 Dunite 7198 Serpentine  
FIGURE 110 Dunite 7199 Olivine  
FIGURE 111 Dunite Olivine  
FIGURE 112 Dunite ac-151  
FIGURE 113 Dunite spinel 2162  
FIGURE 114 Eclogite 2177  
FIGURE 115 Eudialyte  
FIGURE 116 Fayalite  
FIGURE 117 Fayalite  
FIGURE 118 Flourite  
FIGURE 119 flourite  
FIGURE 120 Forsterite  
FIGURE 121 Gabbro 12e Plagioclase  
FIGURE 122 Gabbro 14e Plagioclase  
FIGURE 123 Gabbro 168  
FIGURE 124 Gabbro 1a  
FIGURE 125 Gabbro 2608  
FIGURE 126 Gabbro 2609  
FIGURE 127 Gabbro 2615 Plagioclase  
FIGURE 128 Gabbro 2620  
FIGURE 129 Gabbro 272  
FIGURE 130 Gabbro 458  
FIGURE 131 Gabbroic cataclastic 2790 Plagioclase  
FIGURE 132 Gabbroic cataclastic 2794 Plagioclase  
FIGURE 133 Gabbroic cataclastic 2795 Plagioclase  
FIGURE 134 Gabbroic metasomatic 2791 Plagioclase  
FIGURE 135 Gneiss (biotite plagioclase) 2792  
FIGURE 136 Gneiss (biotite) 2565  
FIGURE 137 Gneiss (granitic) 2578  
FIGURE 138 Gneiss (granitic) 2581  
FIGURE 139 Gneiss (granitic) 2796  
FIGURE 140 Granite  
FIGURE 141 Granite  
FIGURE 142 Granite  
FIGURE 143 Granite (pyroxene) kts-672  
FIGURE 144 Granite 1591  
FIGURE 145 Granite 1592  
FIGURE 146 Granite 1593  
FIGURE 147 Granite 1594  
FIGURE 148 Granite 1597  
FIGURE 149 Granite 1600  
FIGURE 150 Granite 1601  
FIGURE 151 Granite 1779  
FIGURE 152 Granite 1785  
FIGURE 153 Granite 2039  
FIGURE 154 Granite 2198  
FIGURE 155 Granite 251  
FIGURE 156 Granite 2573 metasomatic  
FIGURE 157 Granite 2577  
FIGURE 158 Granite 2585 Plagioclase  
FIGURE 159 Granite 2862

FIGURE 160	Granite 5588
FIGURE 161	Granite 566
FIGURE 162	Granite porphyry 1794
FIGURE 163	Granodiorite 1162 Andesite
FIGURE 164	Granodiorite 153 Plagioclase
FIGURE 165	Granodiorite 6-8
FIGURE 166	Halite
FIGURE 167	Hornblende (amphibole)
FIGURE 168	Hornblende (amphibole)
FIGURE 169	Hornblende (amphibole)
FIGURE 170	Juvite 1464
FIGURE 171	Khadent $\text{NaAlSiO}_6$ (Nepheline ?)
FIGURE 172	Khadent $\text{NaAlSiO}_6$ (Nepheline ?)
FIGURE 173	Labradorite
FIGURE 174	Metadiabase 1661
FIGURE 175	Metagabbro 1450
FIGURE 176	Microcline
FIGURE 177	Migmatite 2193 Plagioclase
FIGURE 178	Migmatite 2572
FIGURE 179	Migmatite 2797
FIGURE 180	Monzodiorite 2799 Plagioclase
FIGURE 181	Monzodiorite 2866 Plagioclase
FIGURE 182	Muscovite
FIGURE 183	Muscovite
FIGURE 184	Nepheline
FIGURE 185	Nepheline
FIGURE 186	Nepheline 1475
FIGURE 187	Nepheline urtite
FIGURE 188	Norite (gabbroic) 2616 Plagioclase
FIGURE 189	Norite (gabbroic) 2622
FIGURE 190	Norite (gabbroic) 466
FIGURE 191	Oligoclase
FIGURE 192	Oligoclase
FIGURE 193	Olivine
FIGURE 194	Olivine (parallel opt.axis)
FIGURE 195	Olivine (perpend. opt.axis)
FIGURE 196	Olivine (pressed powder) 2162
FIGURE 197	Olivine 1
FIGURE 198	Olivine 1381
FIGURE 199	Olivine 1423
FIGURE 200	Olivine 1430
FIGURE 201	Olivine 1473
FIGURE 202	Olivine 1482
FIGURE 203	Olivine 1484
FIGURE 204	Olivine 2
FIGURE 205	Olivine 2162
FIGURE 206	Olivine 3
FIGURE 207	Olivine 5683
FIGURE 208	Olivine 583
FIGURE 209	Olivine 583
FIGURE 210	Olivine 6013
FIGURE 211	Olivine 6014
FIGURE 212	Olivine pyroxene 2712

FIGURE 213	Olivine pyroxene 469
FIGURE 214	Olivine pyroxene 591
FIGURE 215	Omphacite 9152
FIGURE 216	Orthoclase
FIGURE 217	Peridotite (serpentinized) 2428
FIGURE 218	Peridotite (serpentinized) 2519
FIGURE 219	Peridotite (serpentinized) 2610 Olivine
FIGURE 220	Peridotite (serpentinized) 2611
FIGURE 221	Peridotite 2604
FIGURE 222	Peridotite a66-016
FIGURE 223	Phlogopite
FIGURE 224	Piroa kkk-674
FIGURE 225	Plagioclase 671
FIGURE 226	Plagiogneiss 2575
FIGURE 227	Plagiogneiss 855
FIGURE 228	Polymigmatite 2187
FIGURE 229	Pyrope peridotite 2161
FIGURE 230	Pyrope peridotite 2163
FIGURE 231	Pyrophyllite
FIGURE 232	Pyroxene (biotite) 8771
FIGURE 233	Pyroxene 1001 Titanaugite
FIGURE 234	Pyroxene 1002 Aegerine-augite
FIGURE 235	Pyroxene 1003
FIGURE 236	Pyroxene 1004
FIGURE 237	Pyroxene 1006
FIGURE 238	Pyroxene 1508
FIGURE 239	Pyroxene 1585
FIGURE 240	Pyroxene 1646
FIGURE 241	Pyroxene 2492 Diopside-chlorite
FIGURE 242	Pyroxene 2497 Diopside
FIGURE 243	Pyroxene 340
FIGURE 244	Riebeckite (amphibole)
FIGURE 245	Rischorrit 710
FIGURE 246	Serpentine
FIGURE 247	Serpentine
FIGURE 248	Serpentinite
FIGURE 249	Serpentinite 2183
FIGURE 250	Serpentinite 2185
FIGURE 251	Serpentinite 2494
FIGURE 252	Serpentinite 2512
FIGURE 253	Serpentinite 2514
FIGURE 254	Serpentinite 2518
FIGURE 255	Serpentinite ab-45
FIGURE 256	Sphene
FIGURE 257	Syenite (nepheline) 1456
FIGURE 258	Syenite (pseudoleucite) 8957
FIGURE 259	Syenite 8996 Eicitite
FIGURE 260	Sylvite
FIGURE 261	Talc
FIGURE 262	Taznite (fine pored)
FIGURE 263	Trachyte (nepheline) 610
FIGURE 264	Trachyte 1438





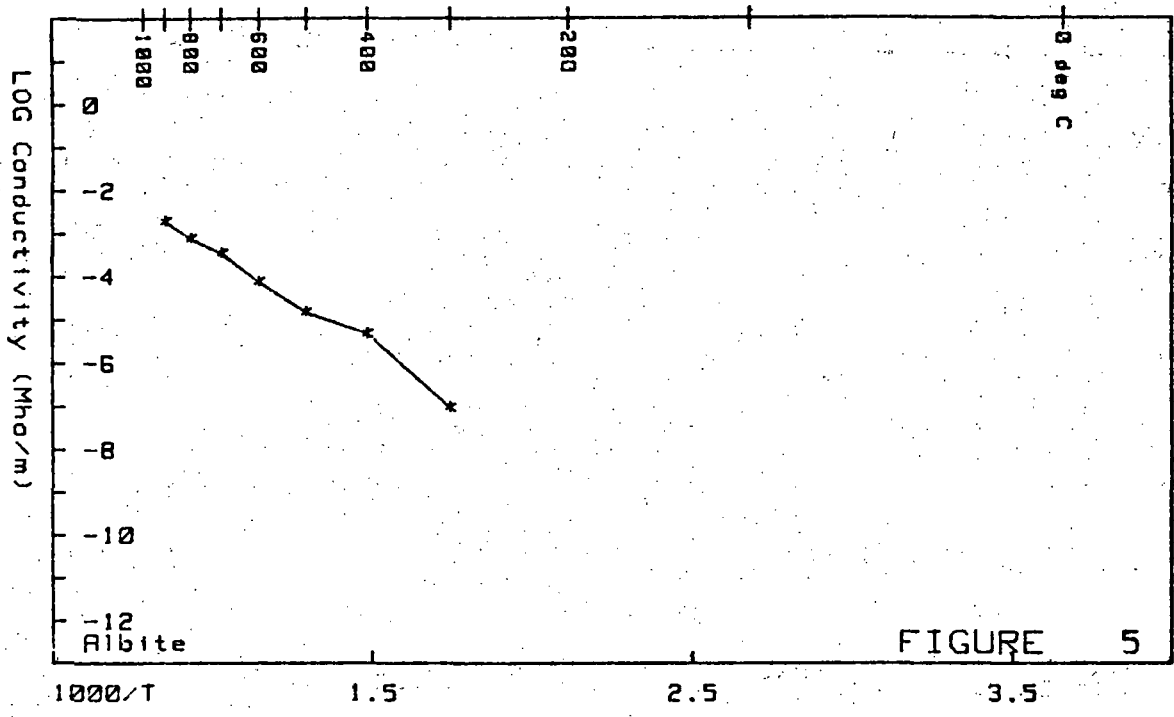


FIGURE 5

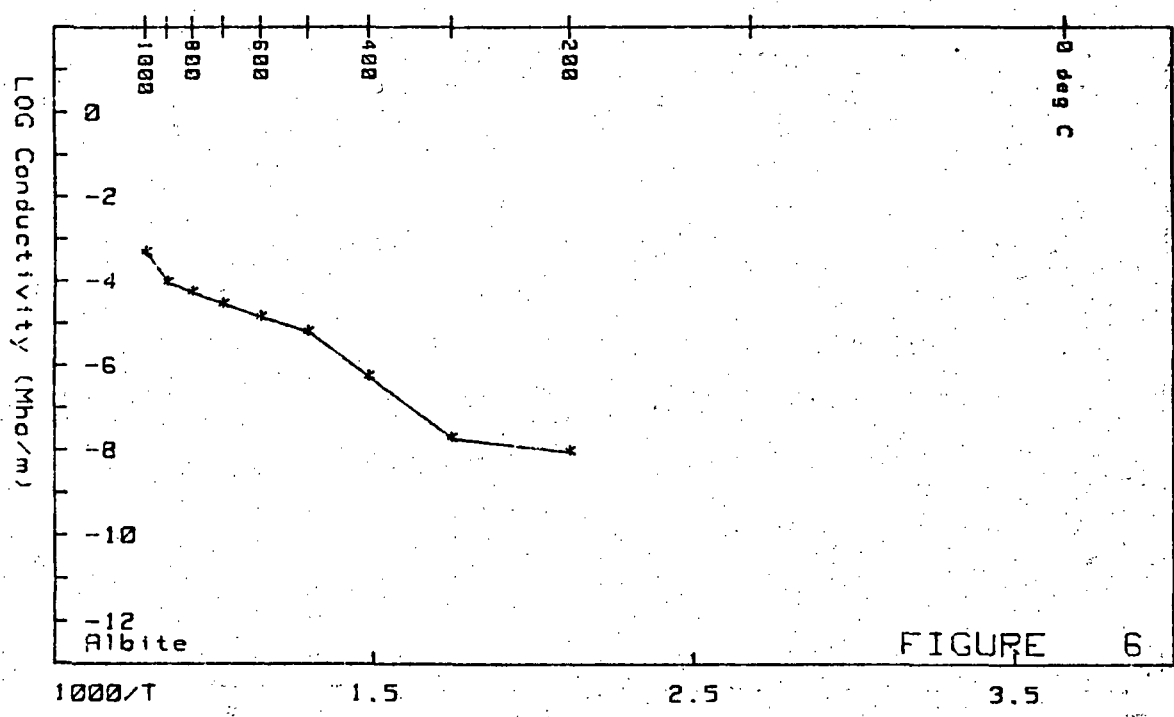
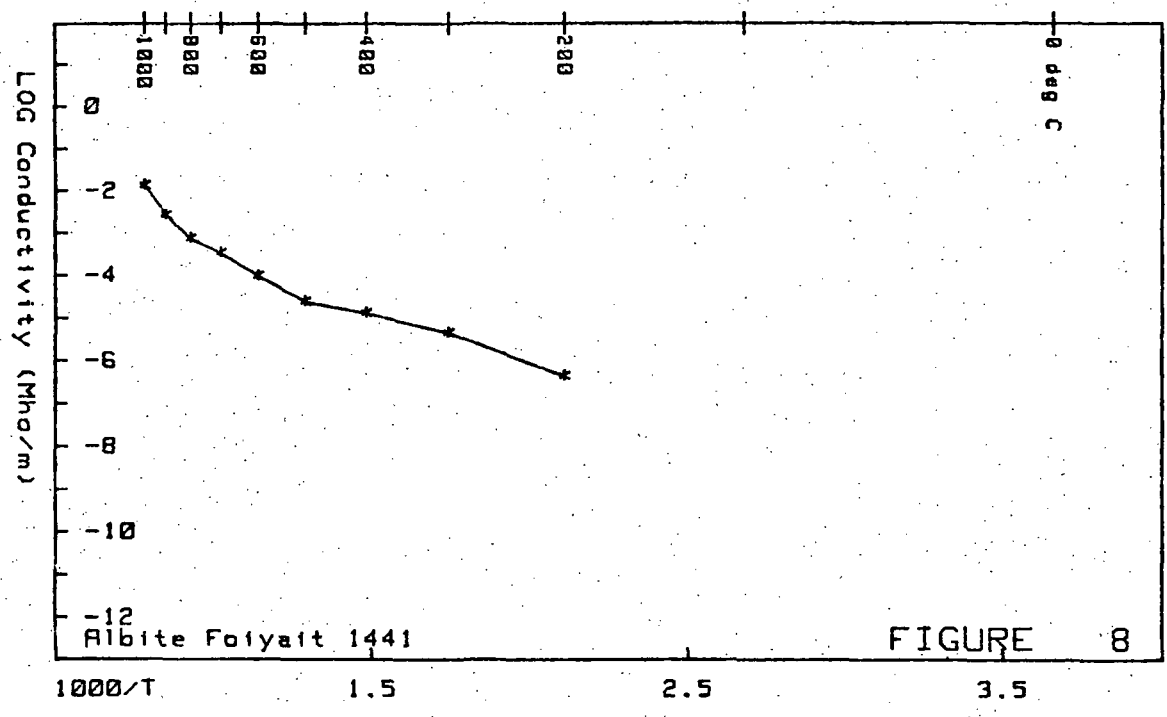
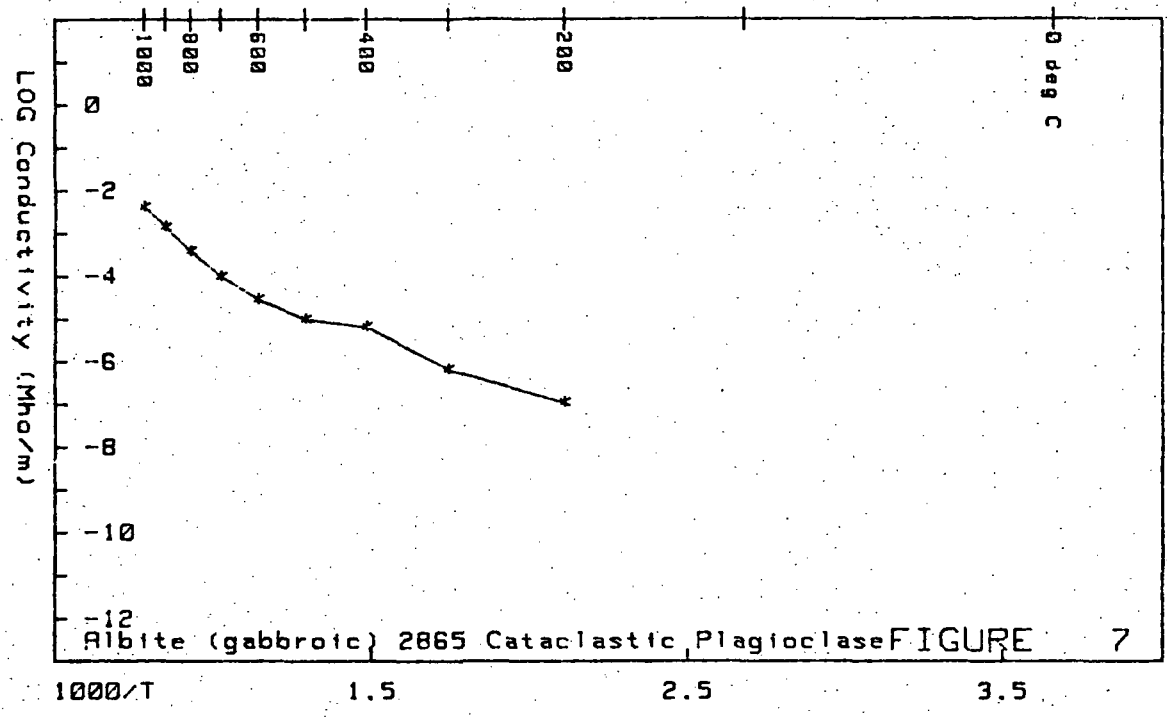
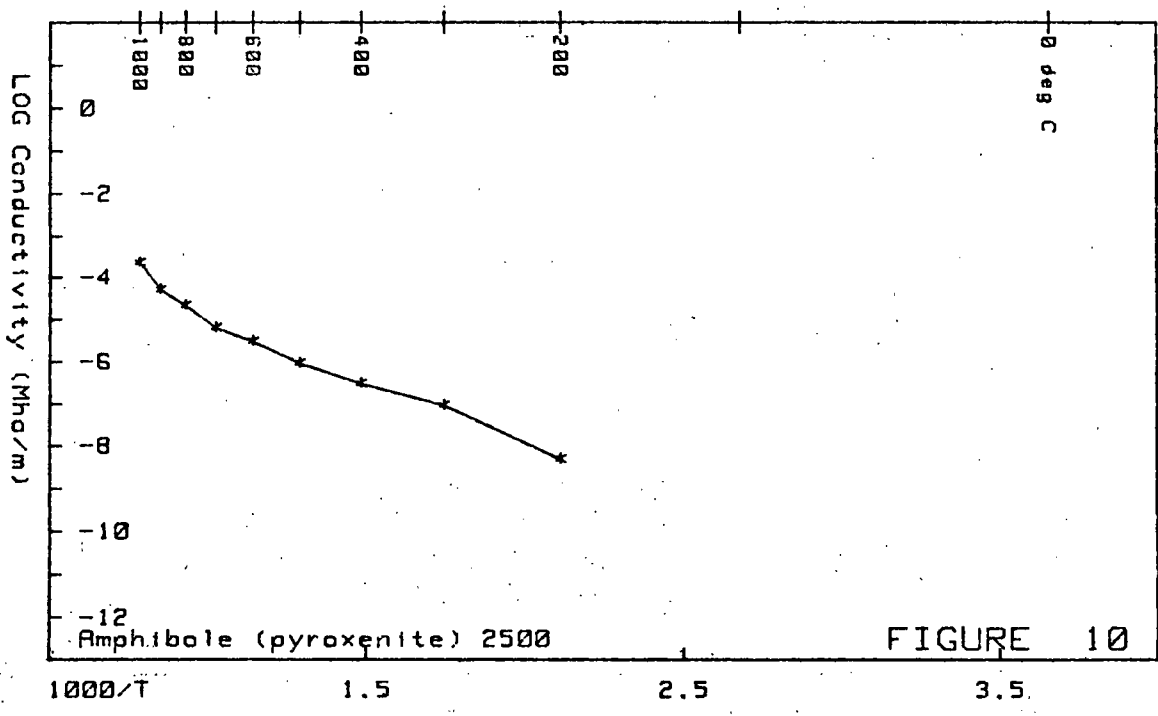
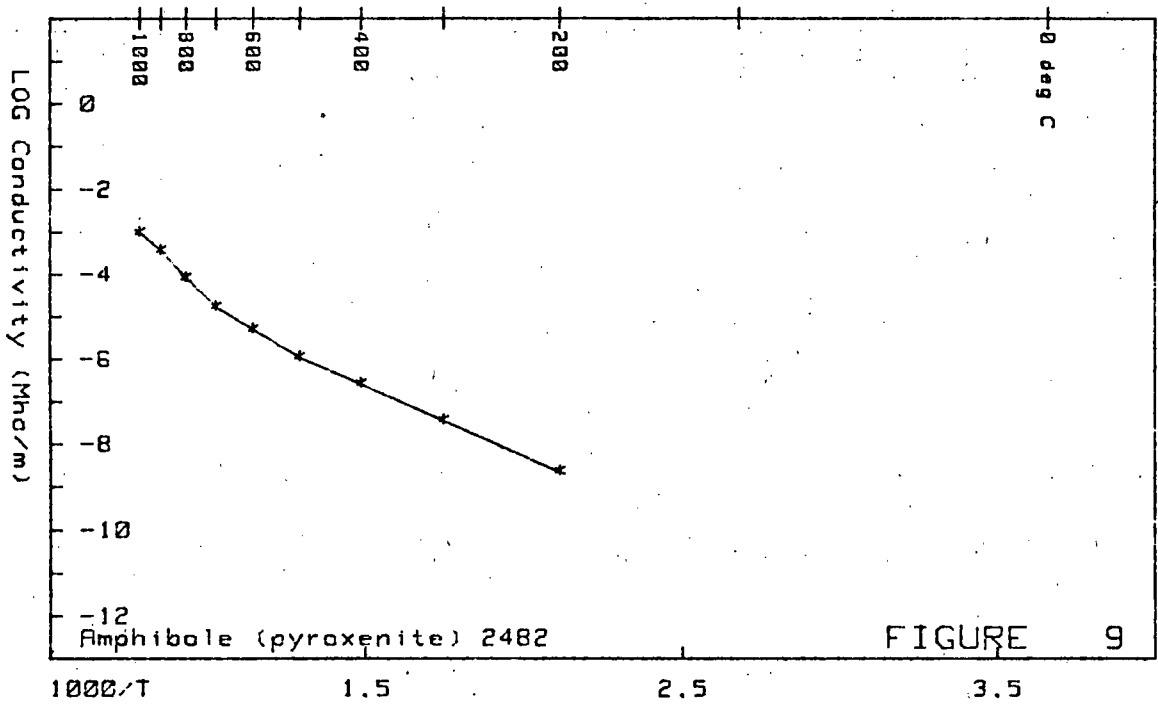
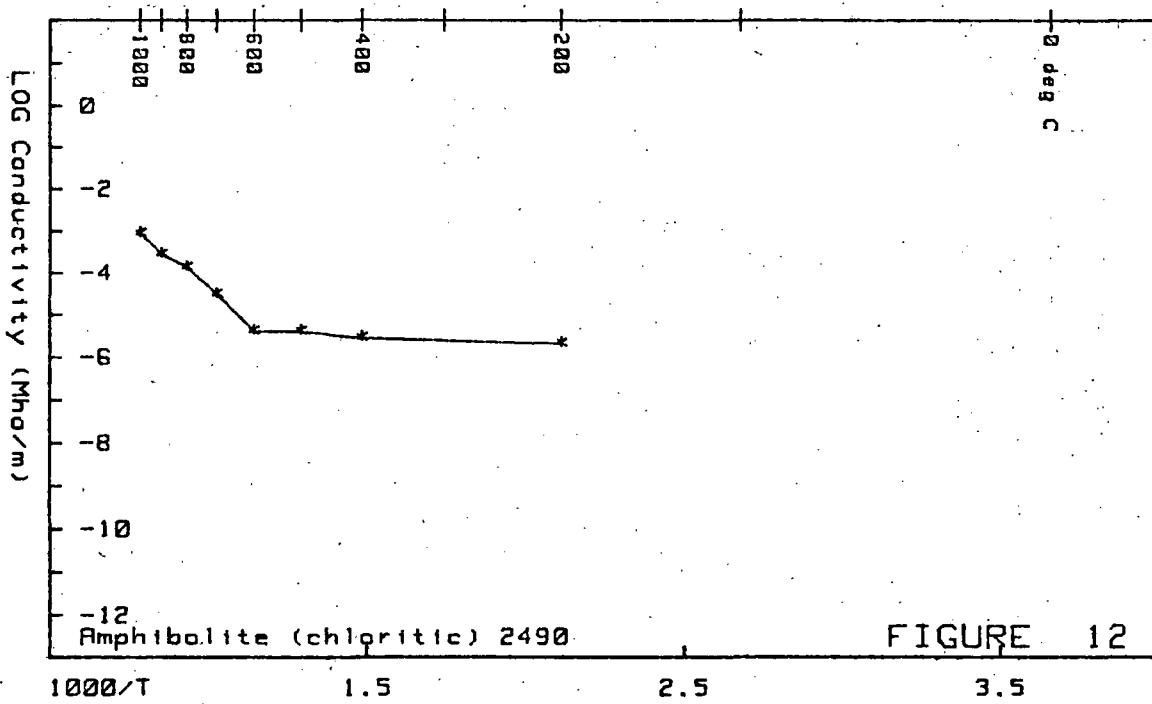
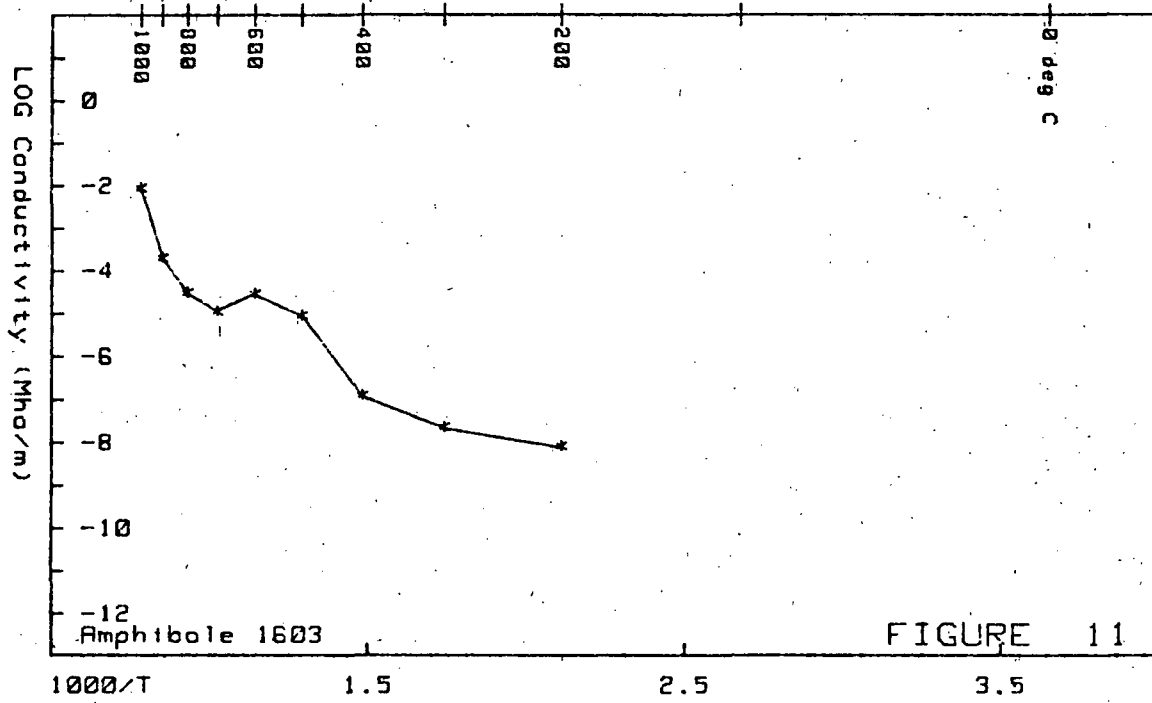


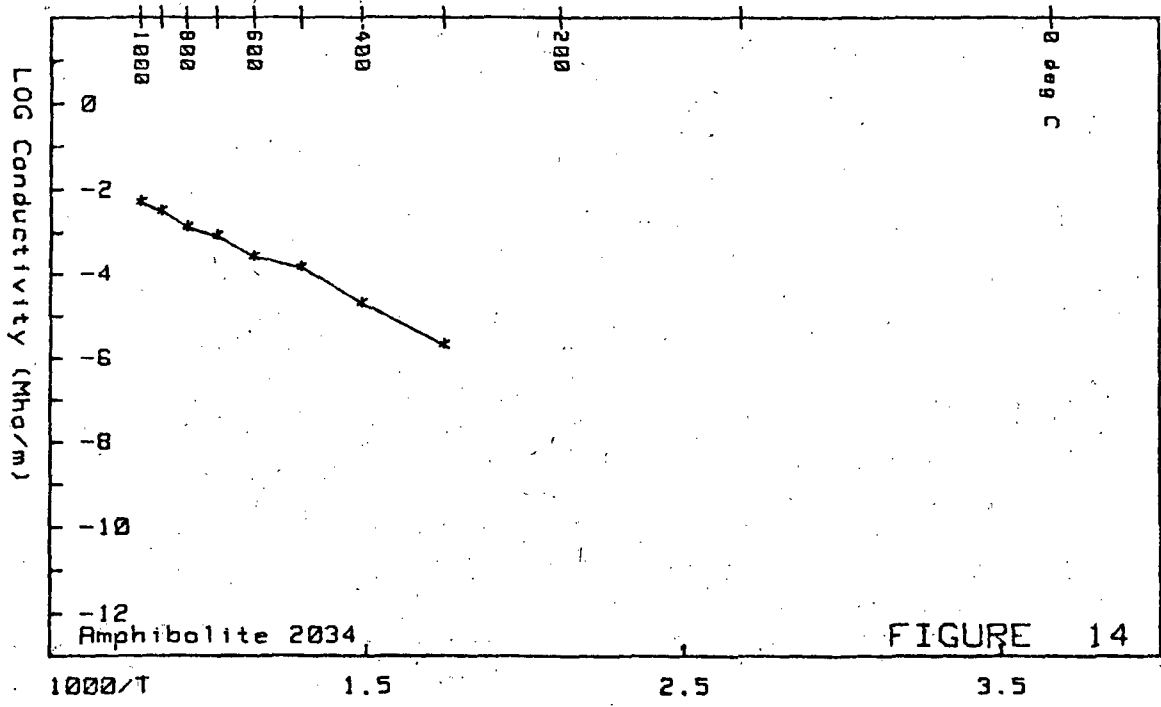
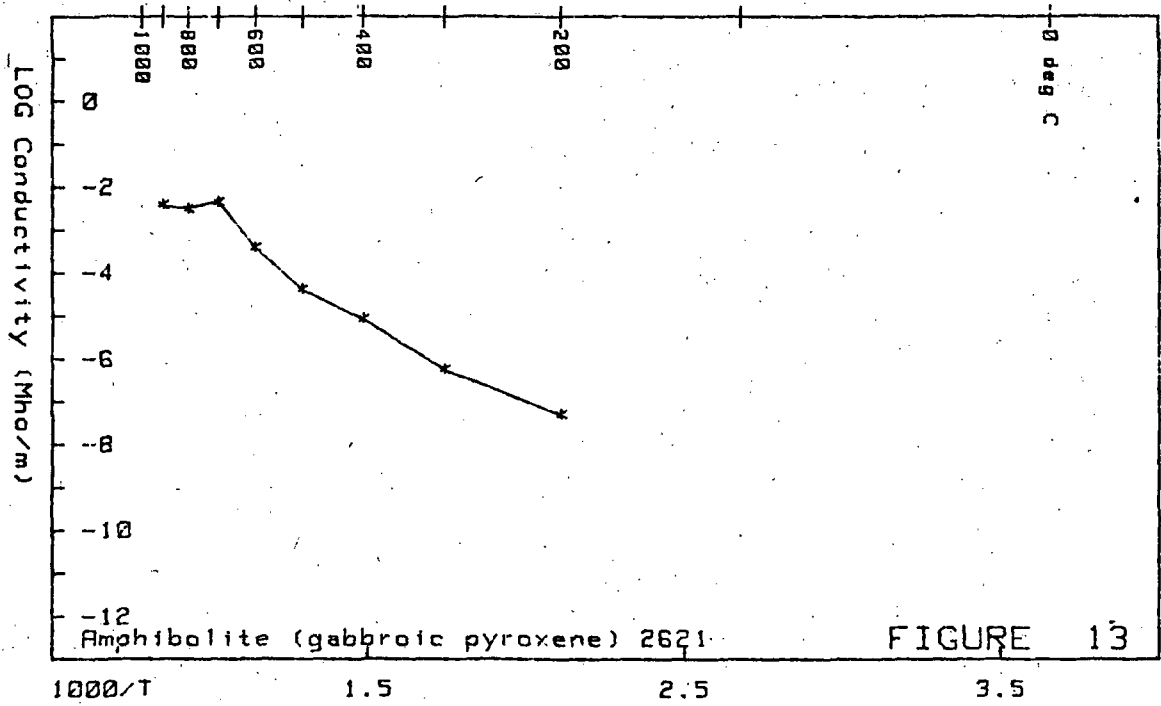
FIGURE 6

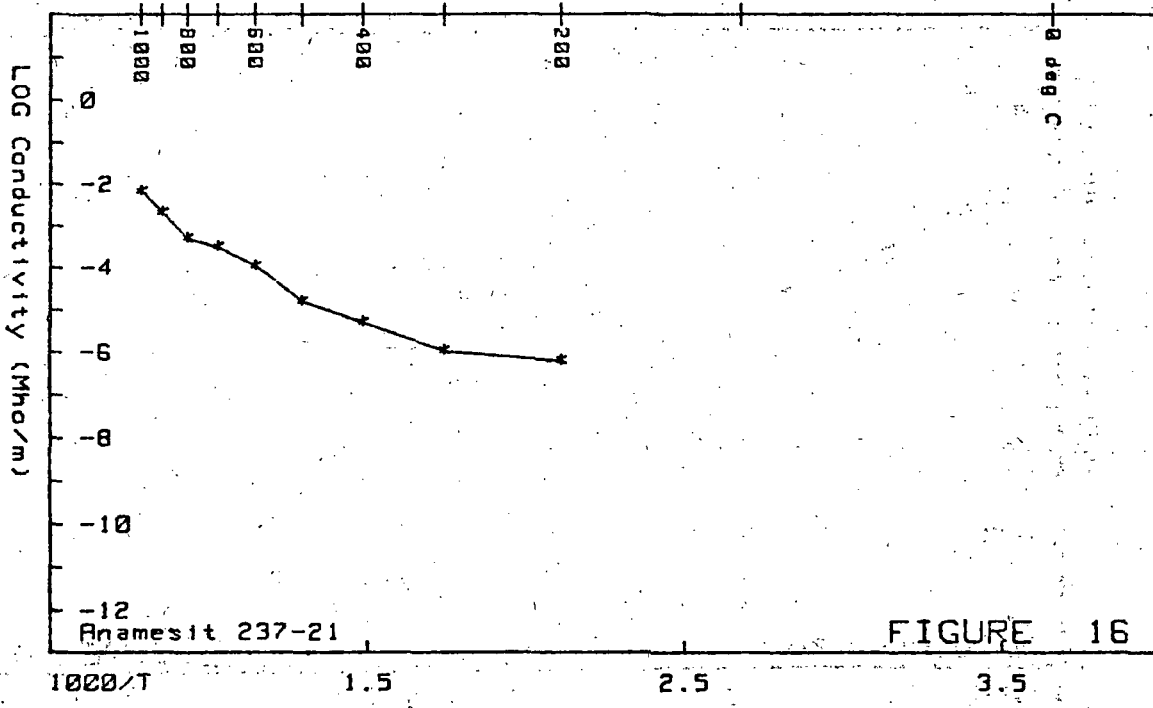
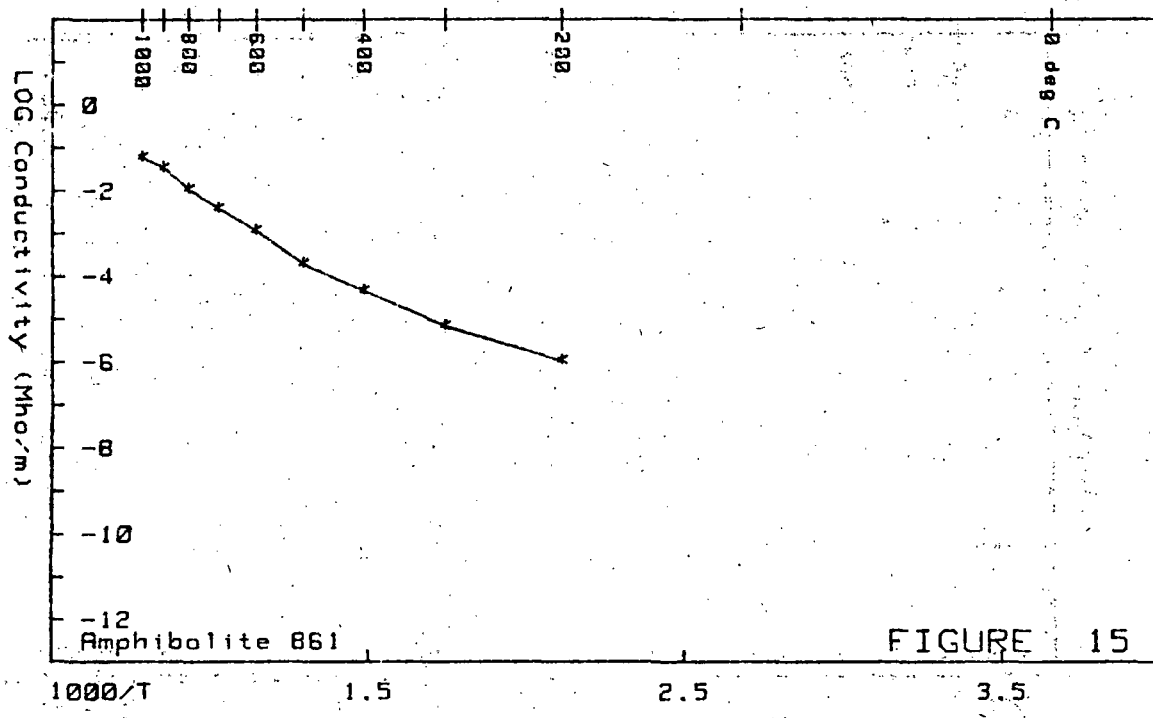


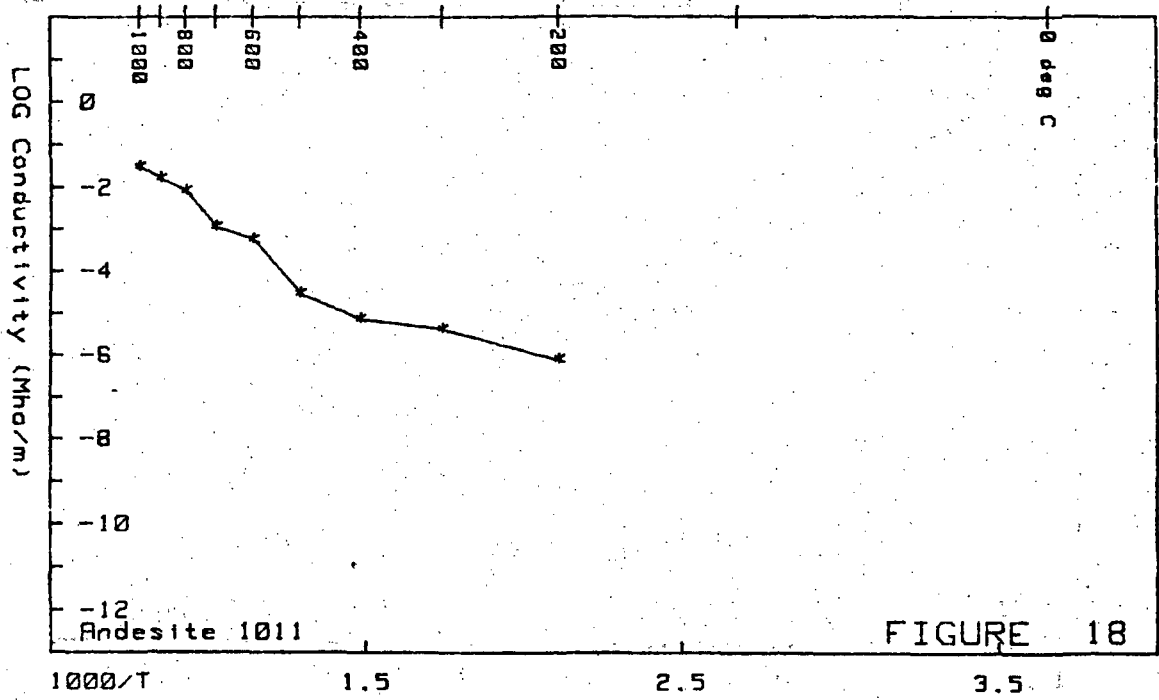
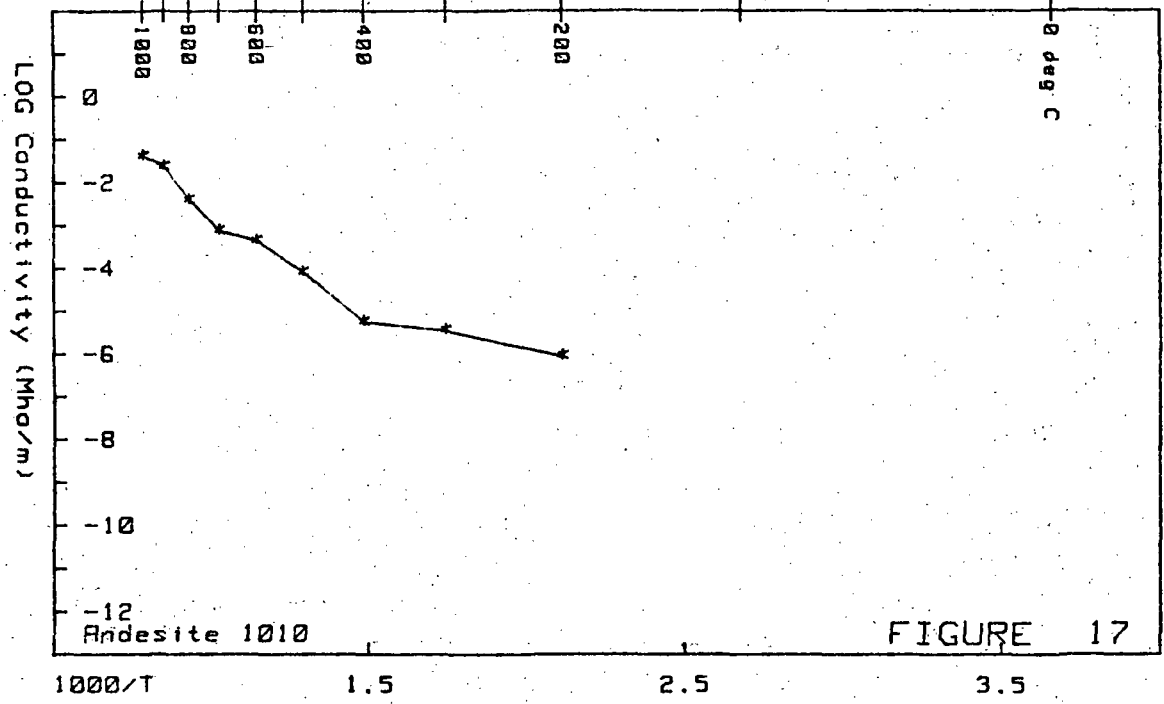


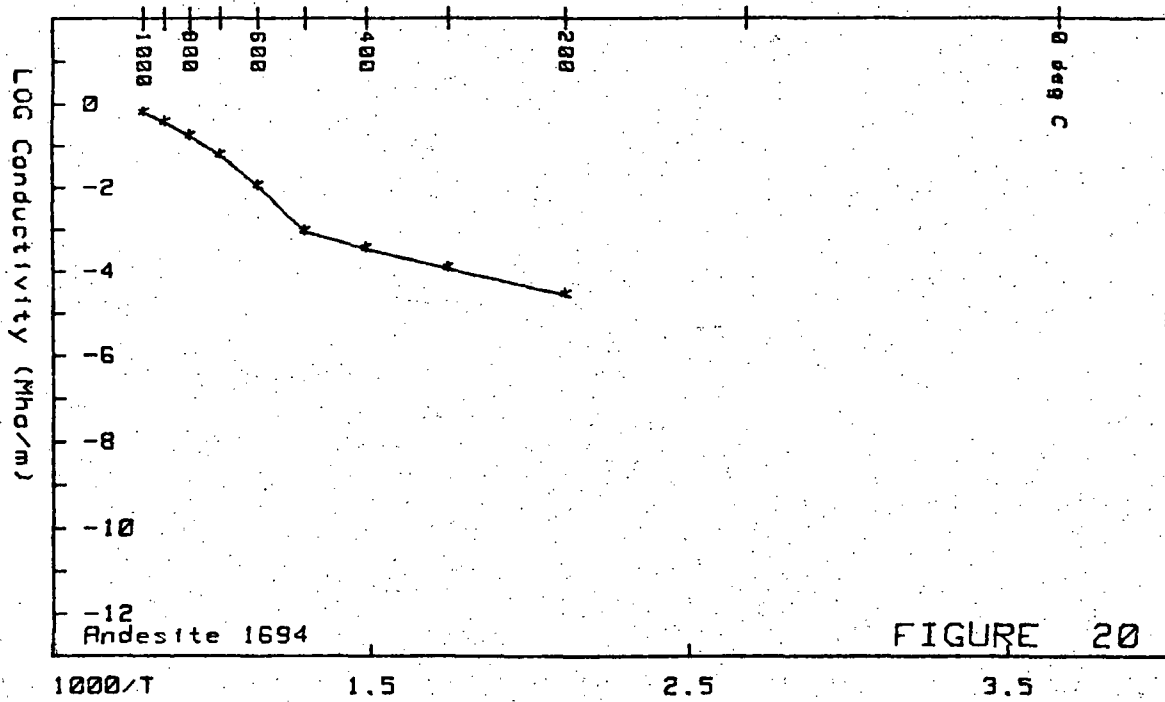
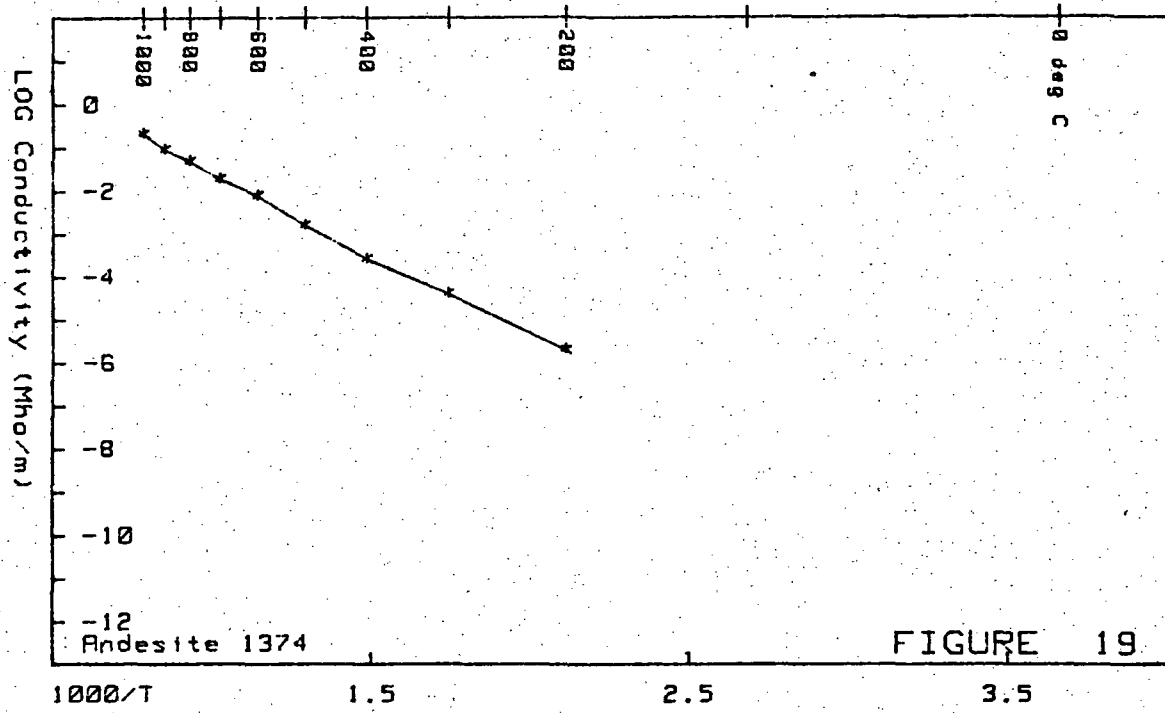


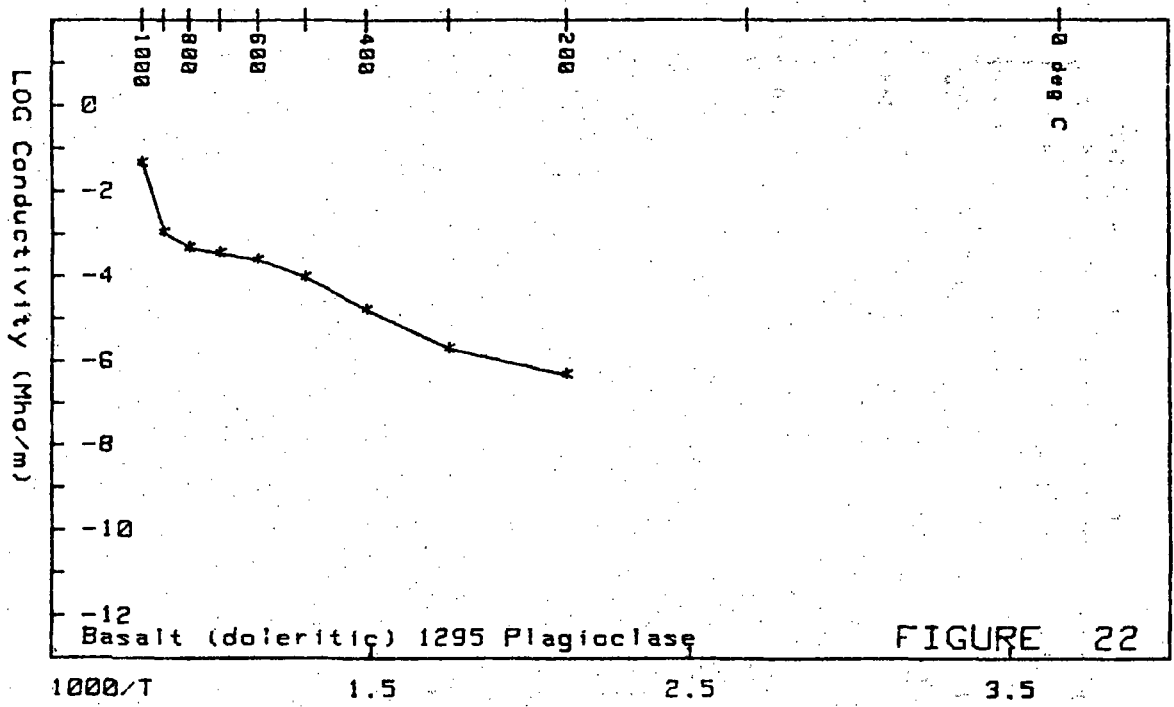
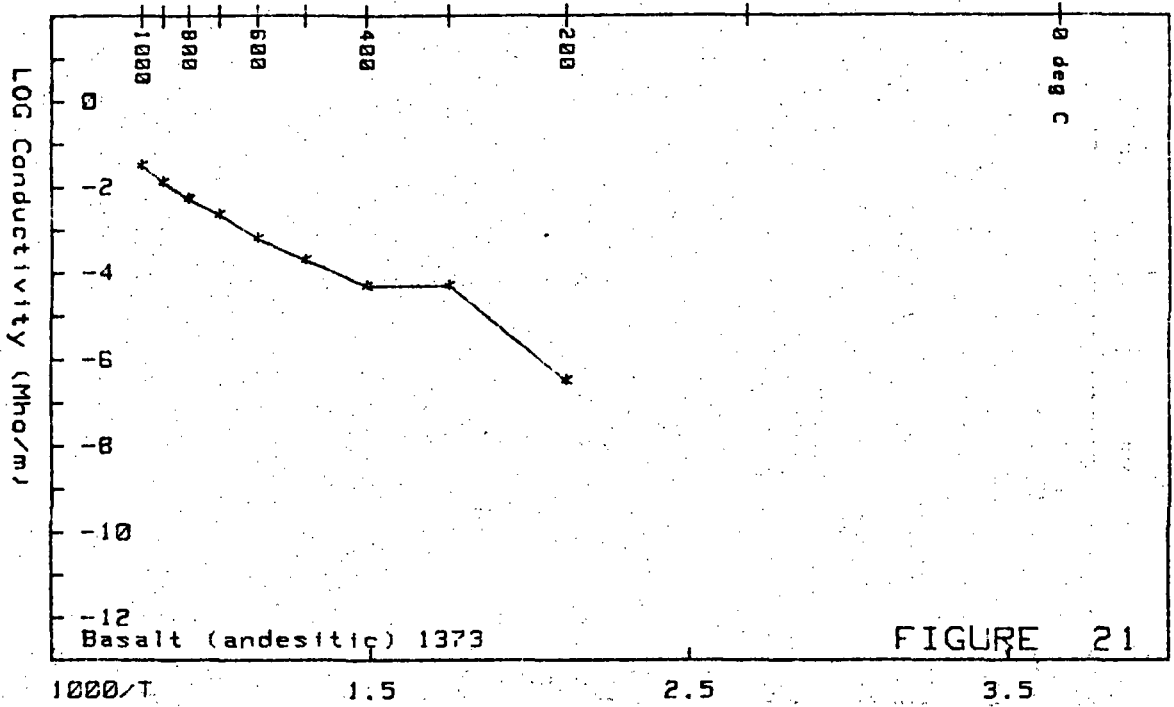


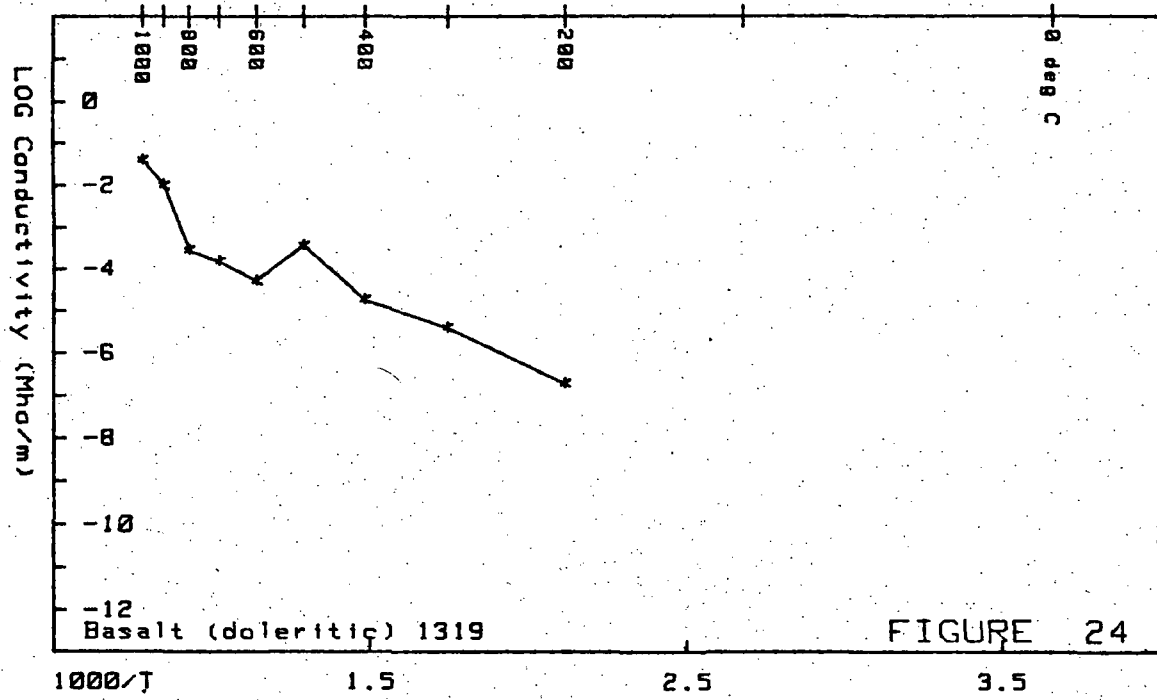
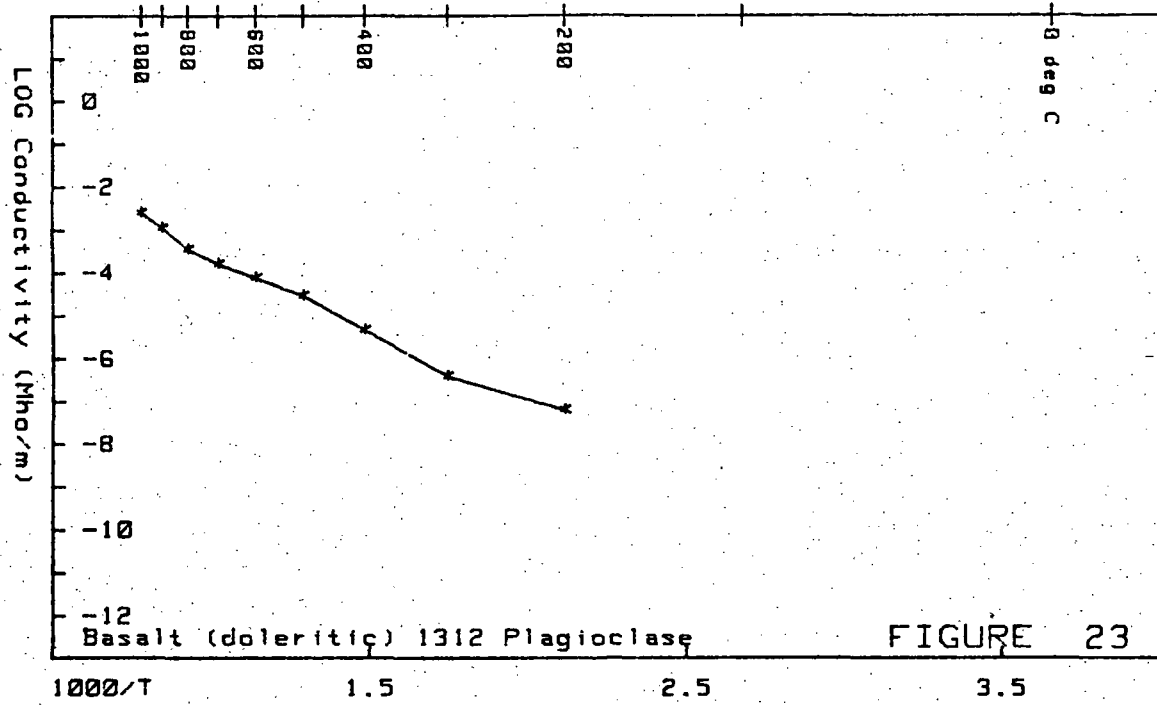














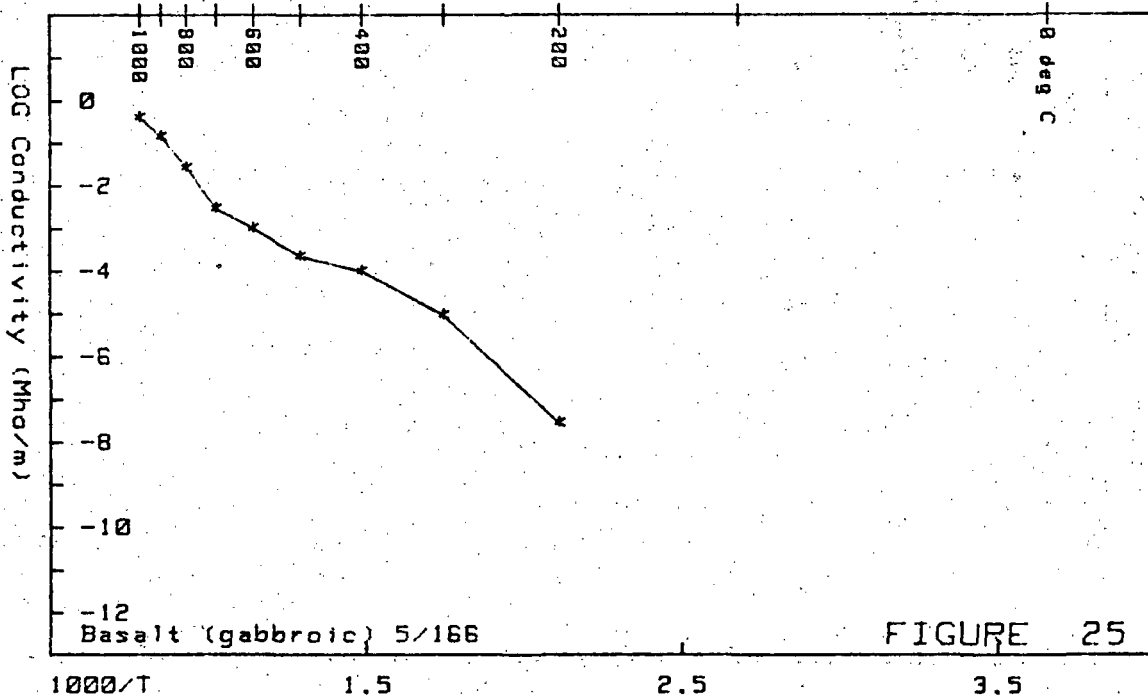


FIGURE 25

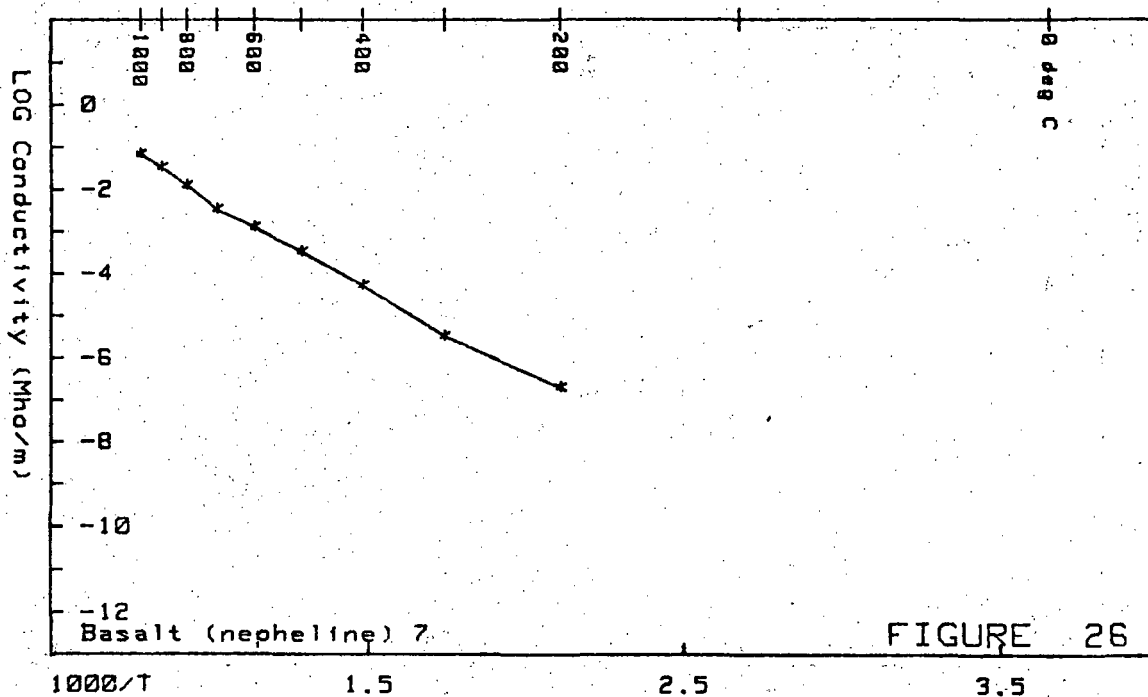
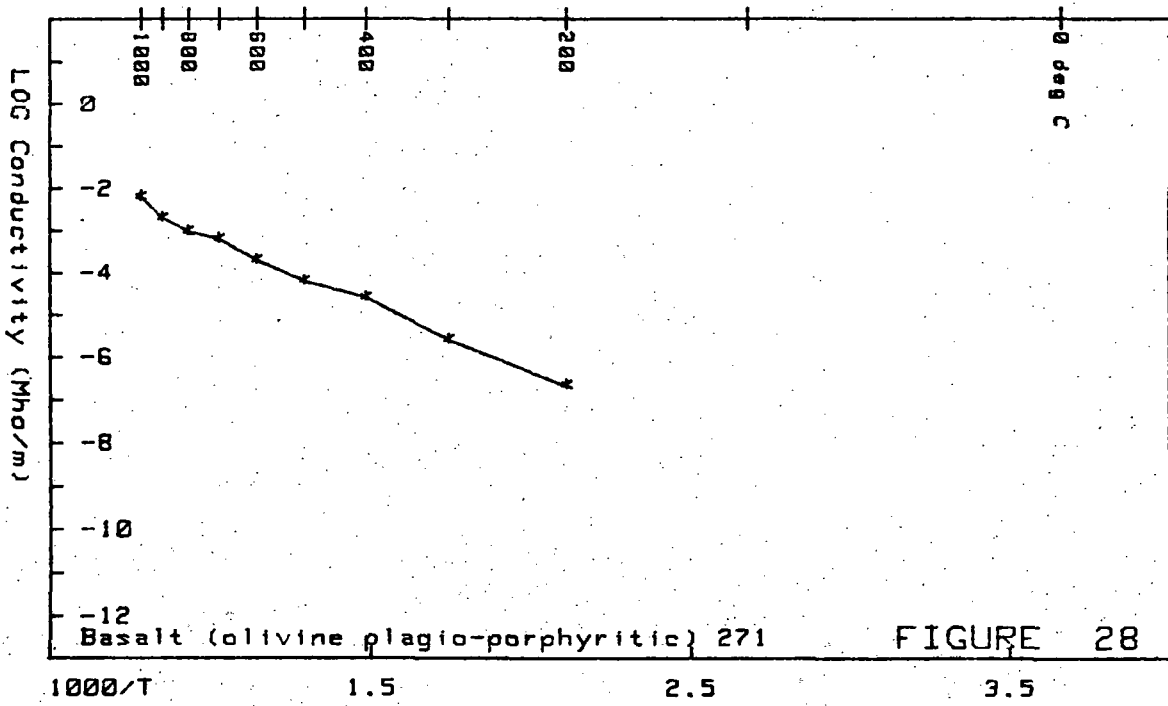
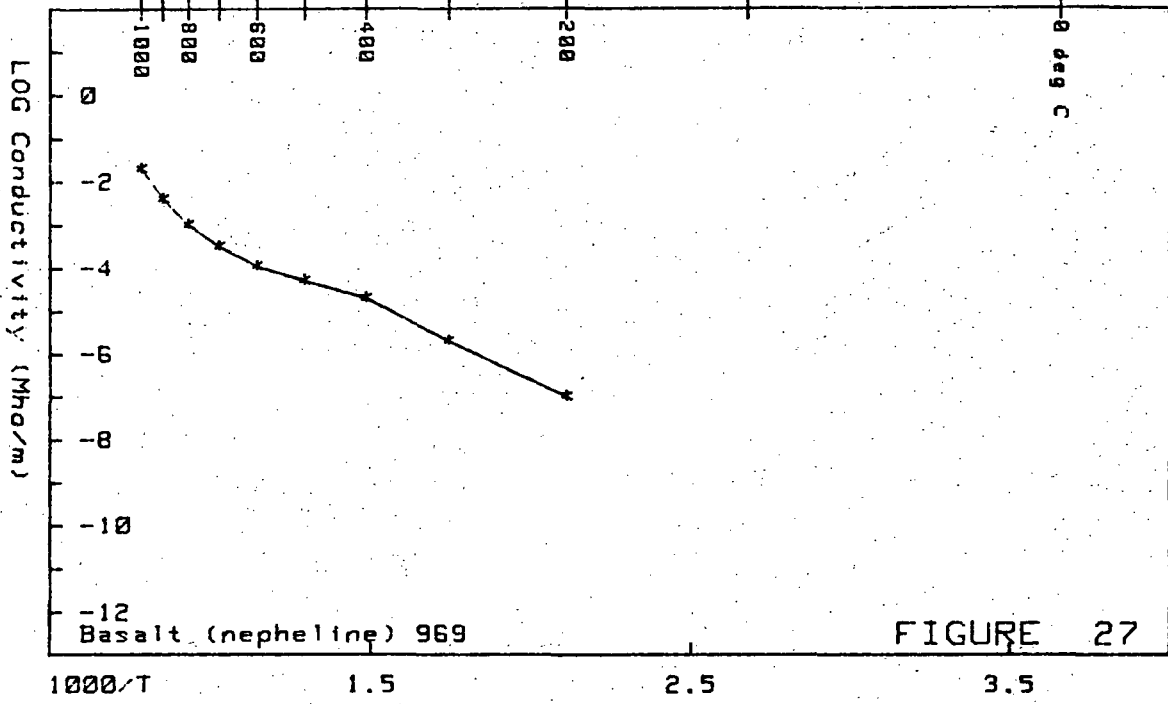
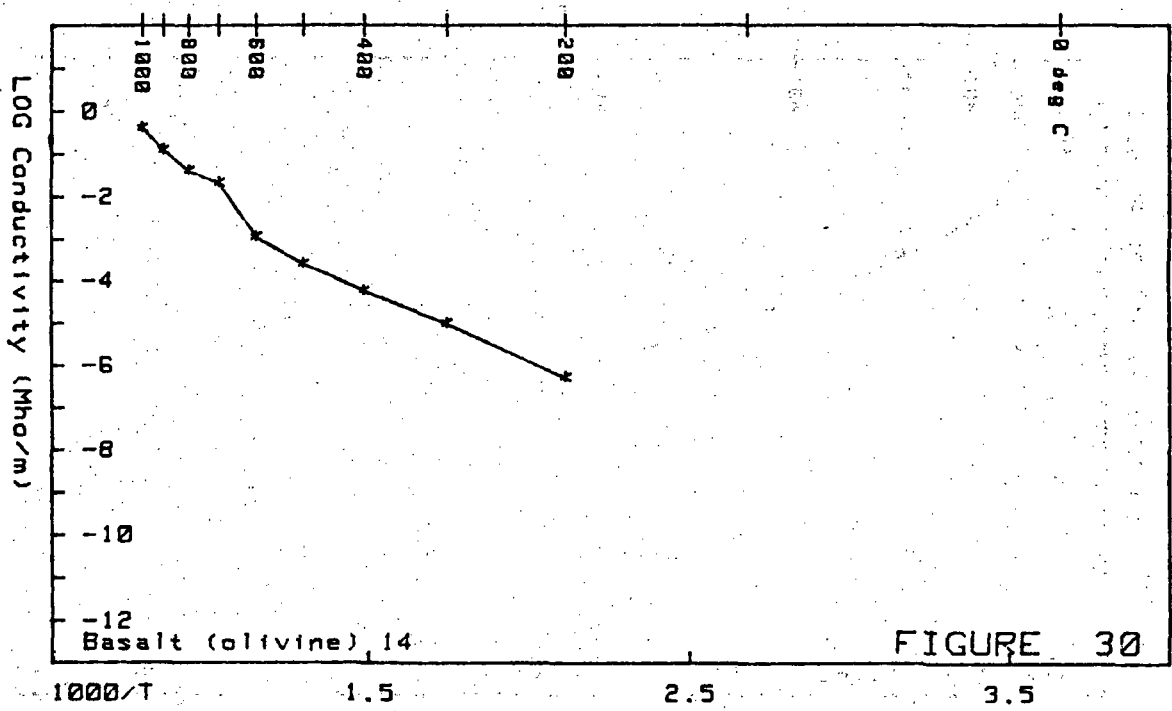
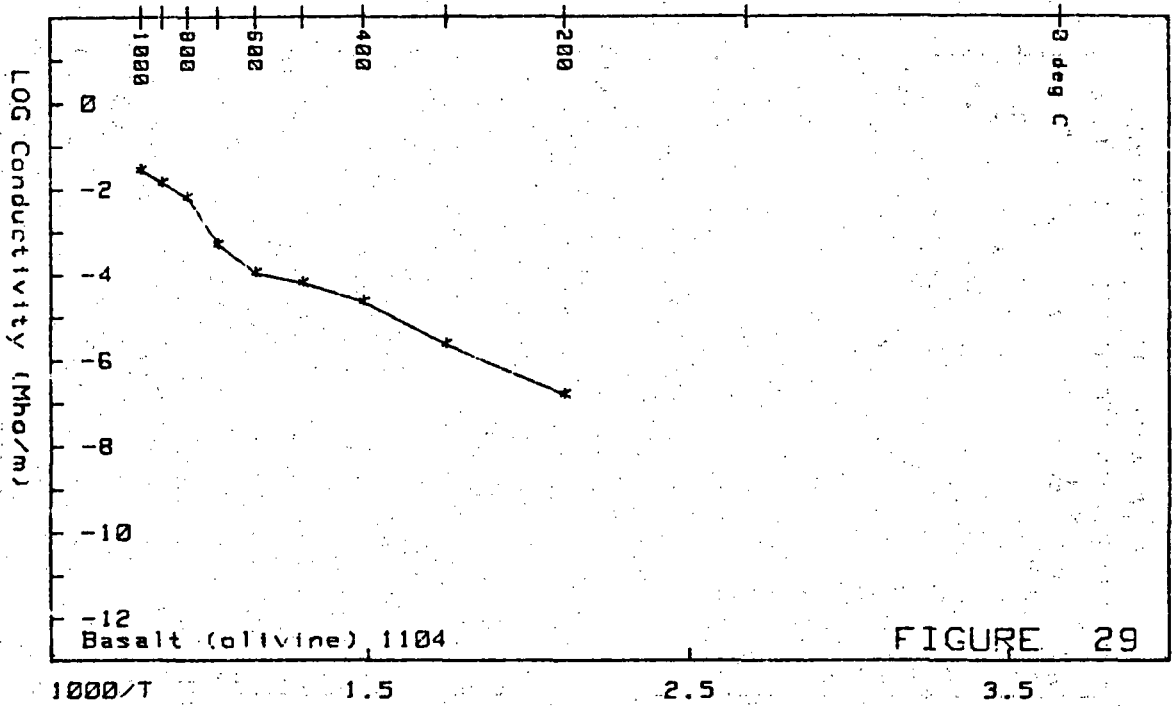
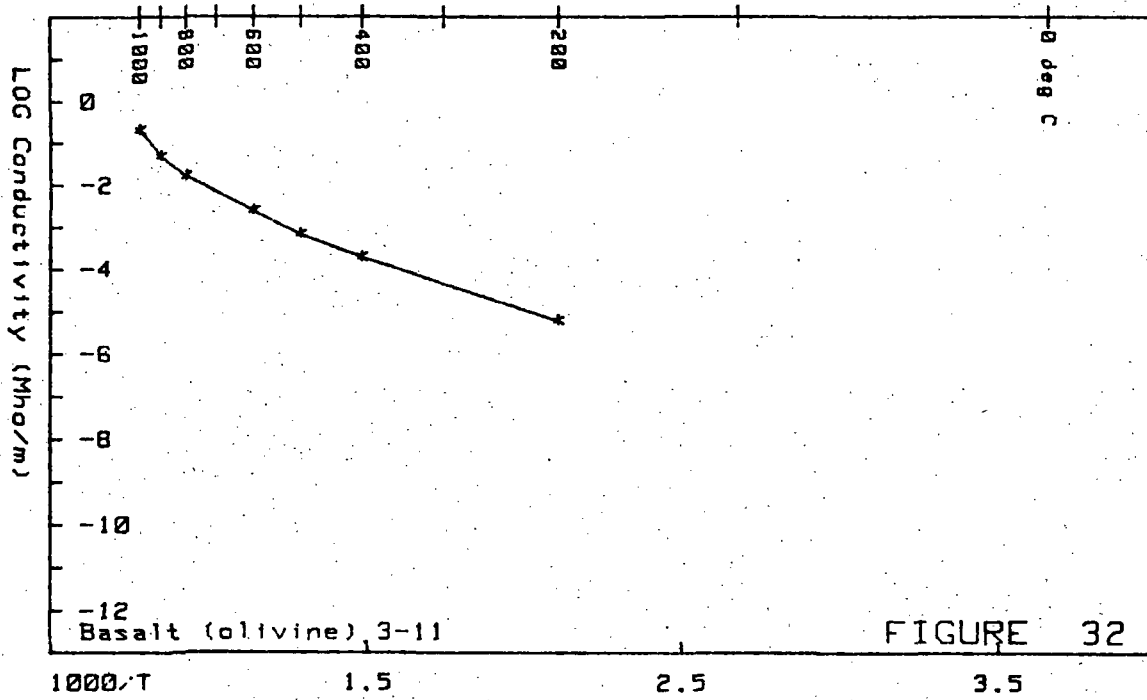
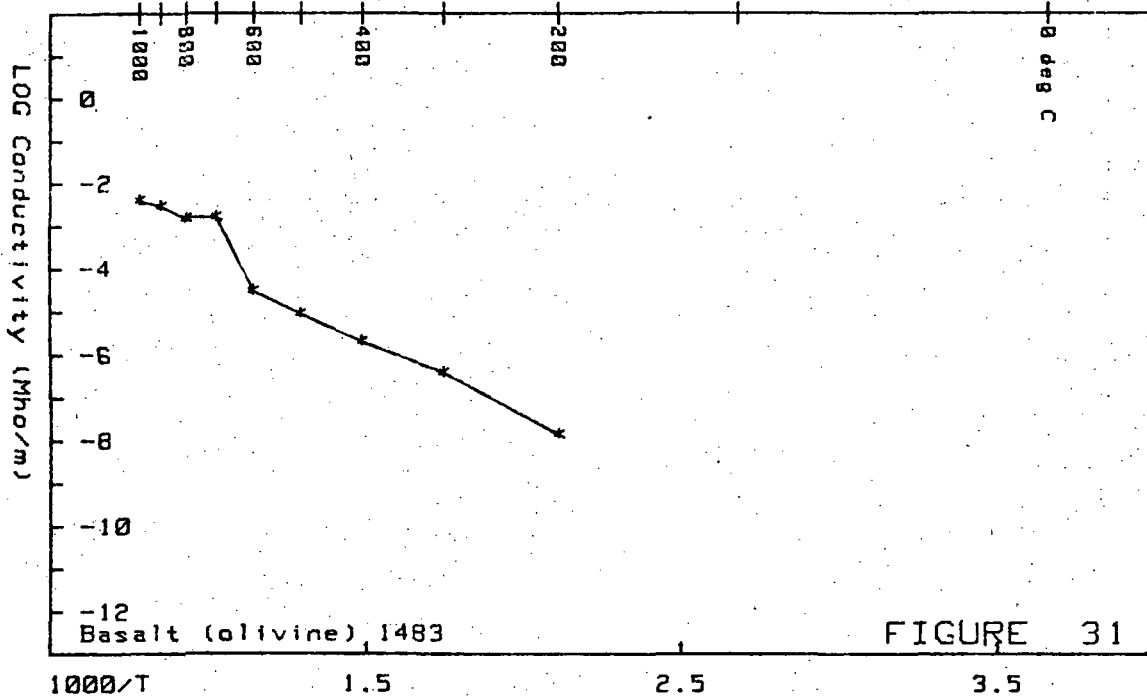
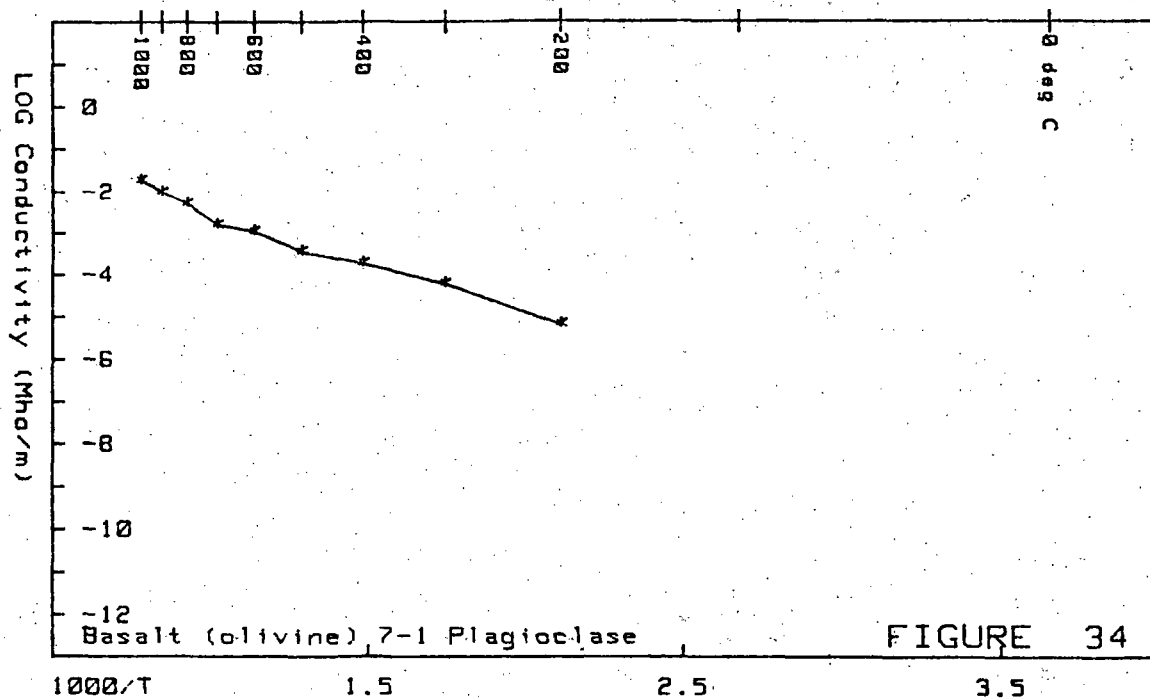
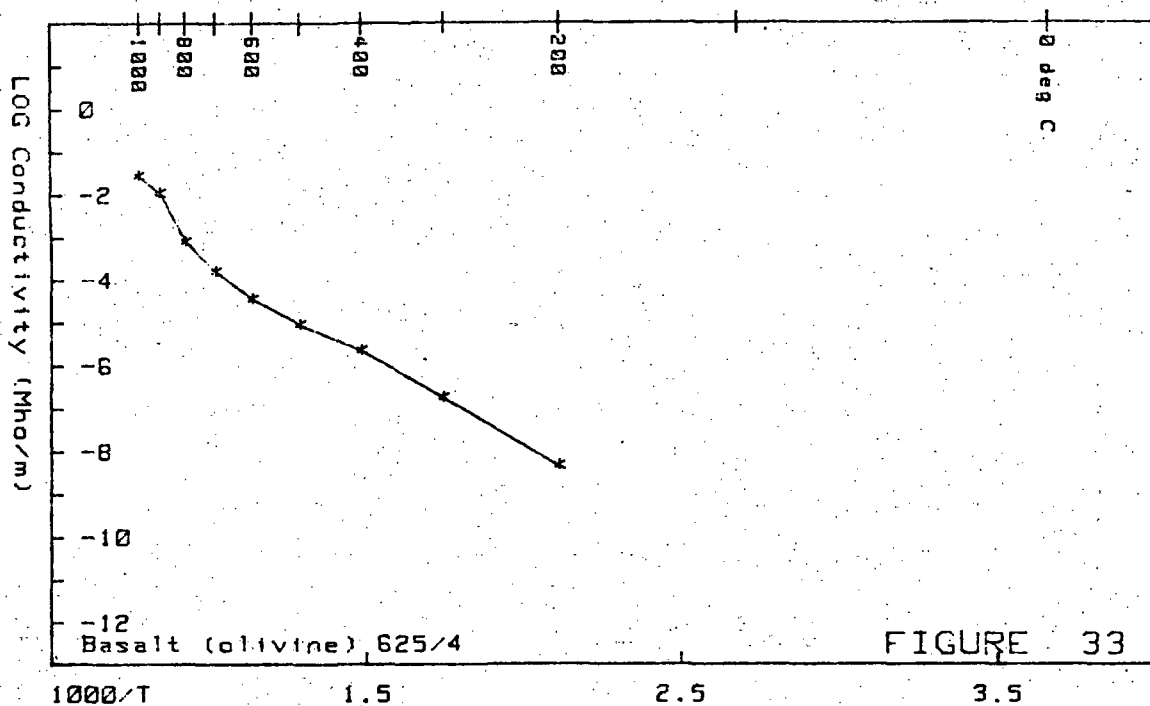


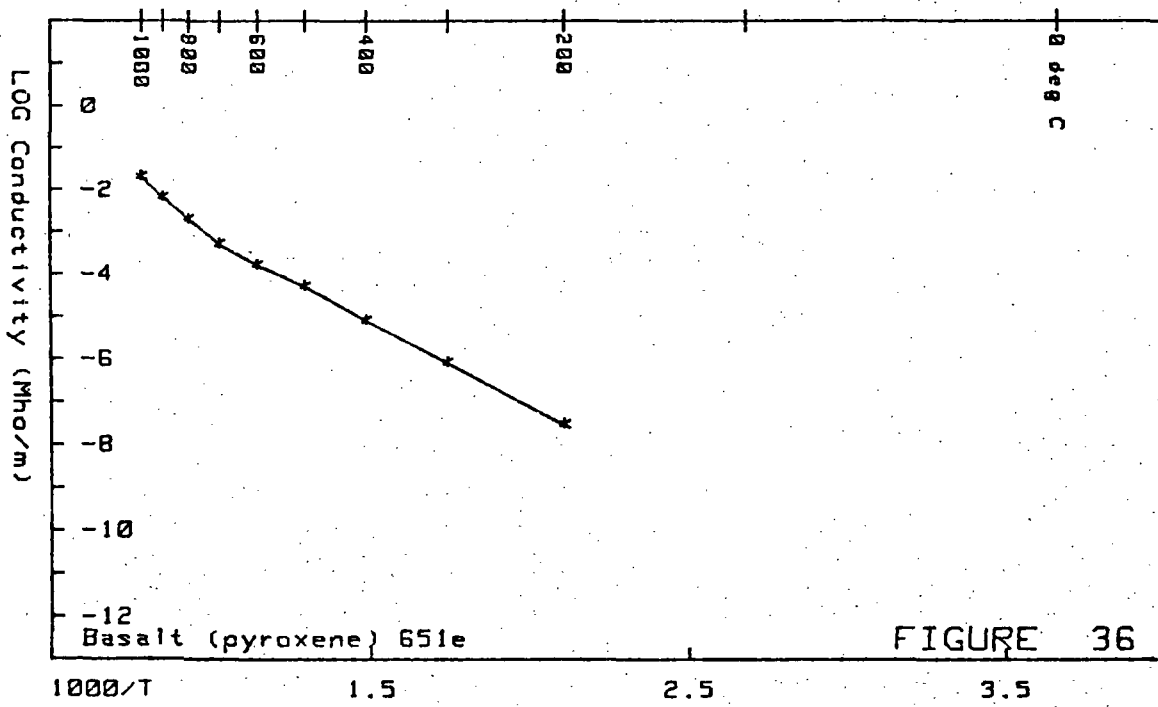
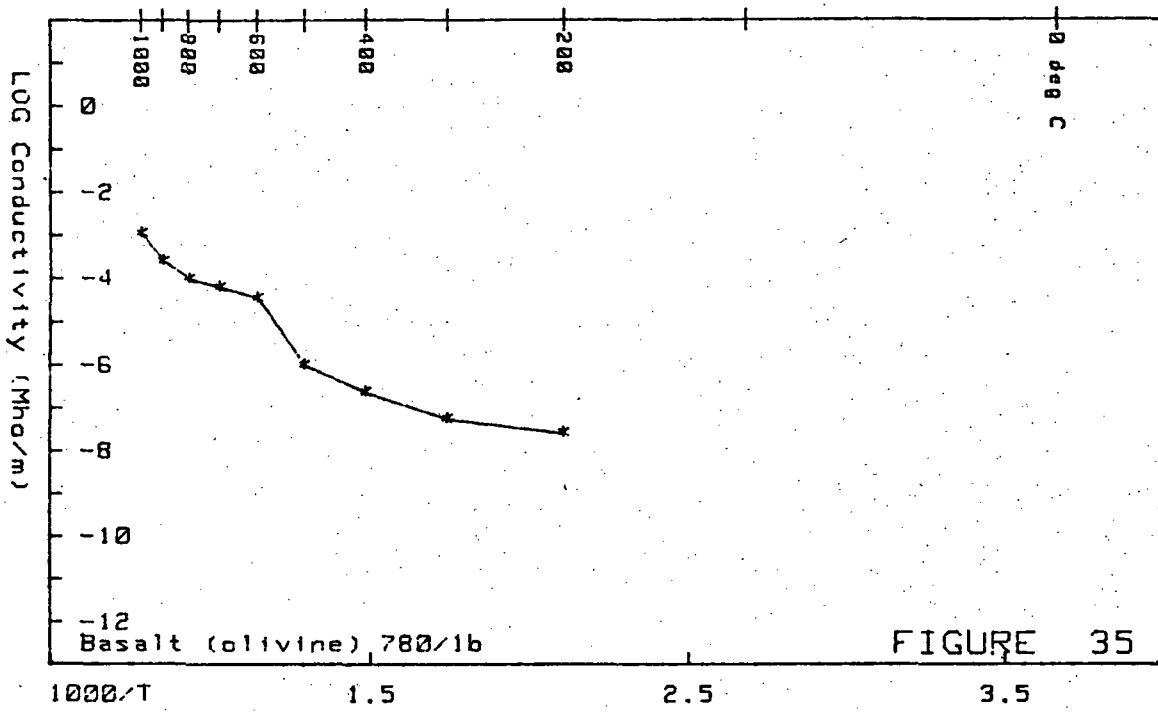
FIGURE 26

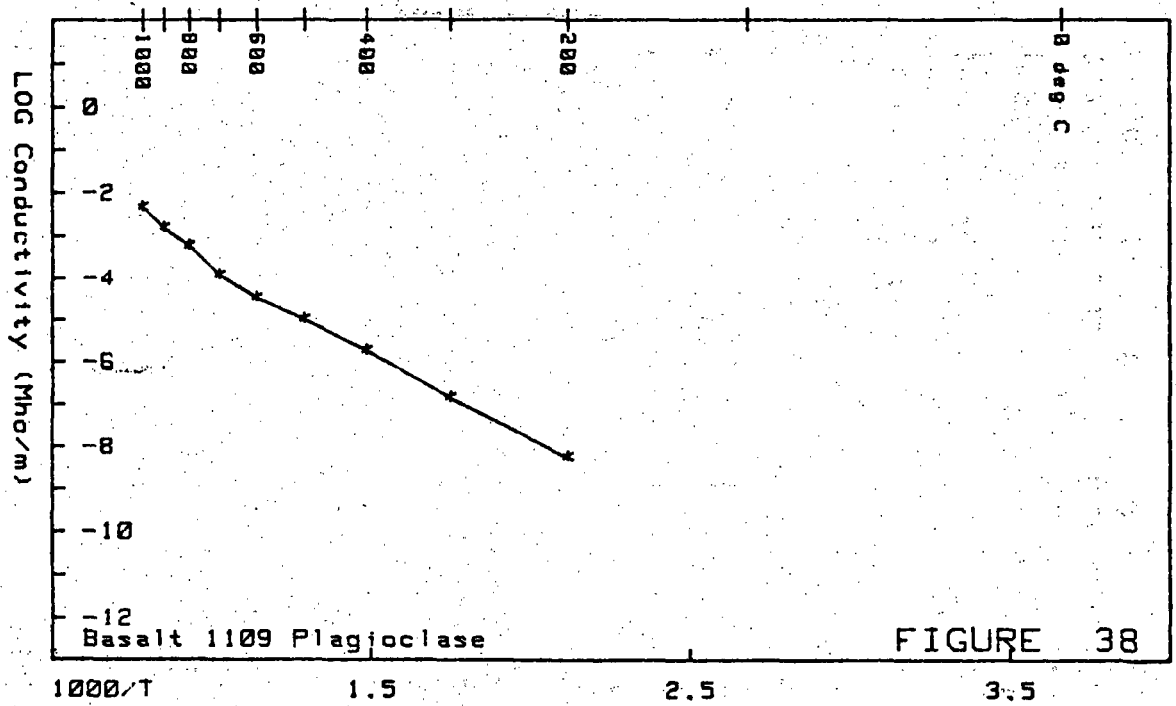
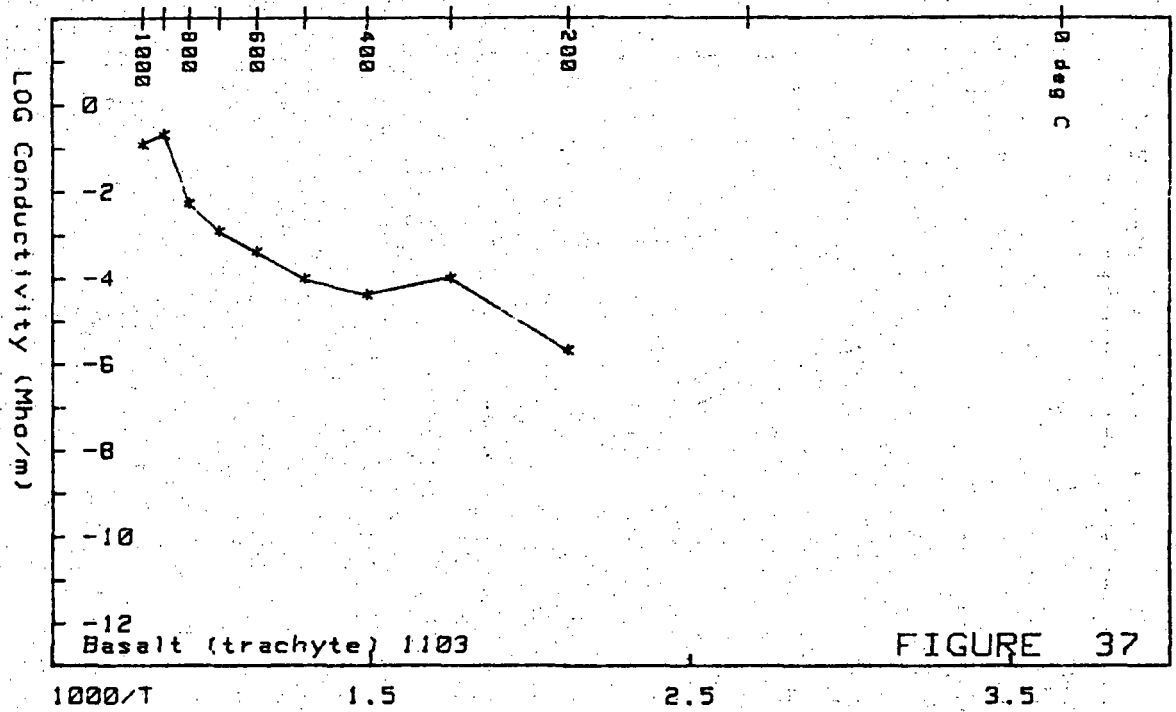


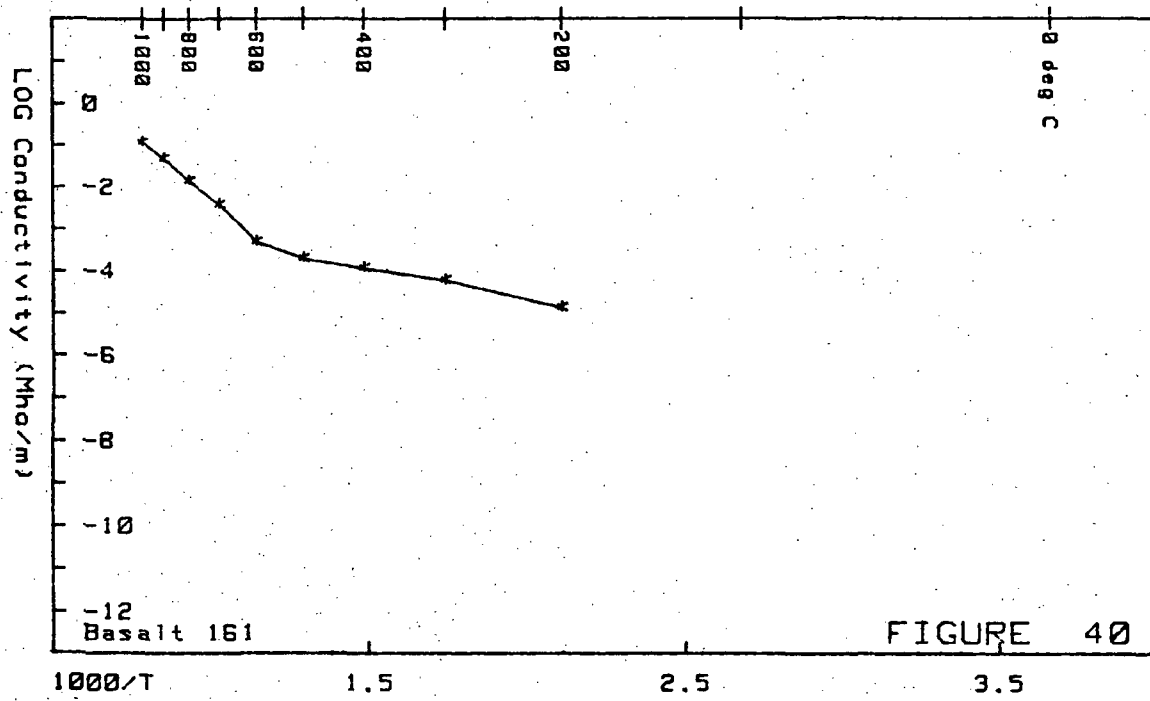
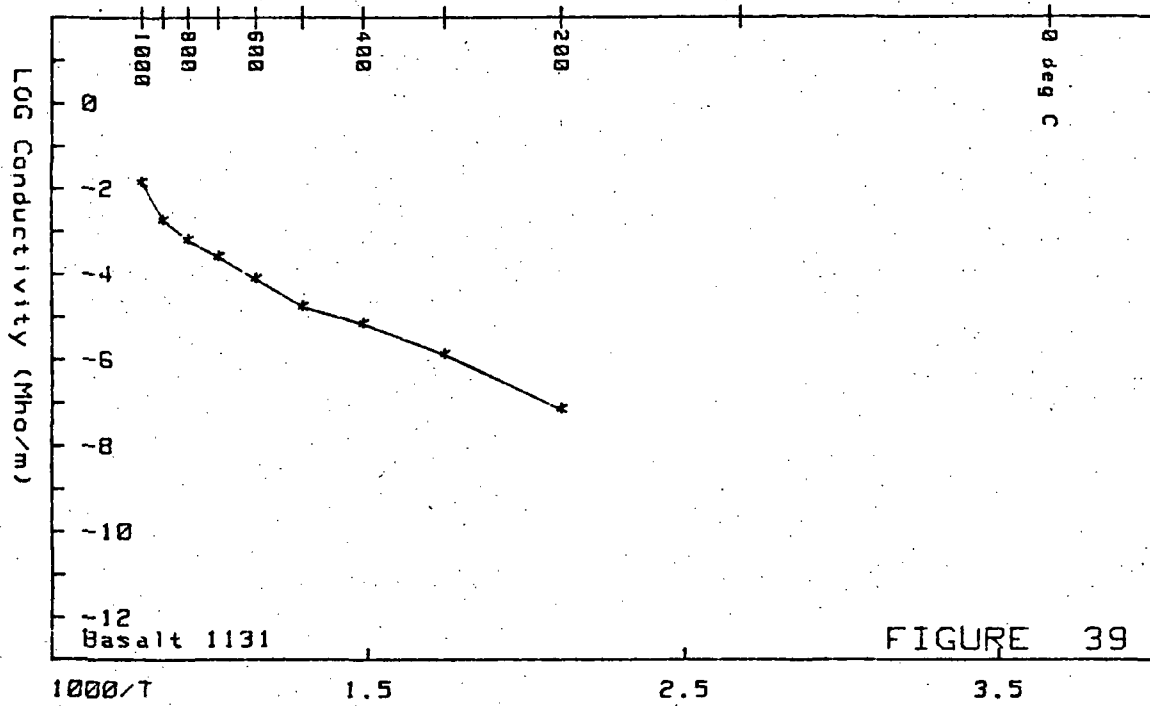




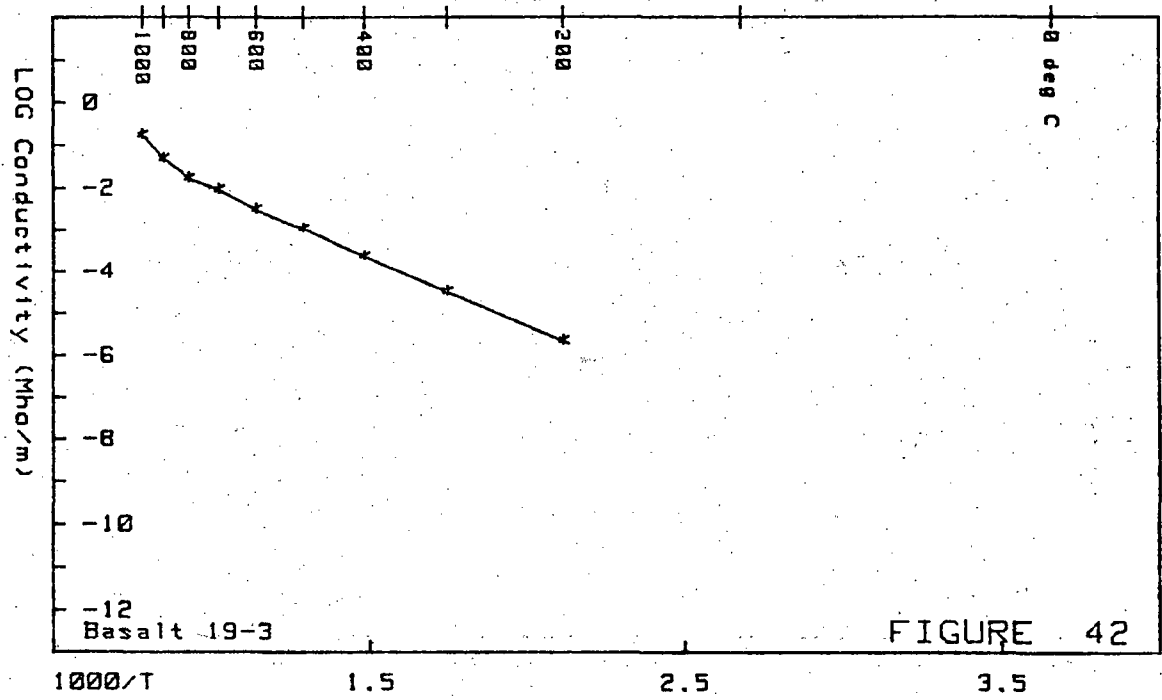
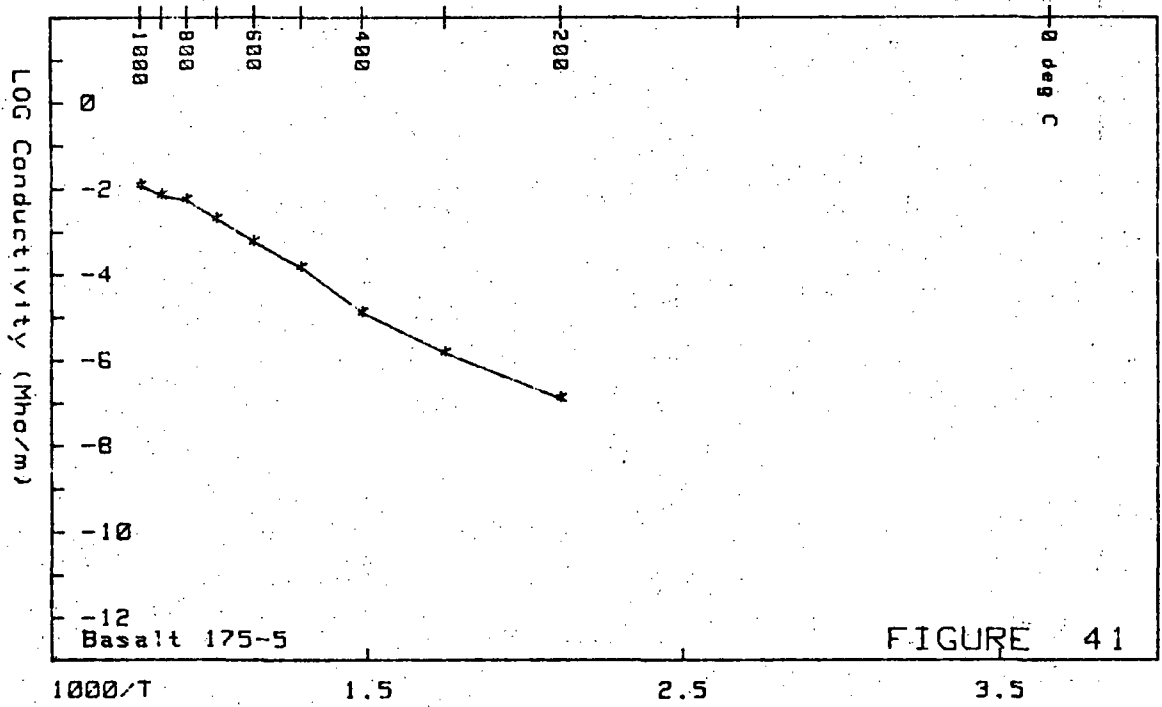


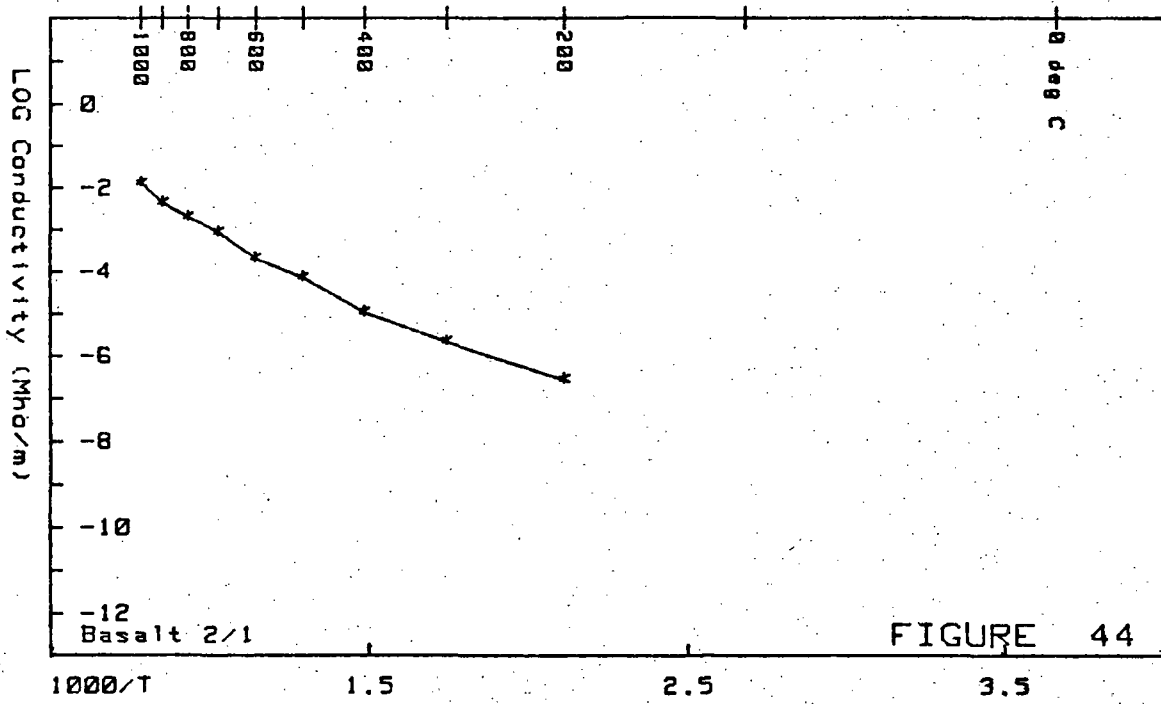
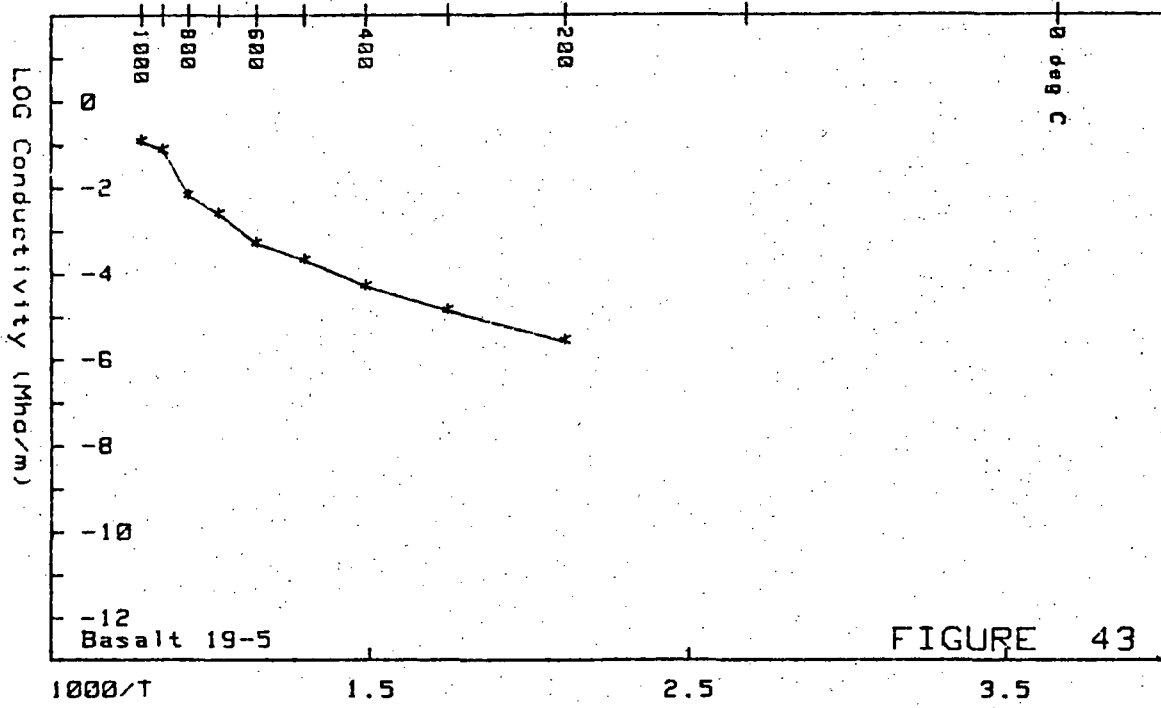


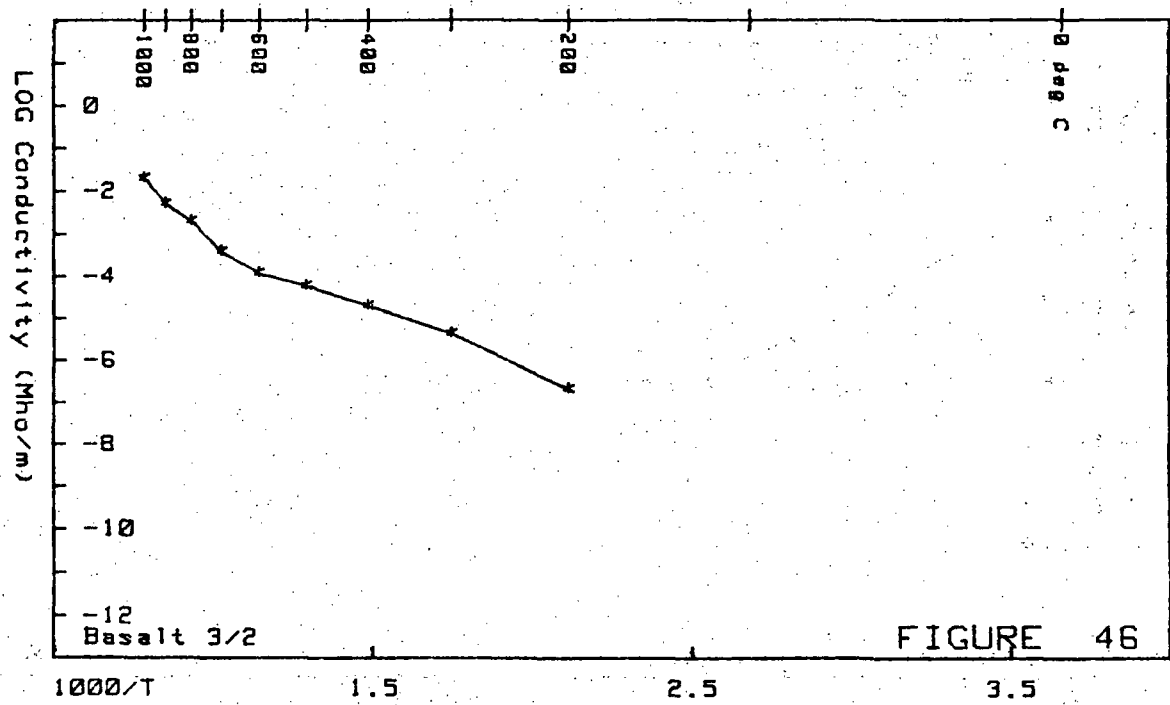
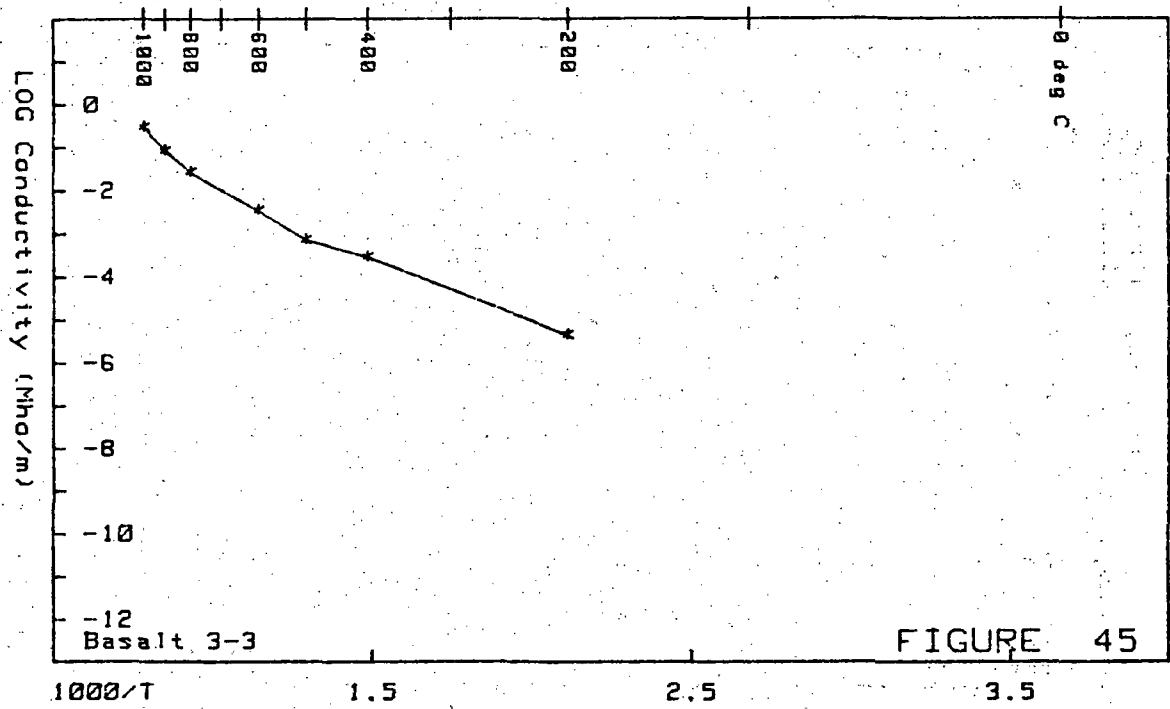


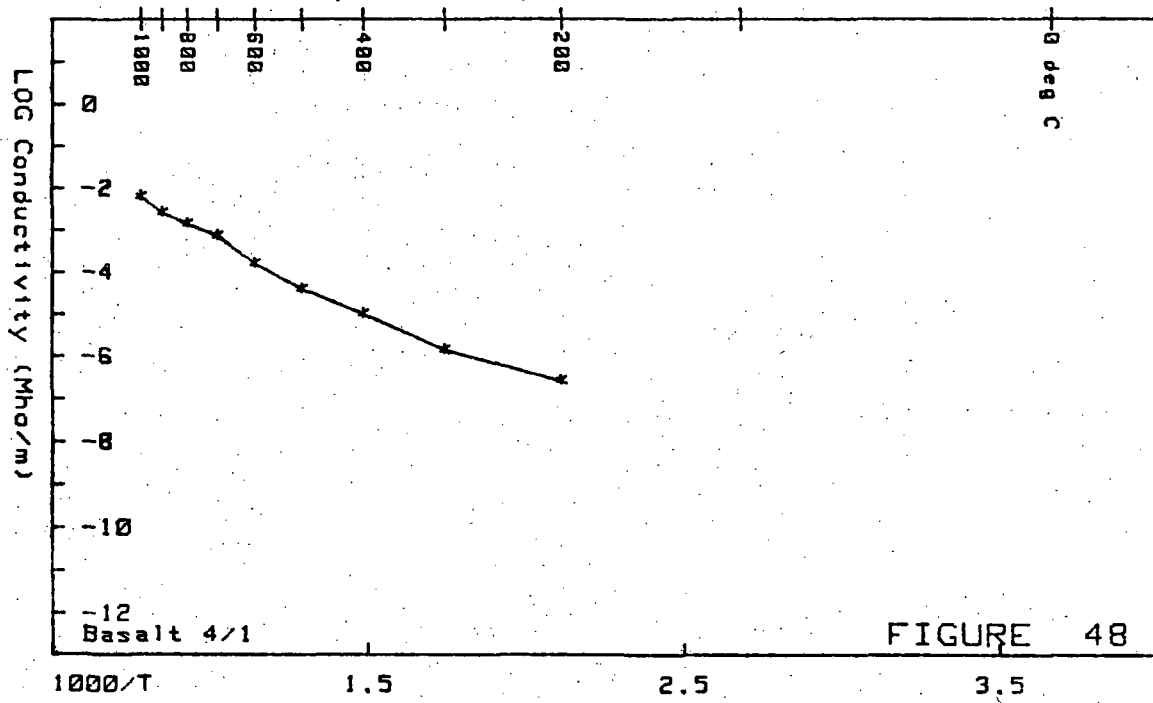
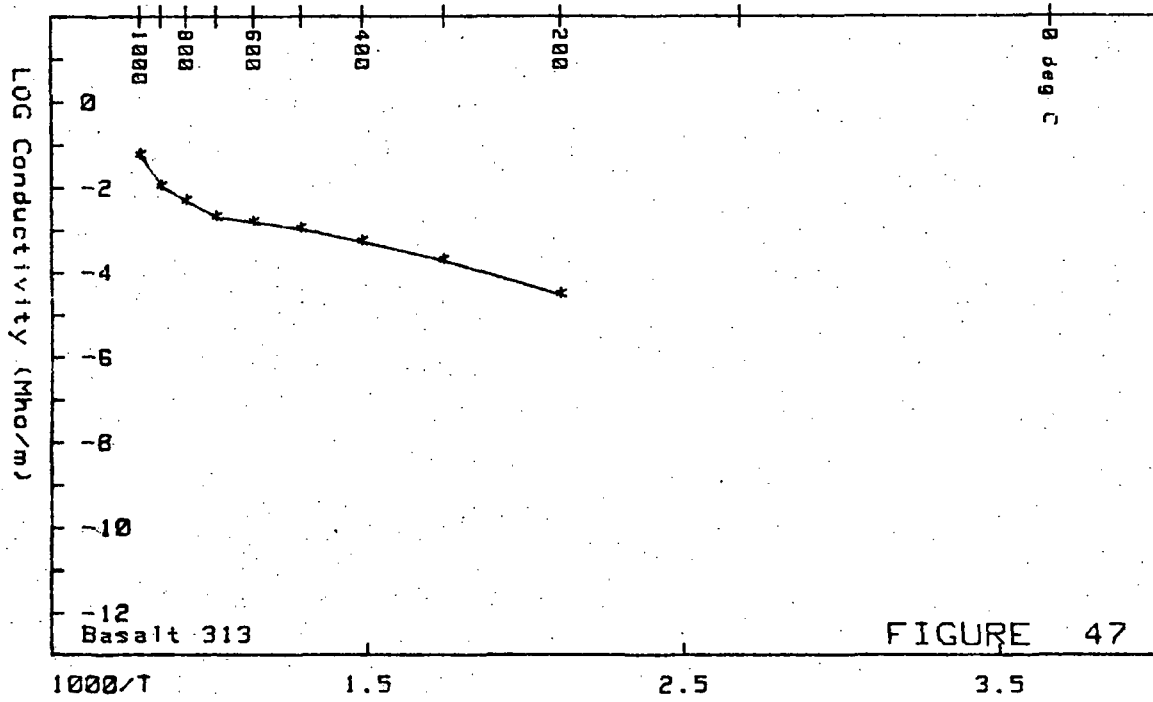


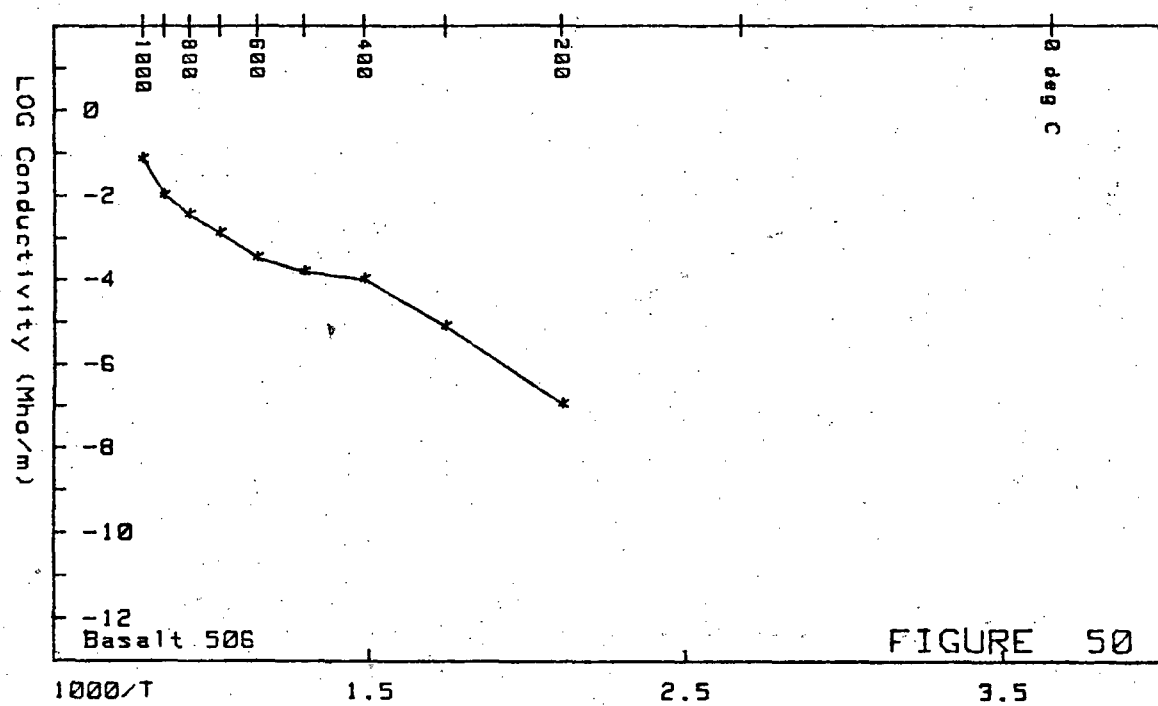
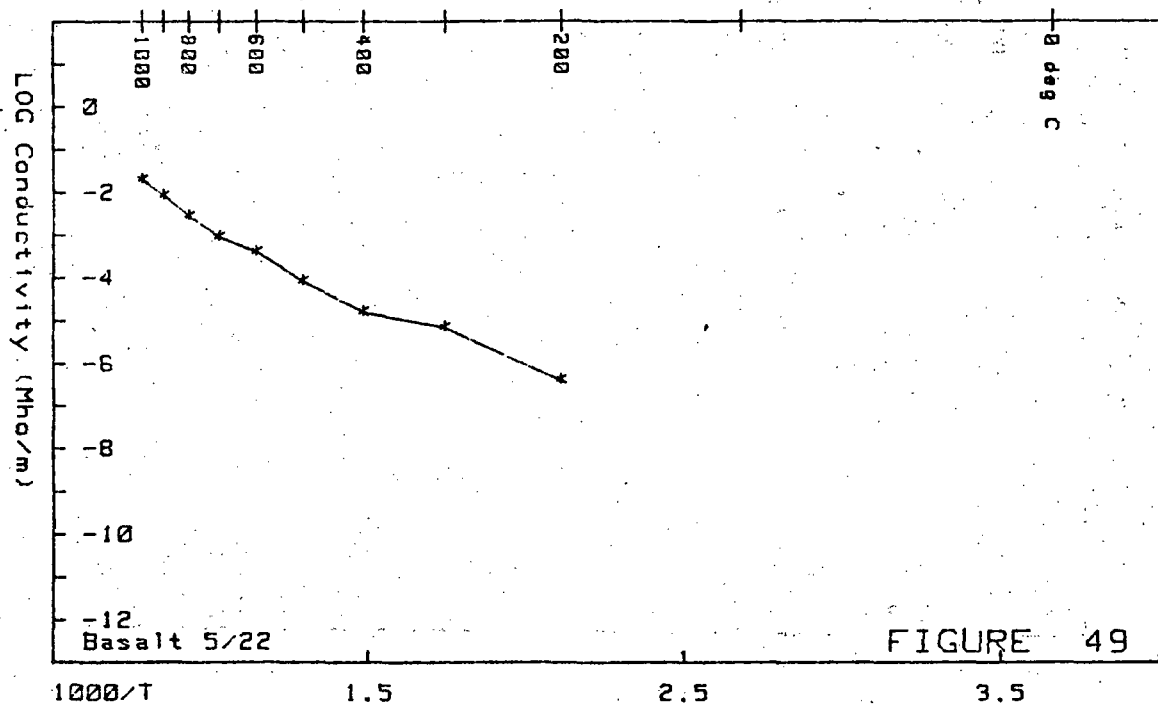


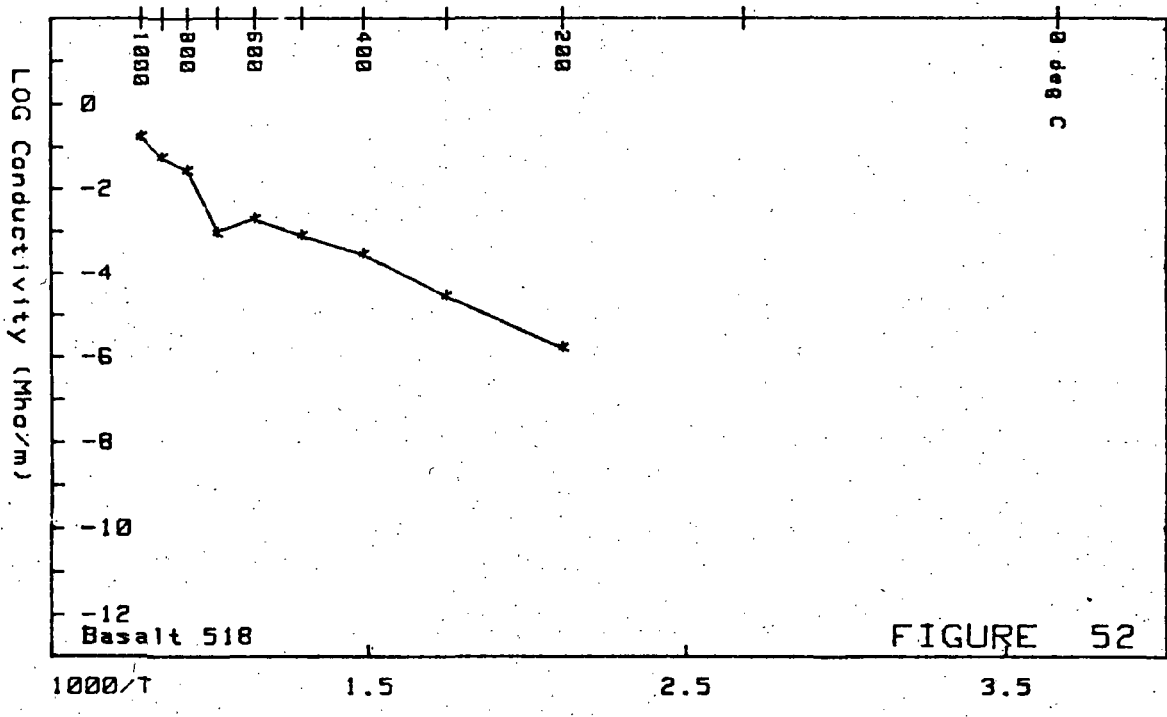
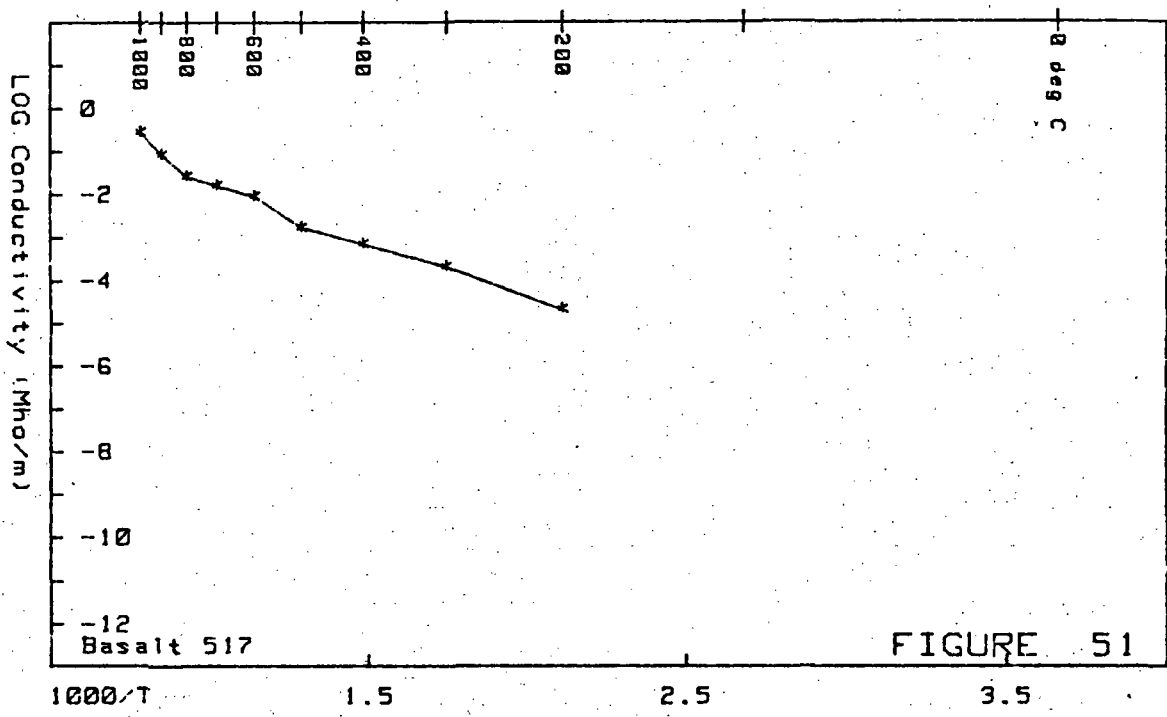


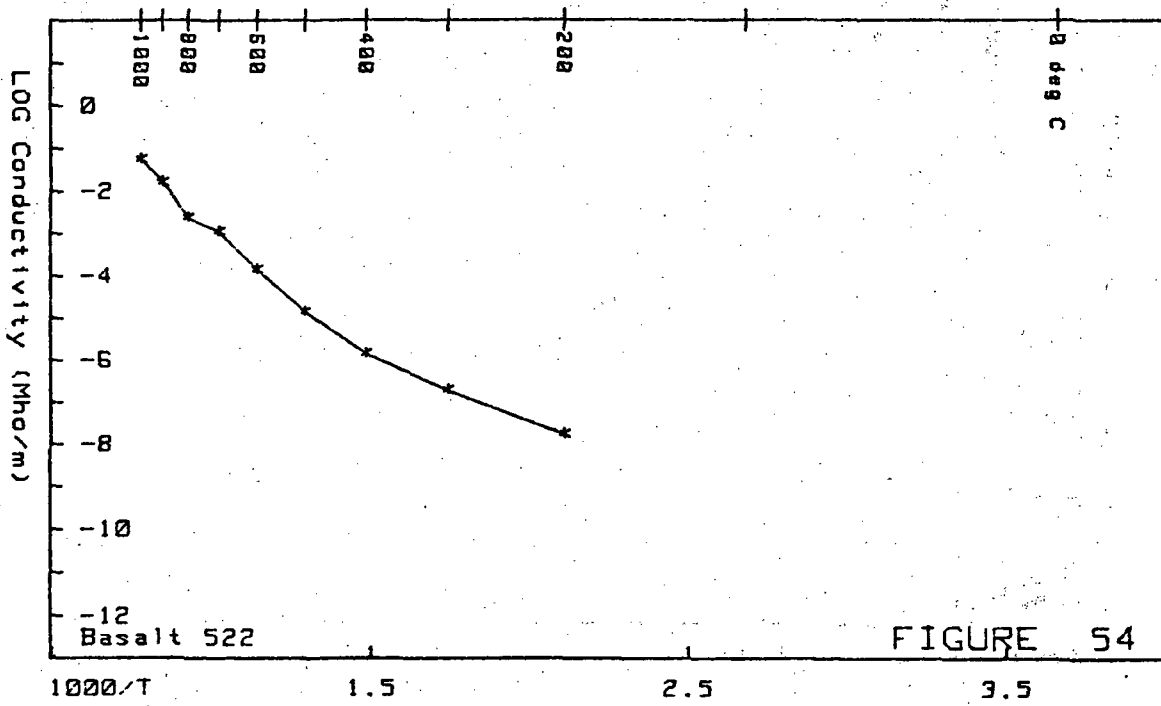
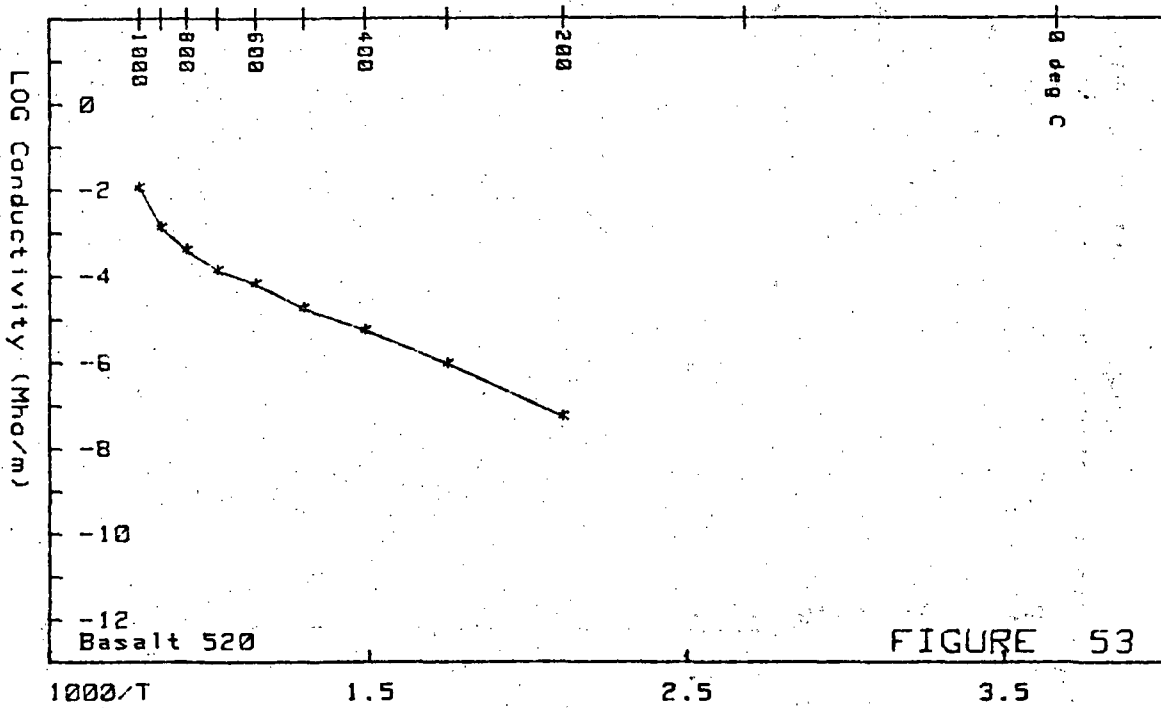


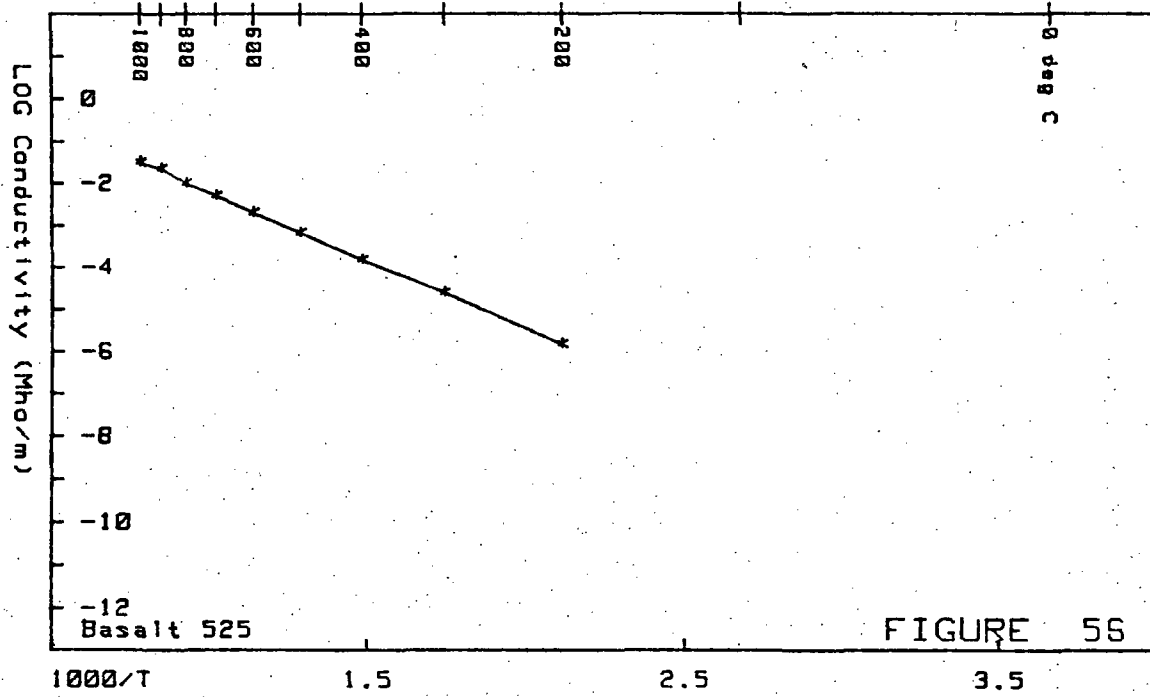
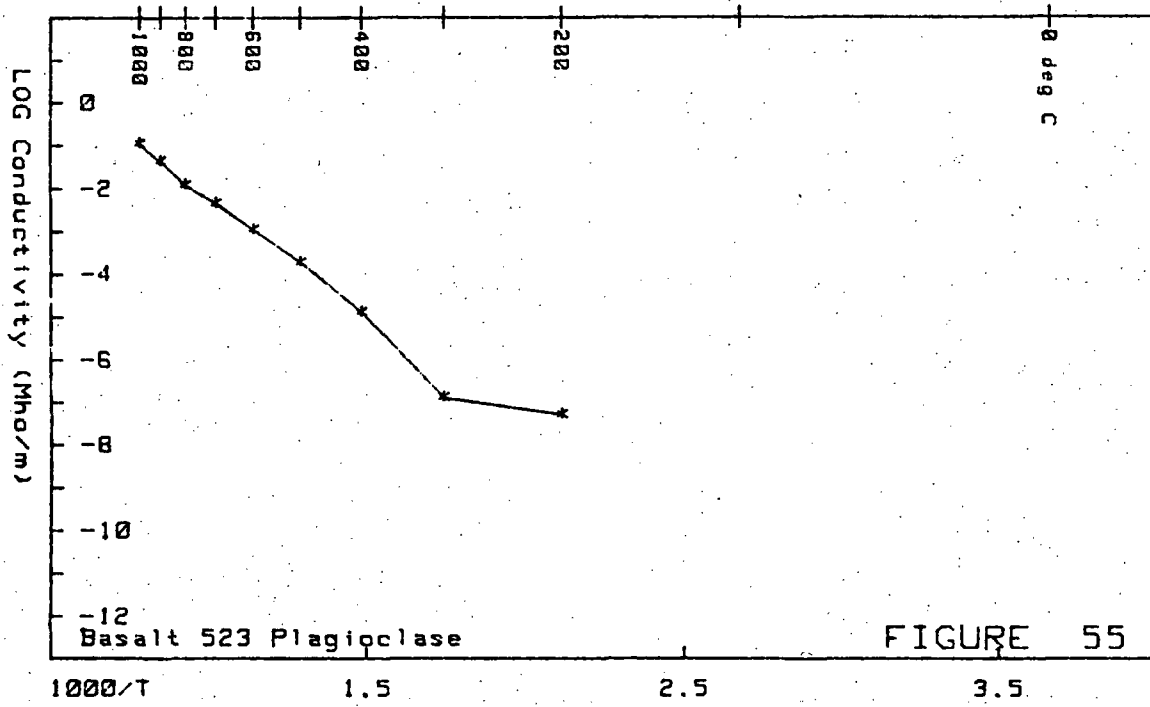




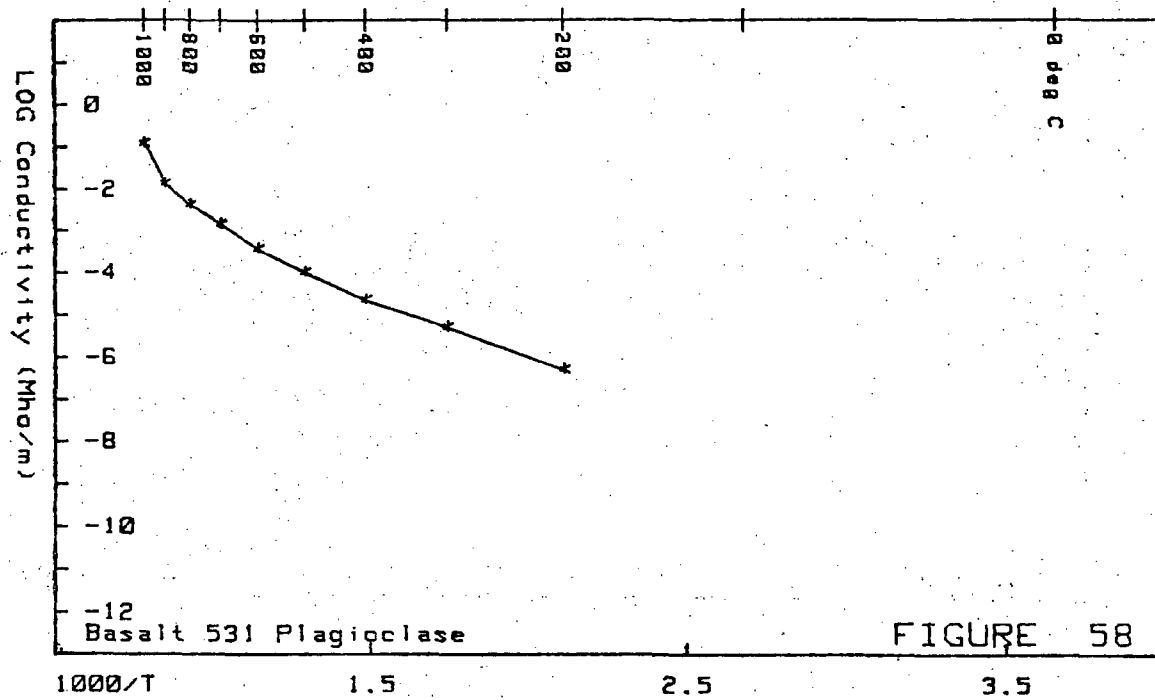
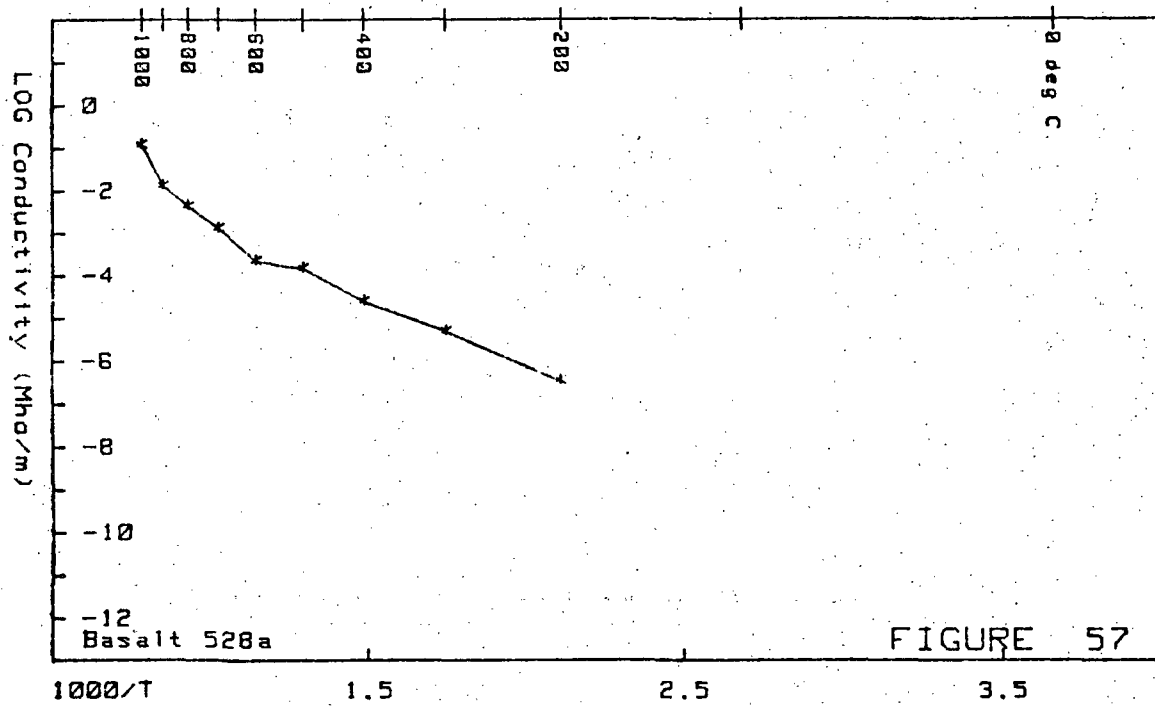


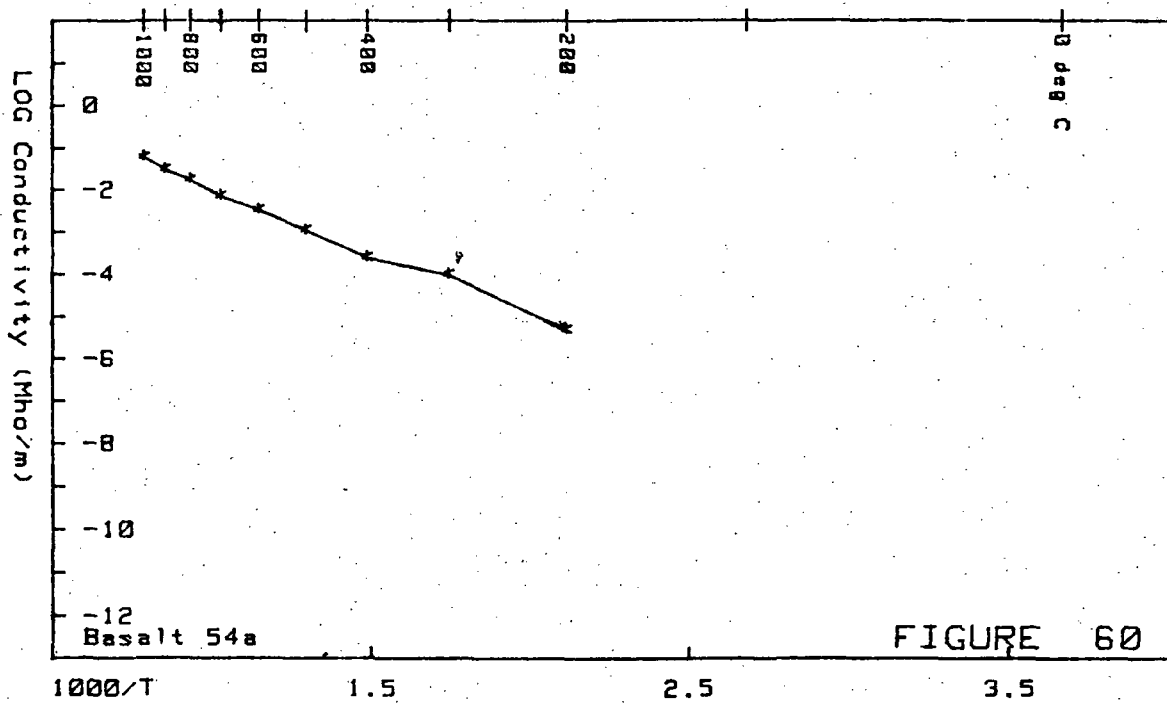
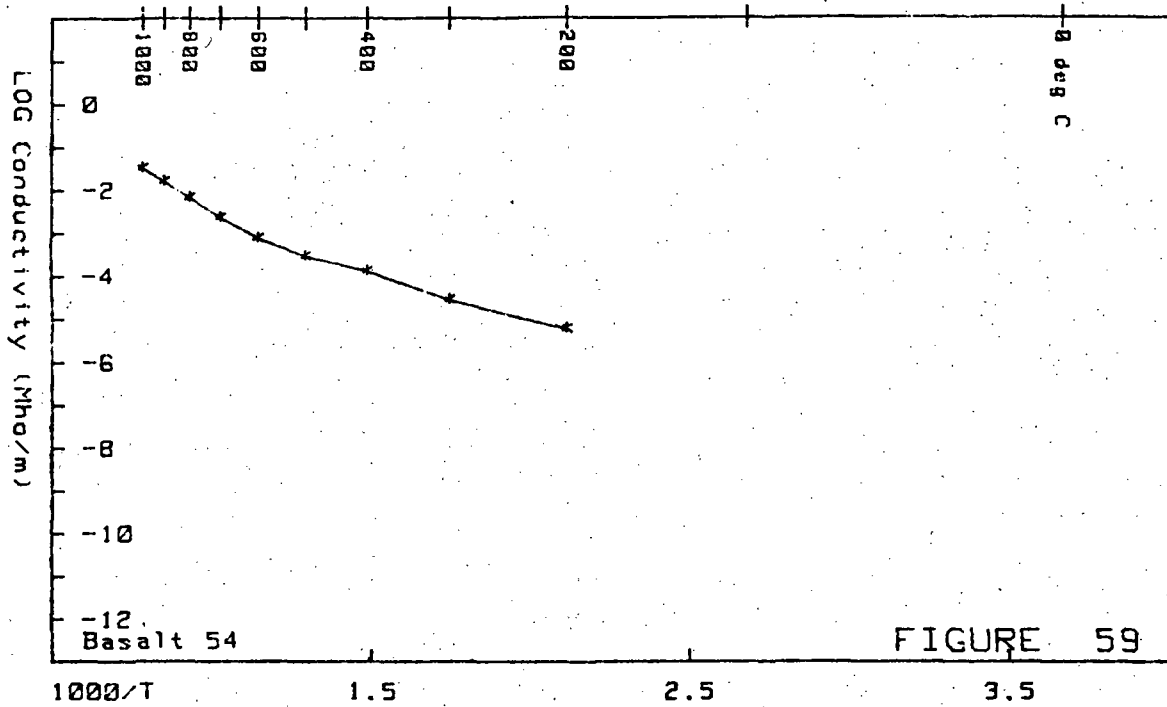


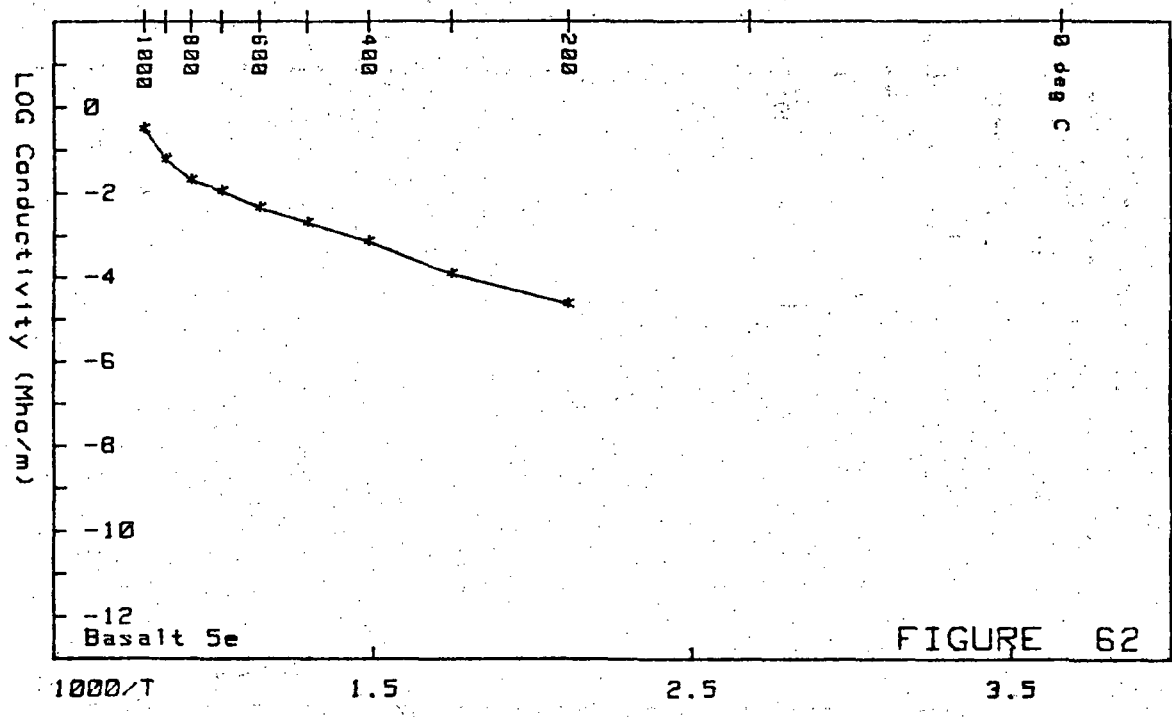
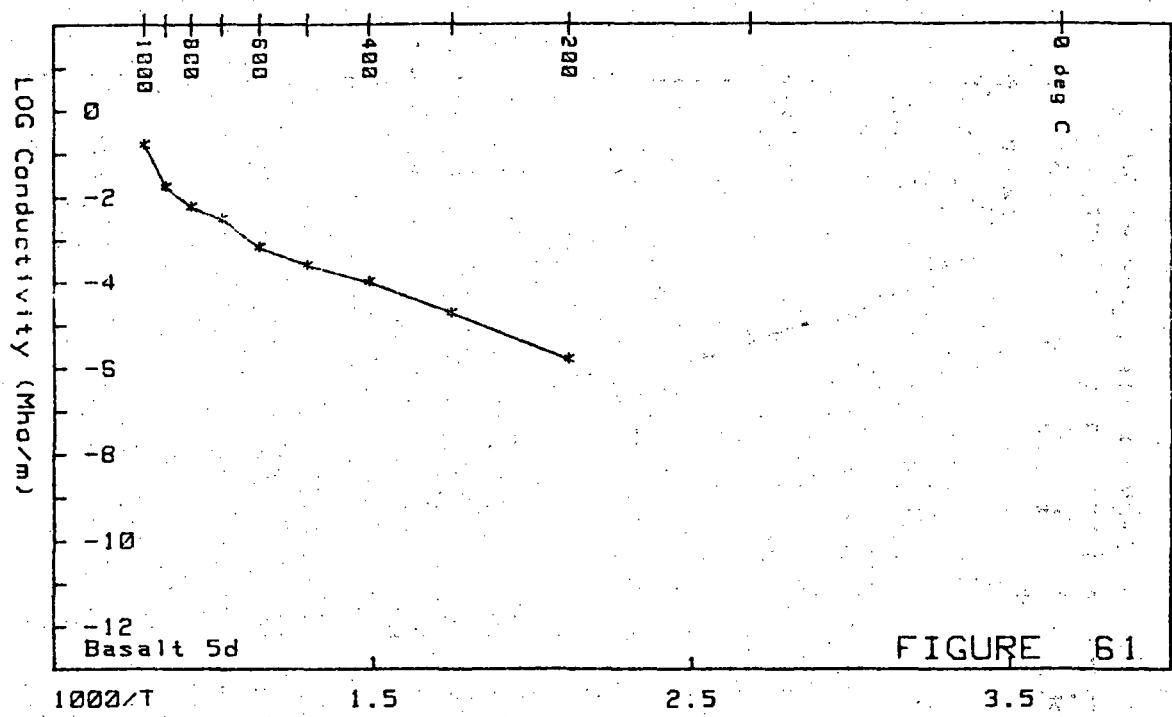


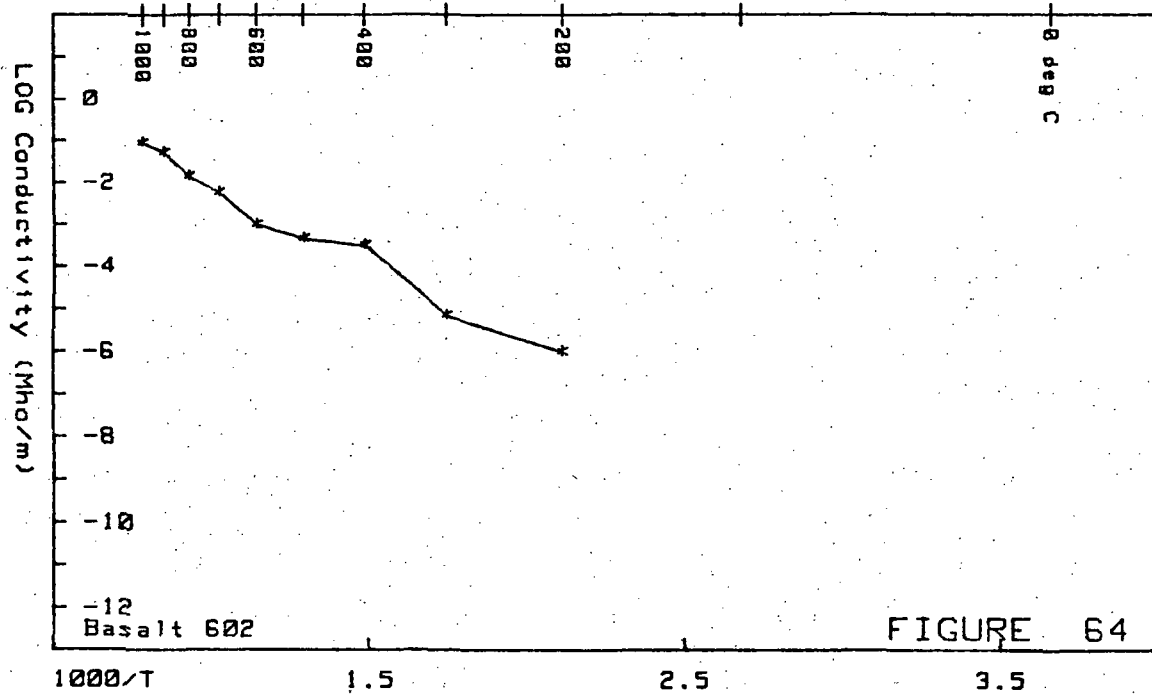
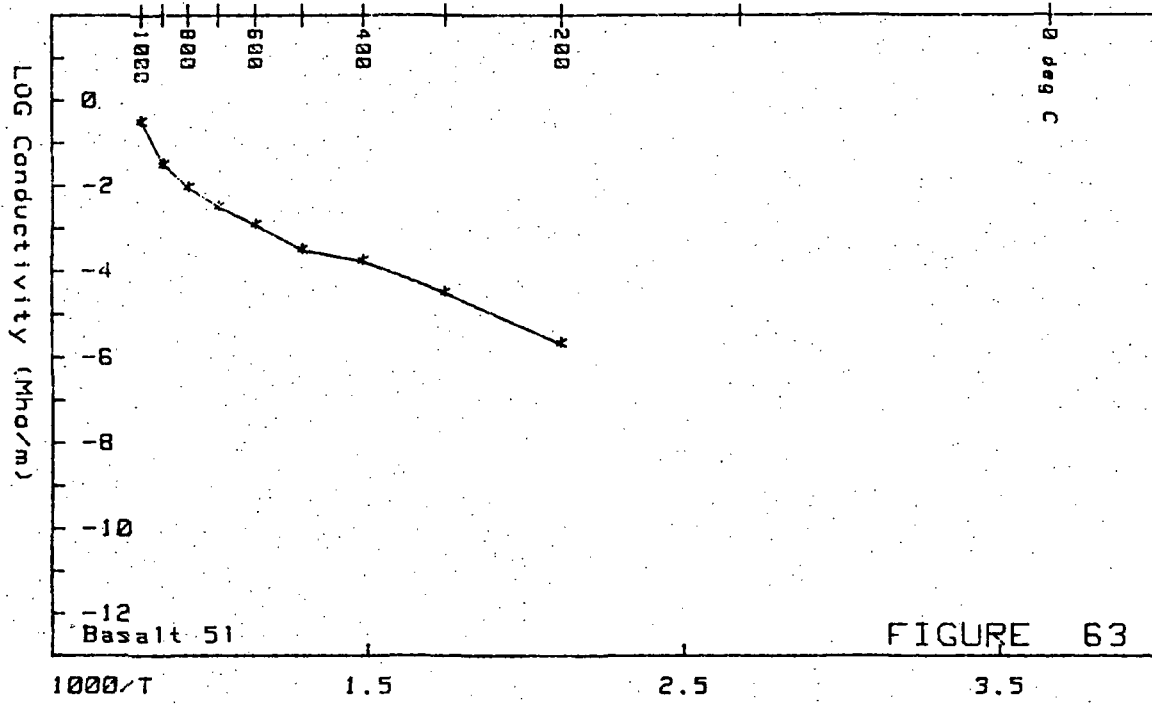


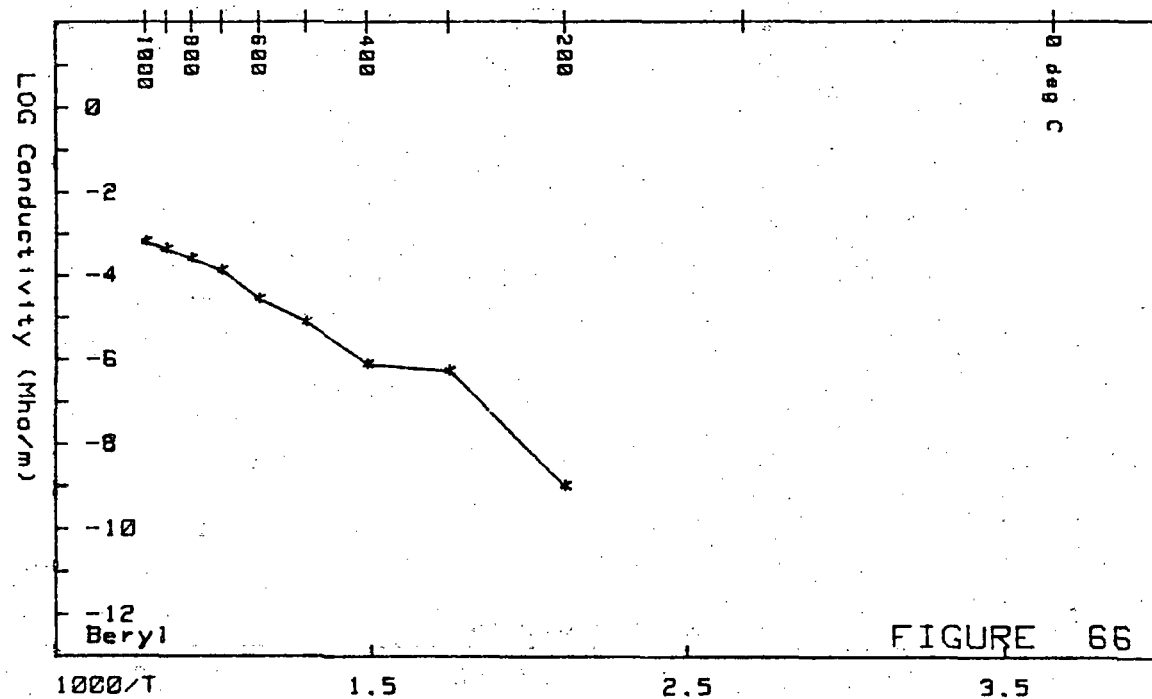
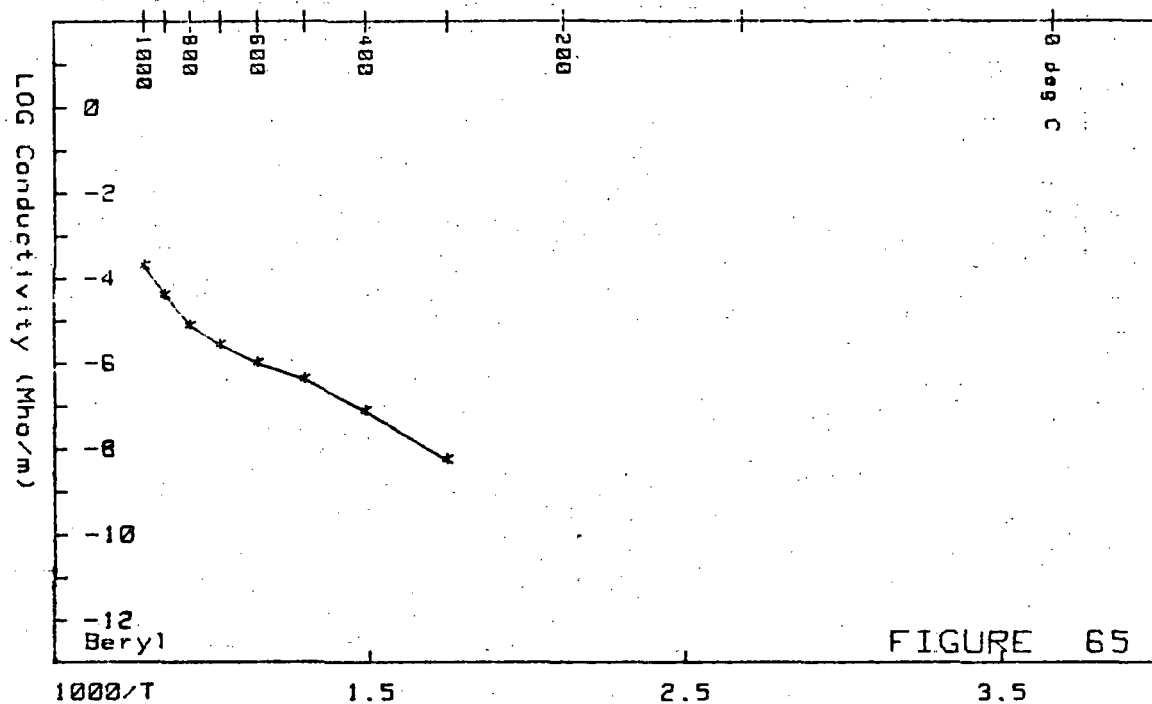


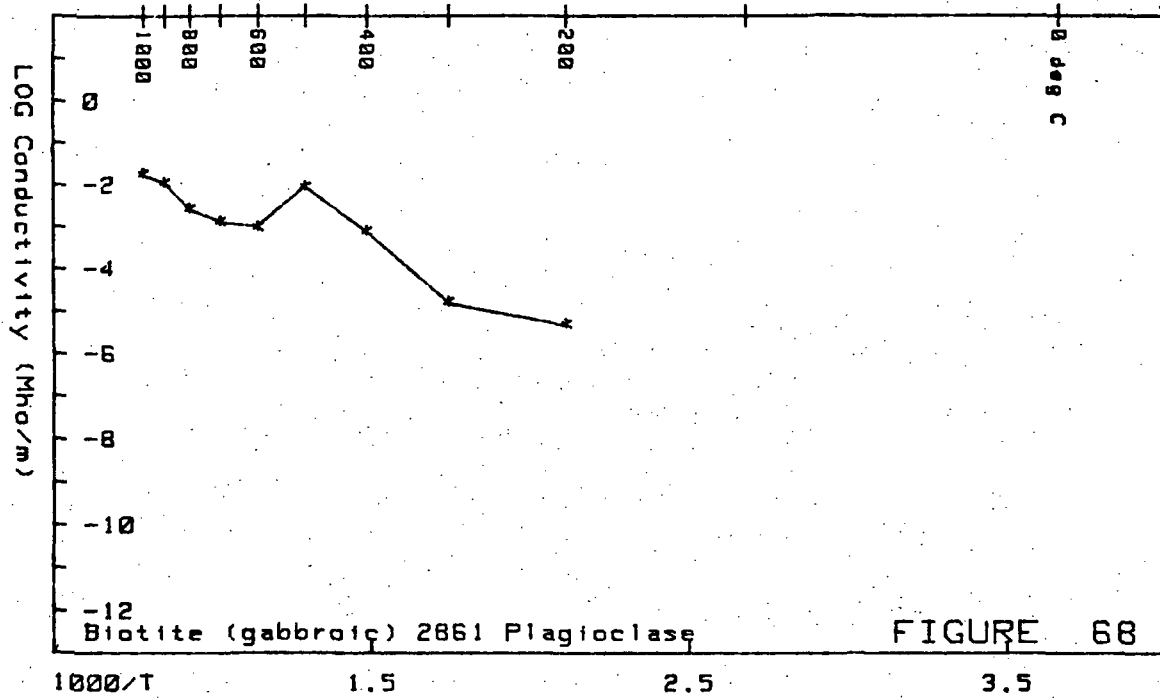
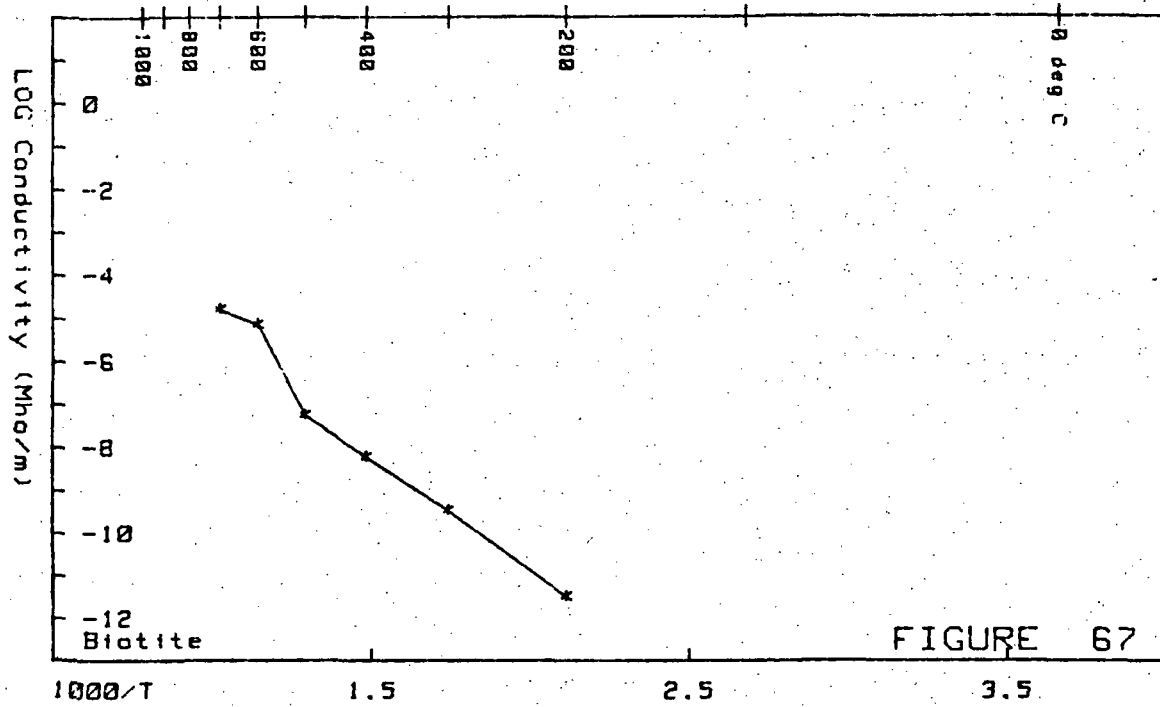


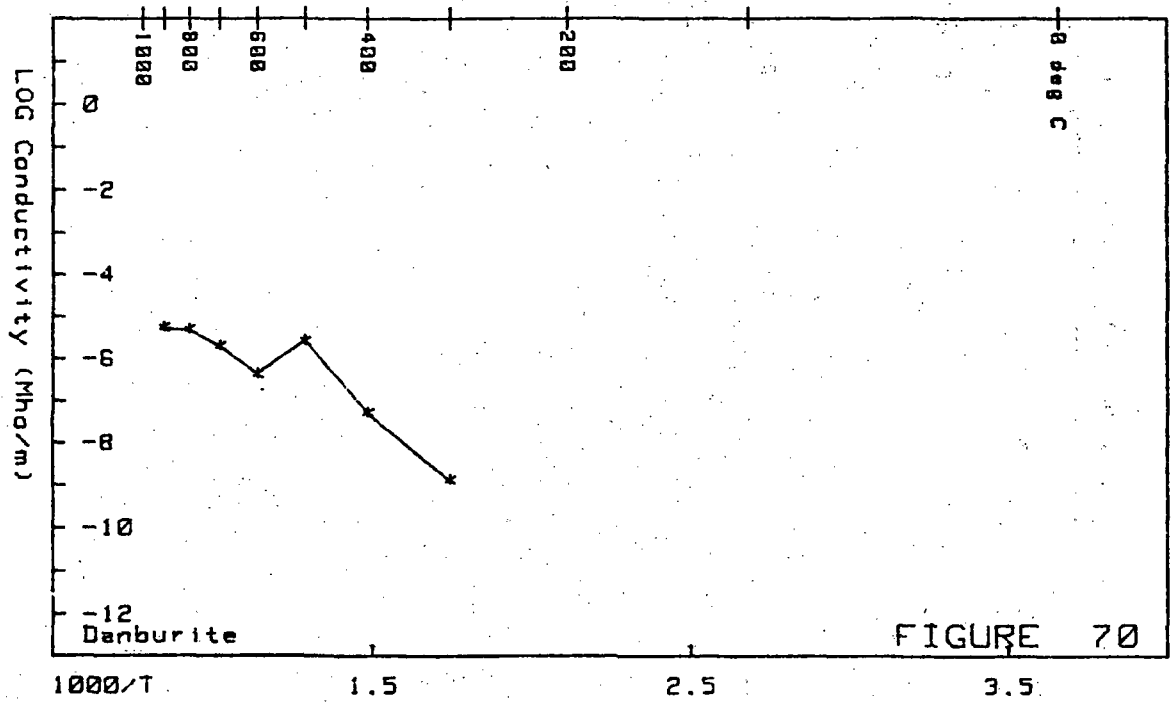
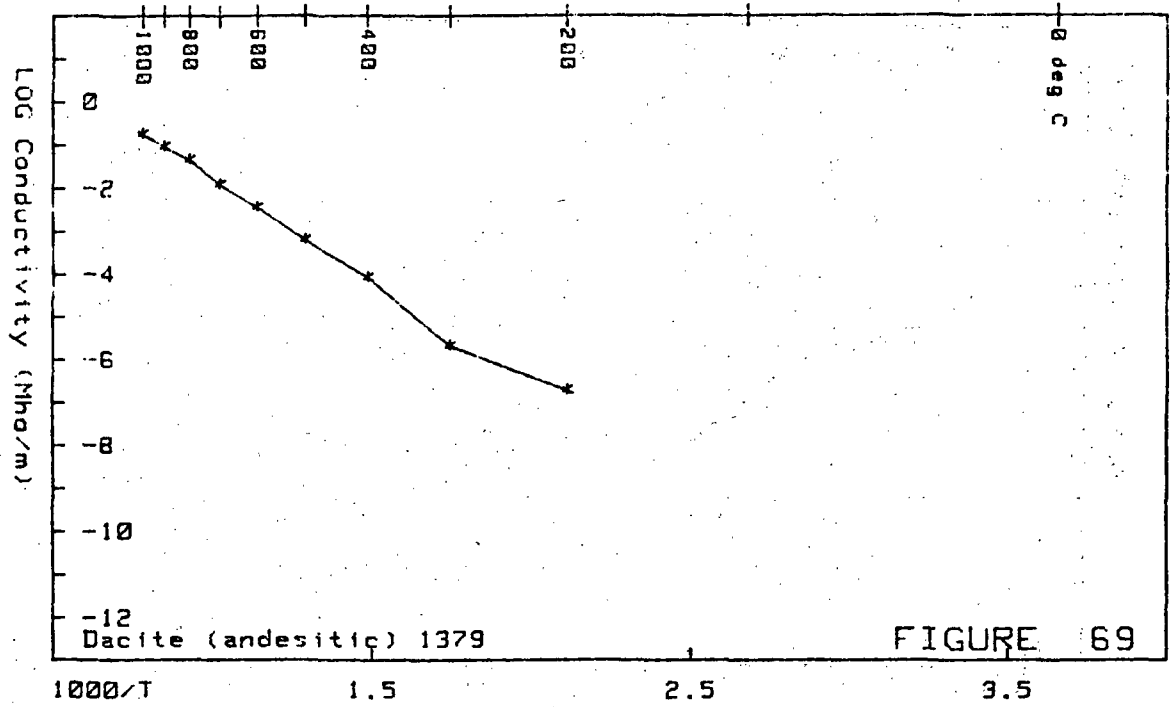


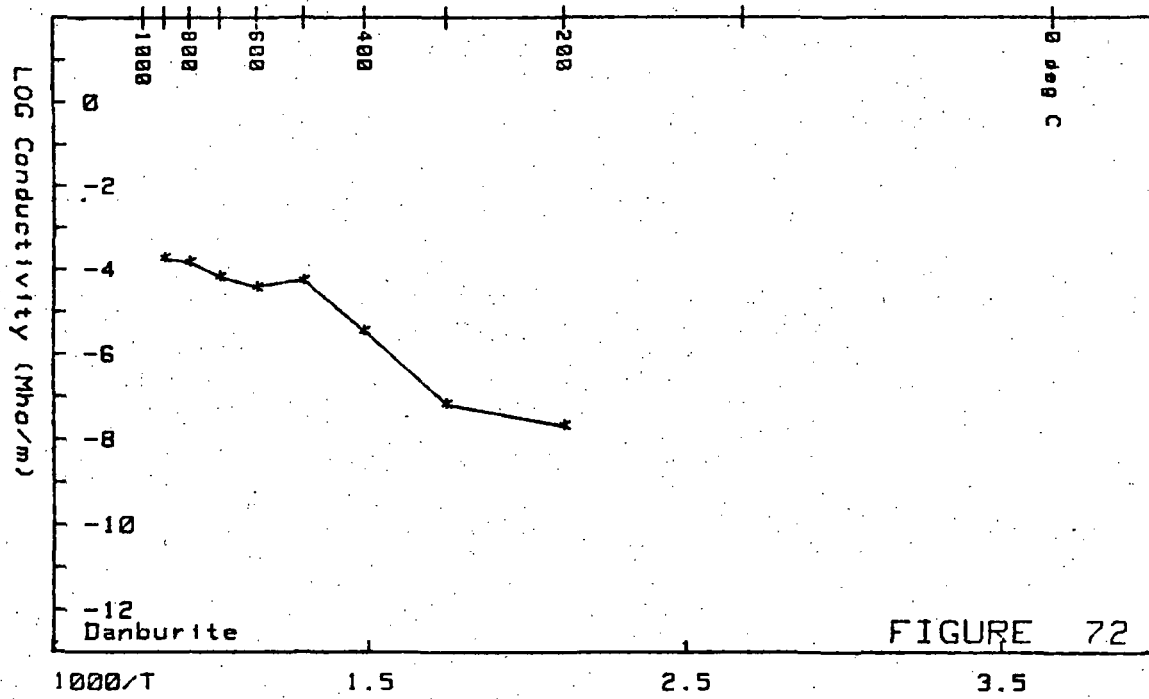
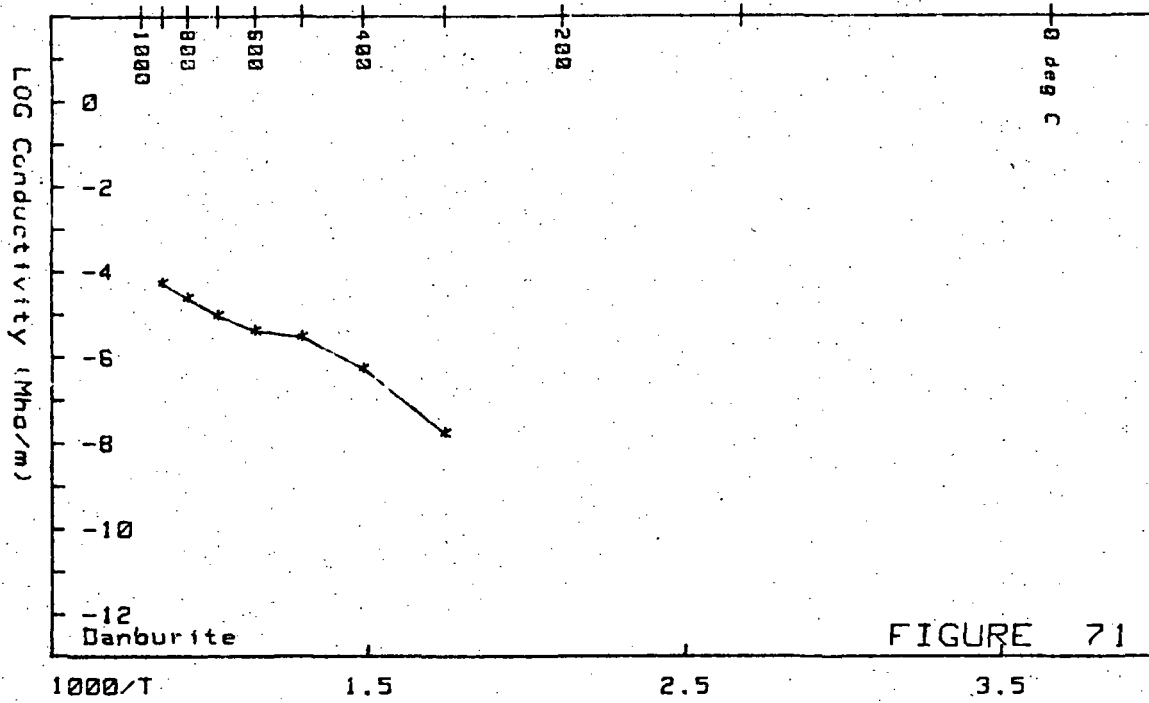




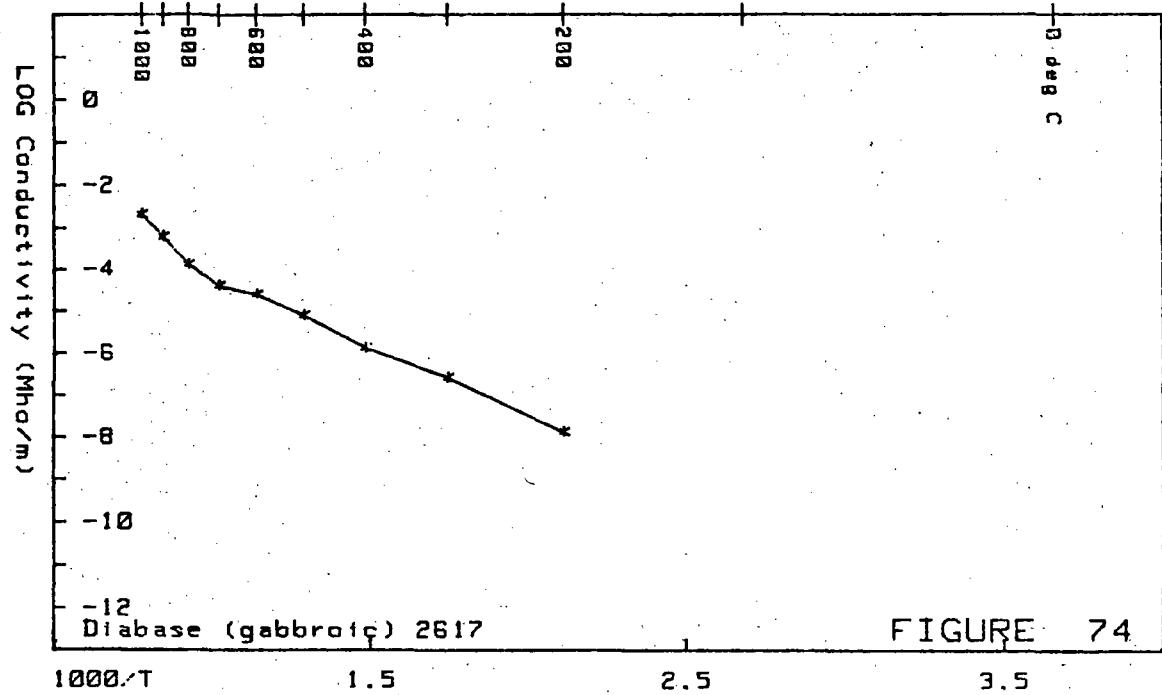
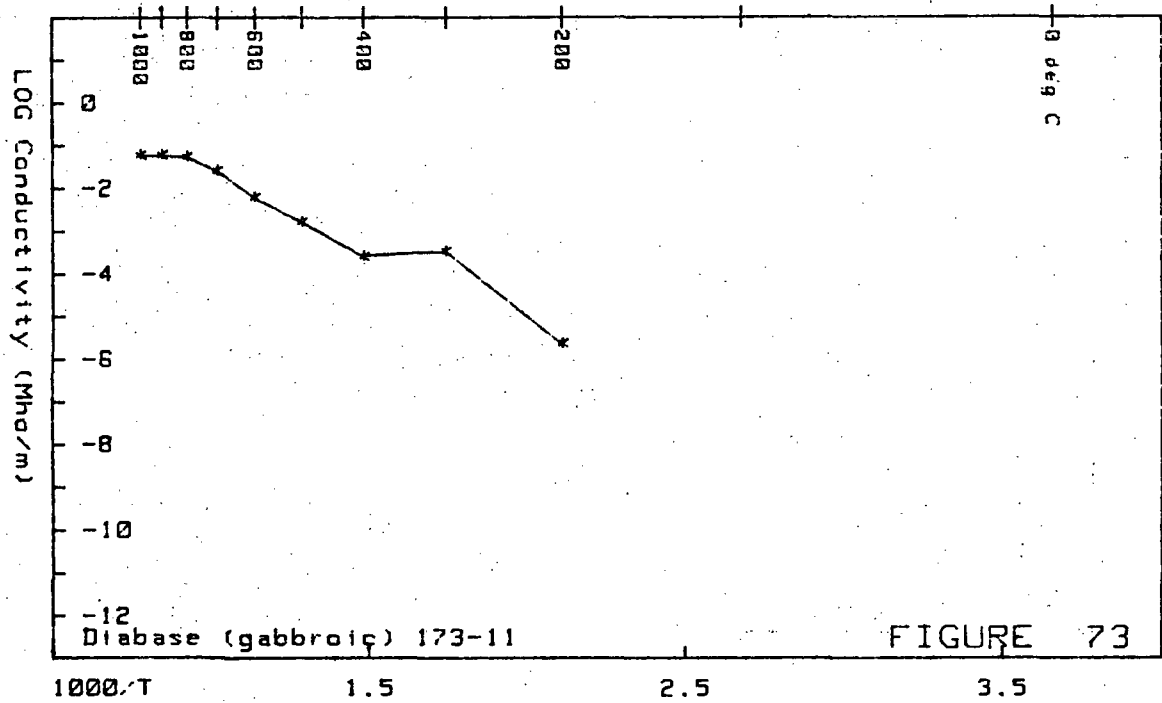


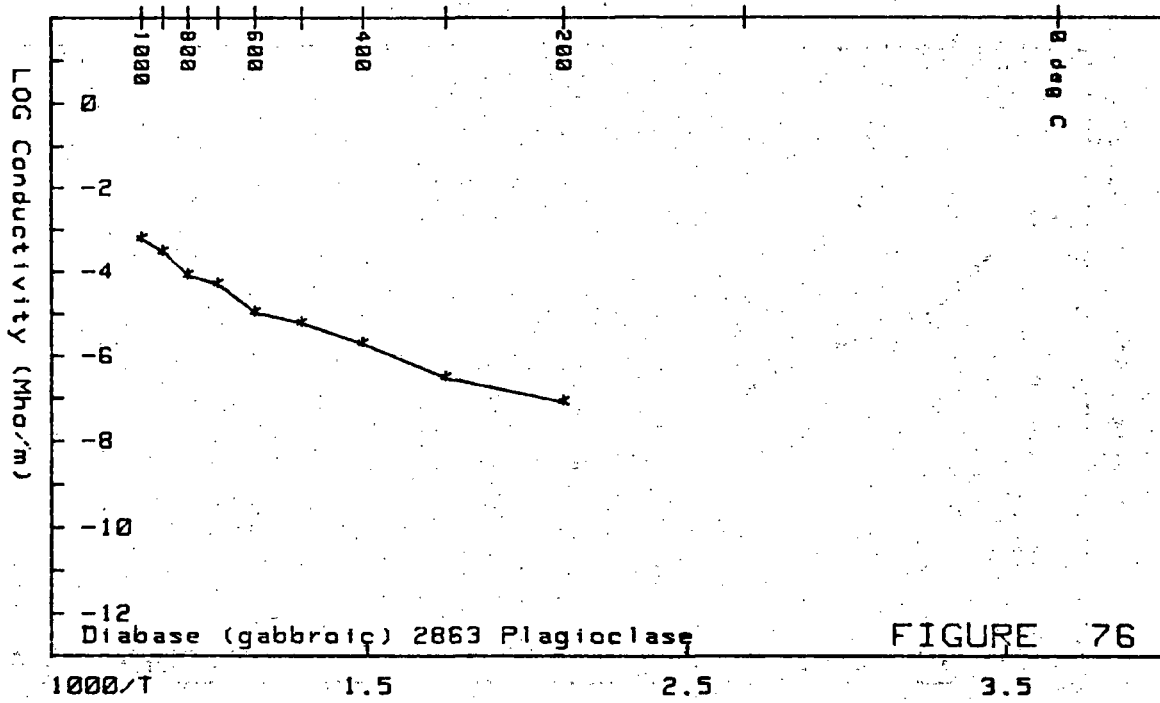
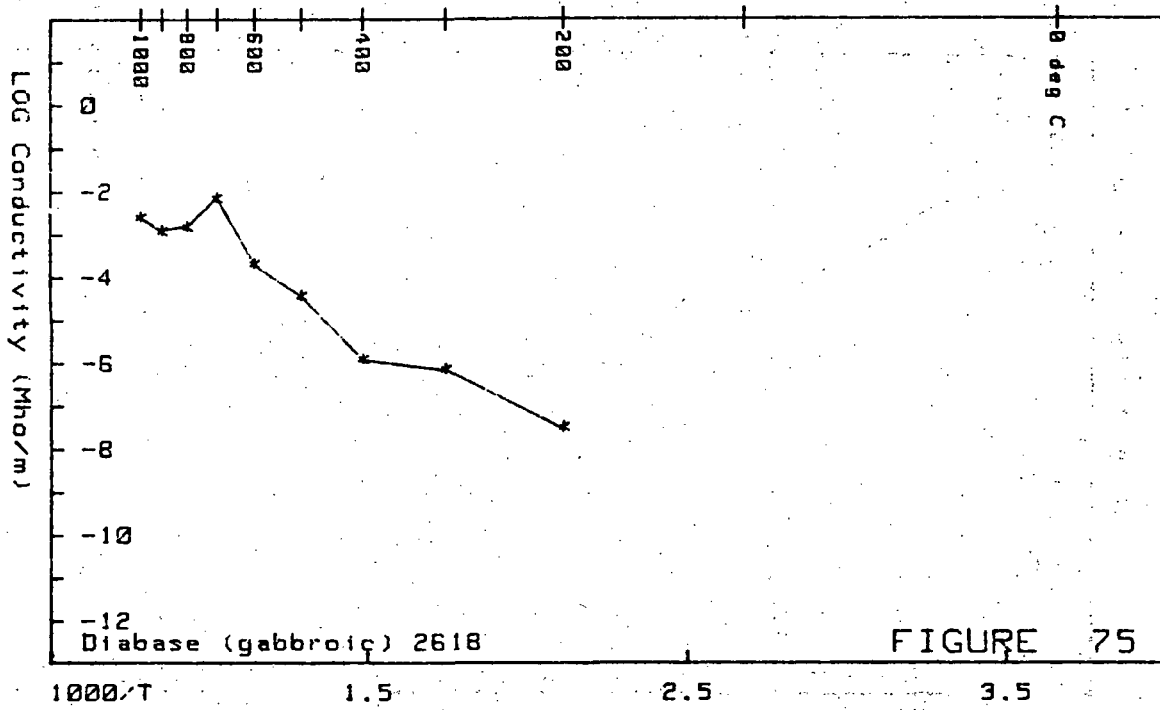


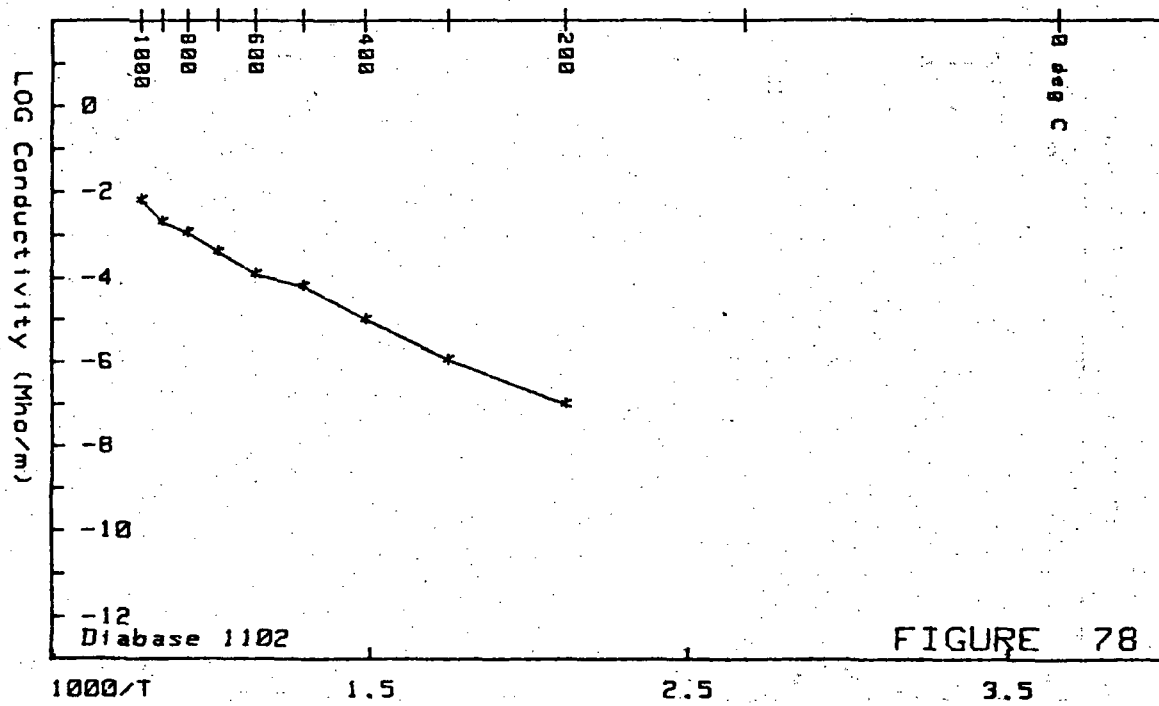
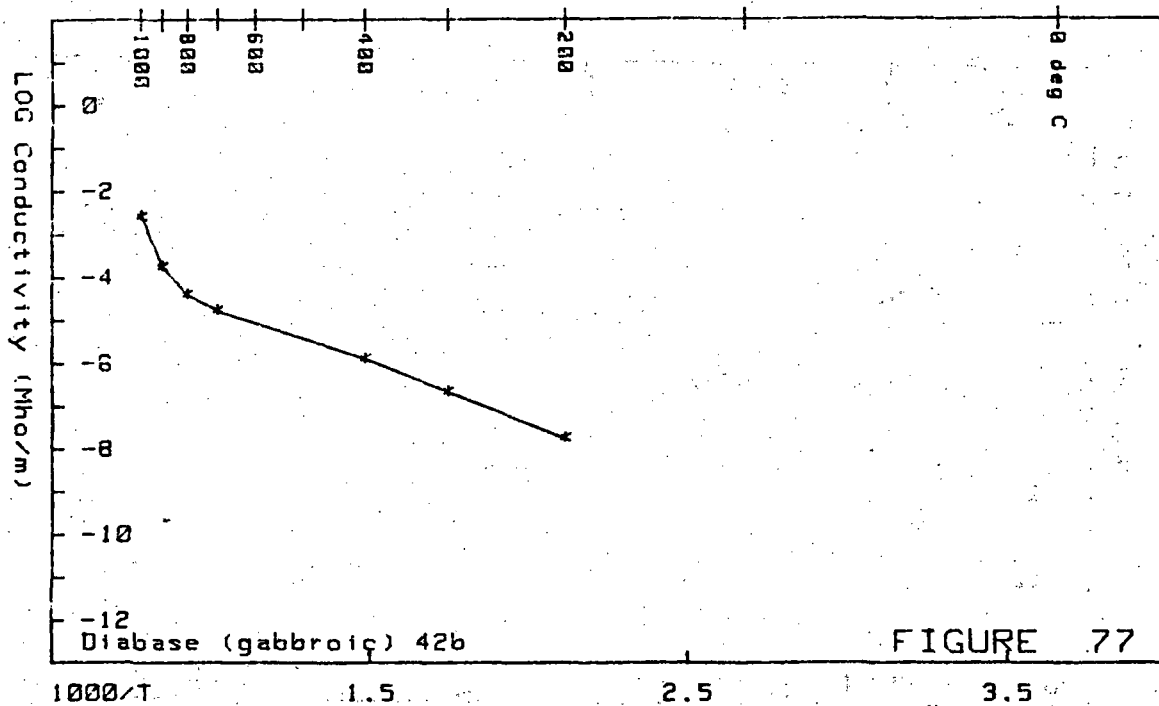


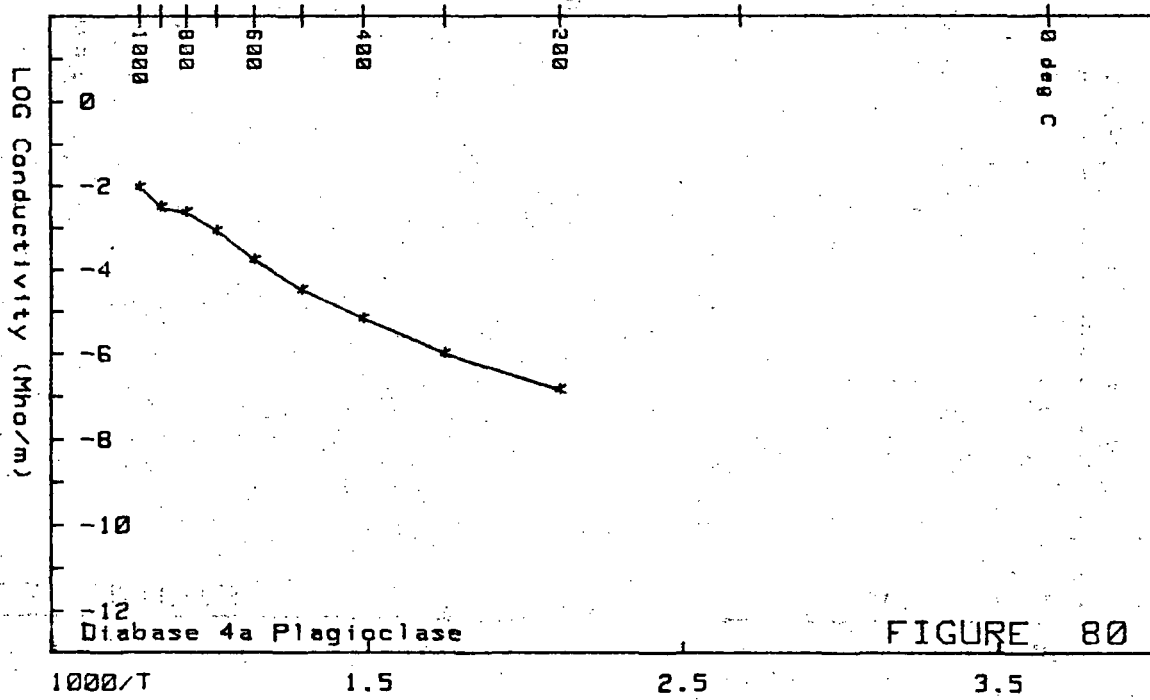
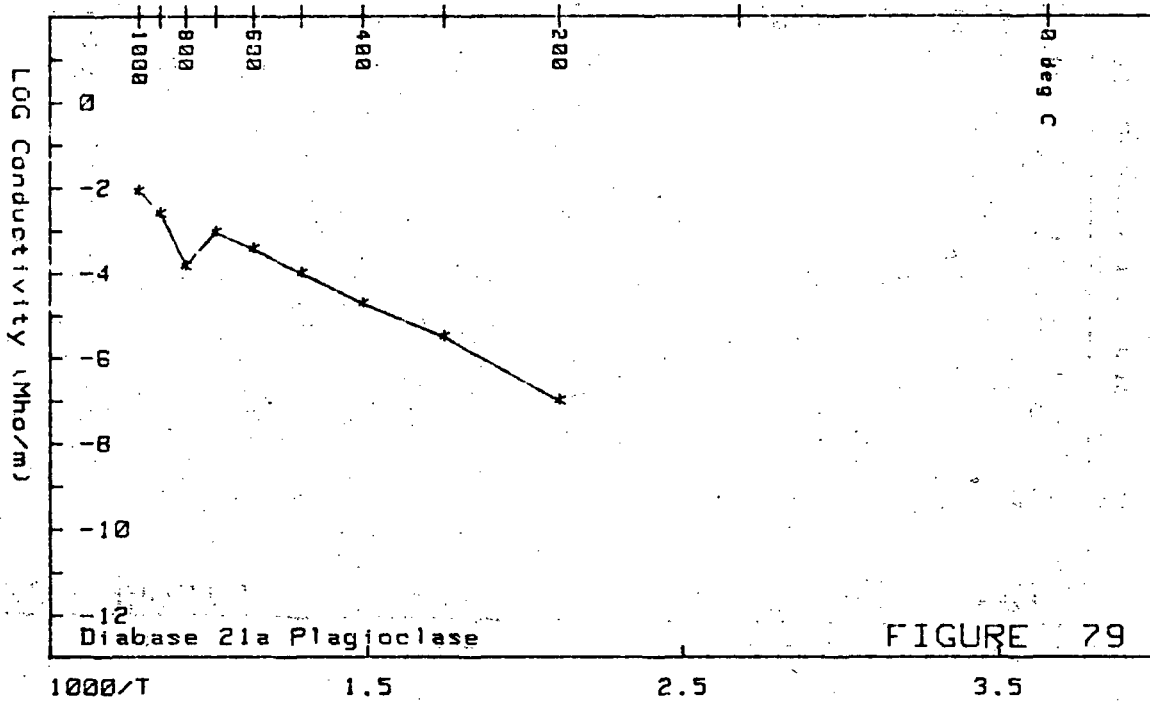


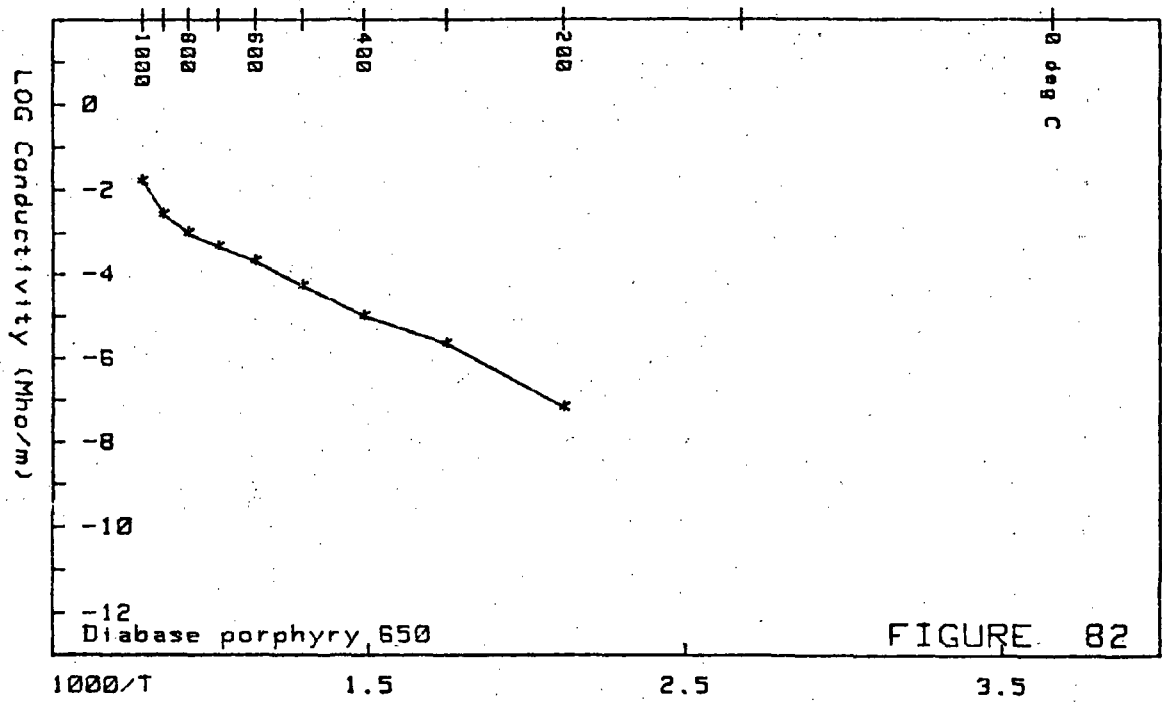
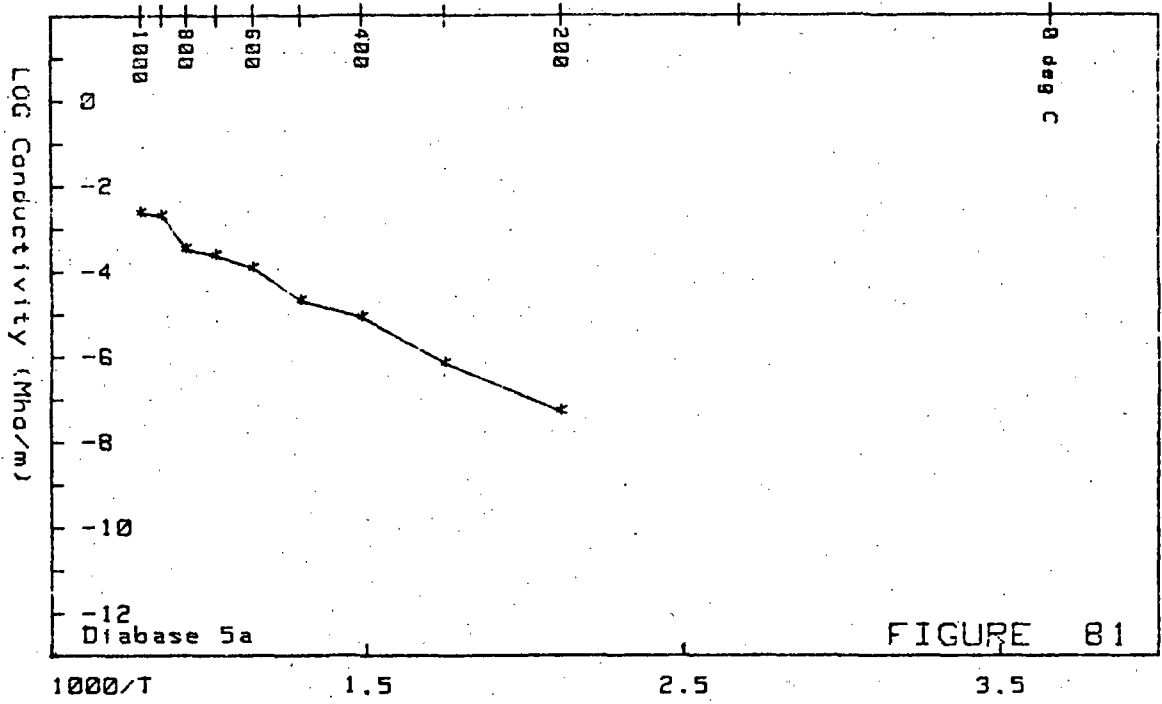


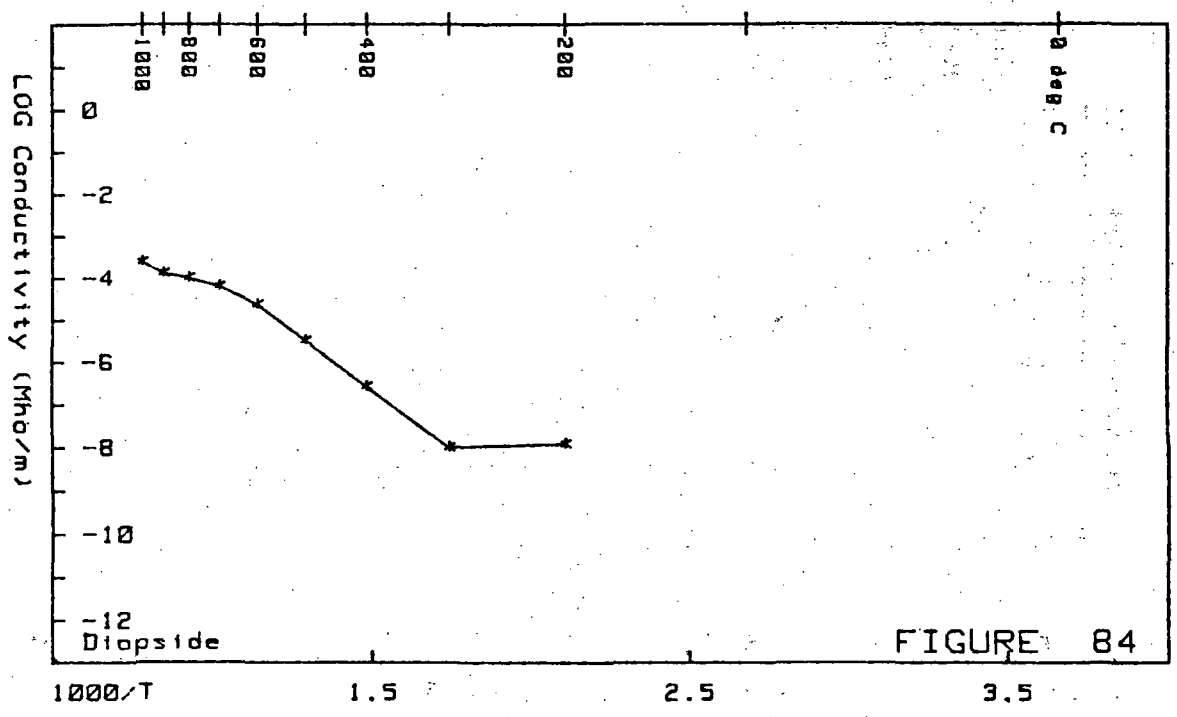
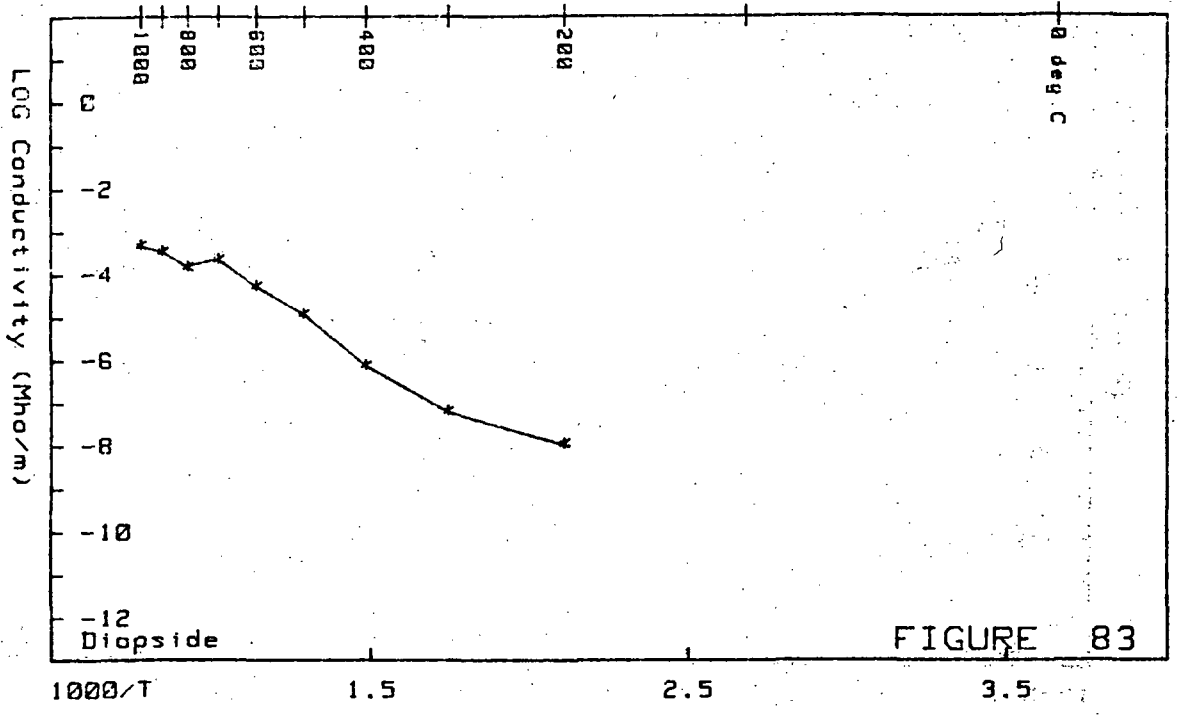


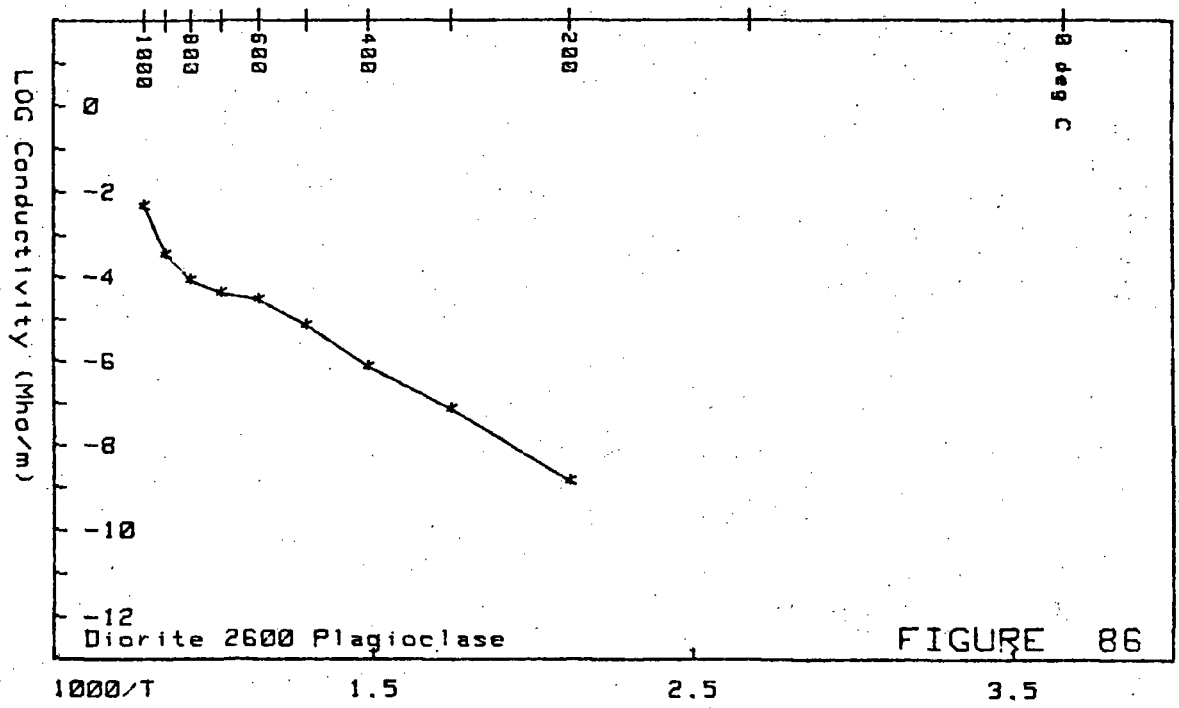
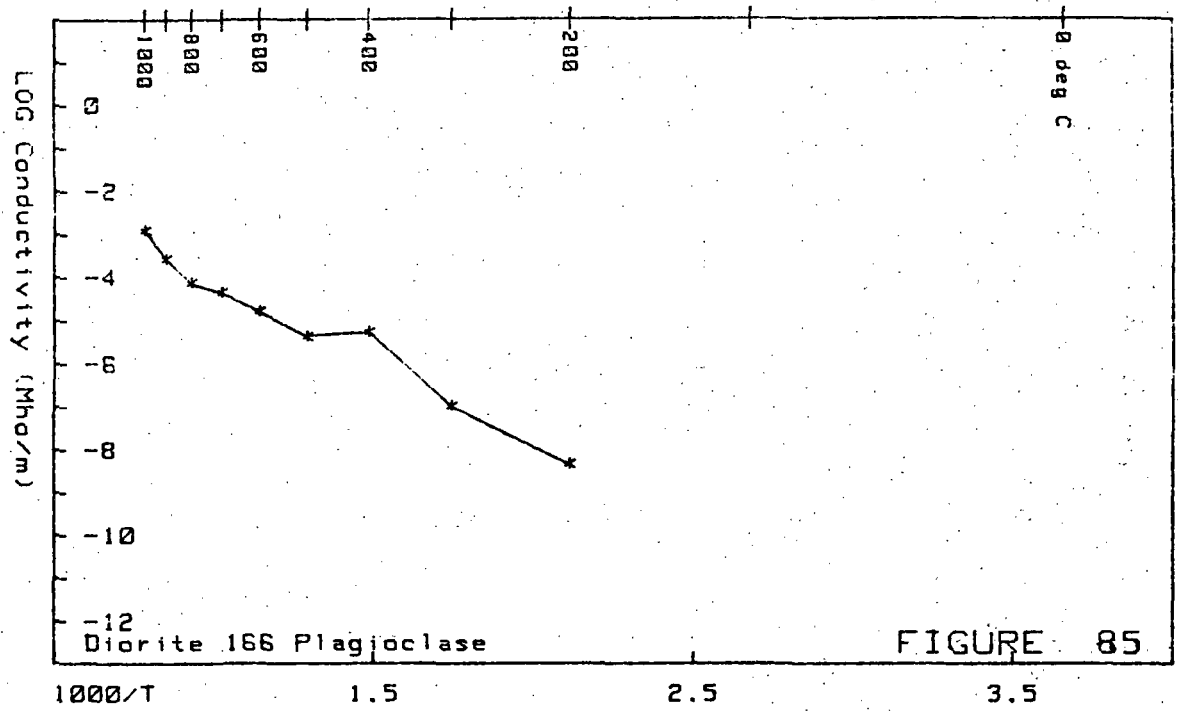


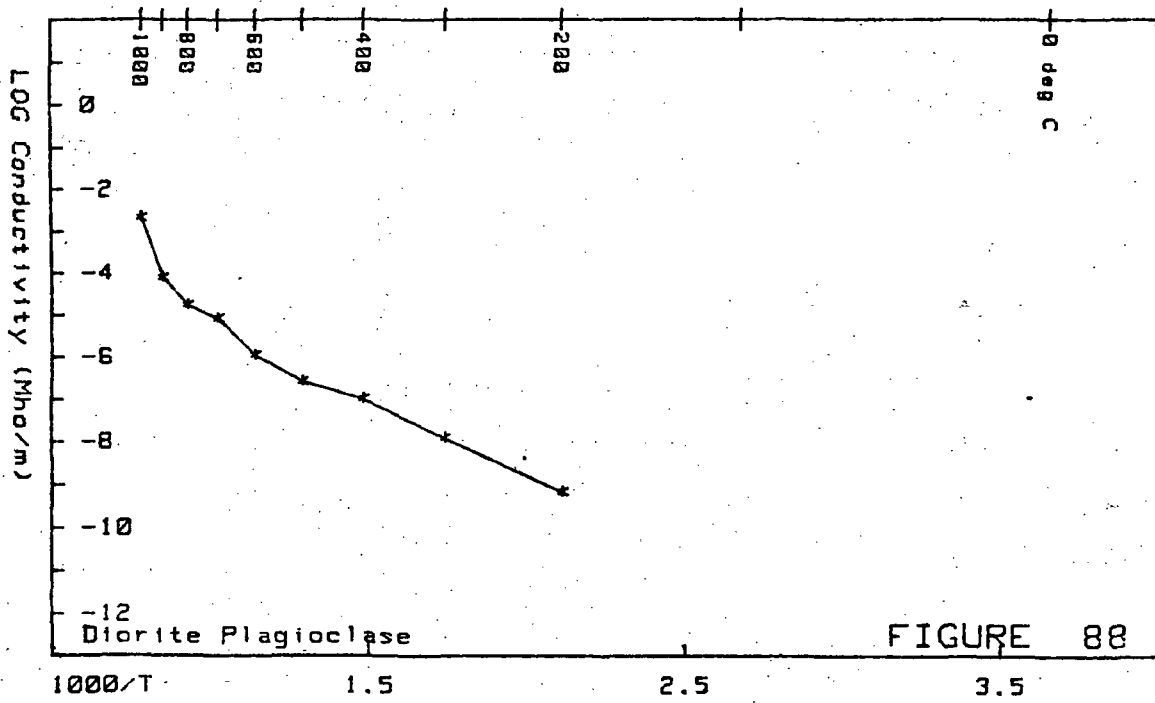
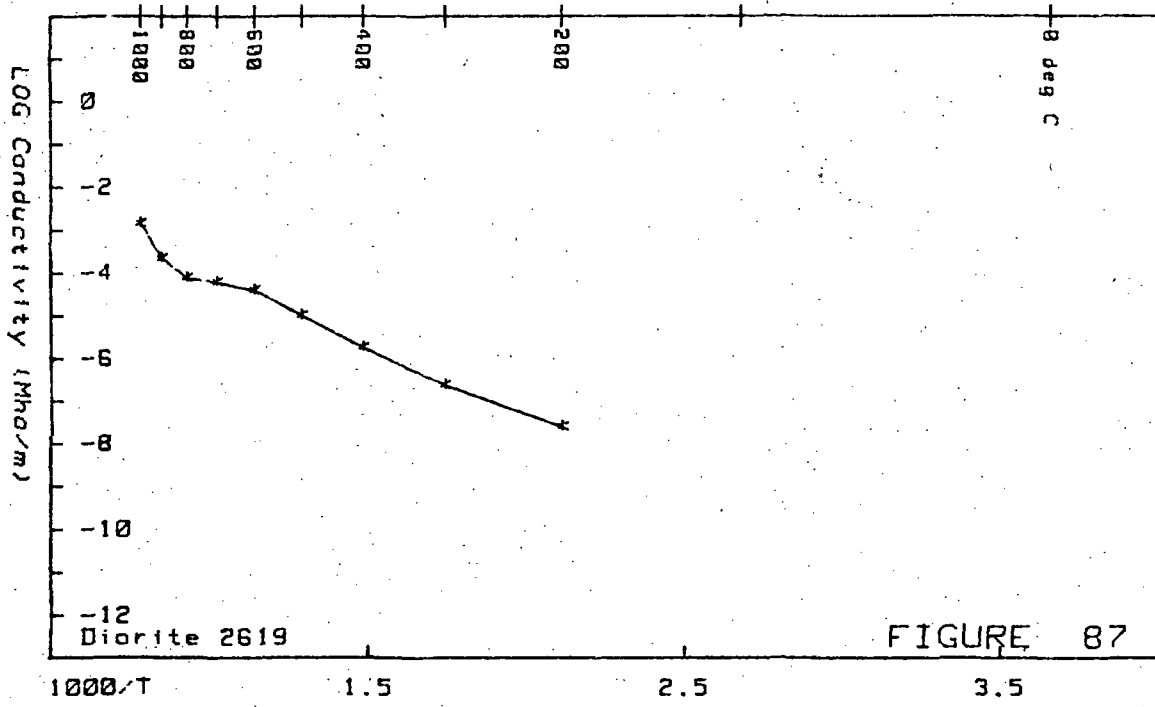




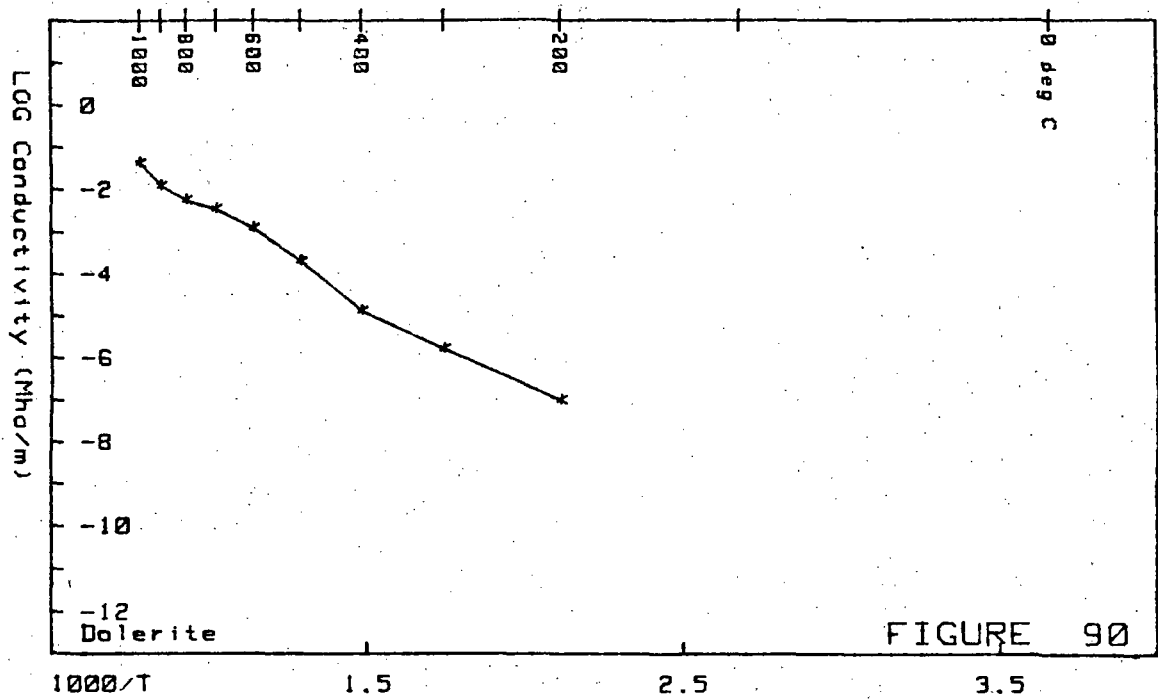
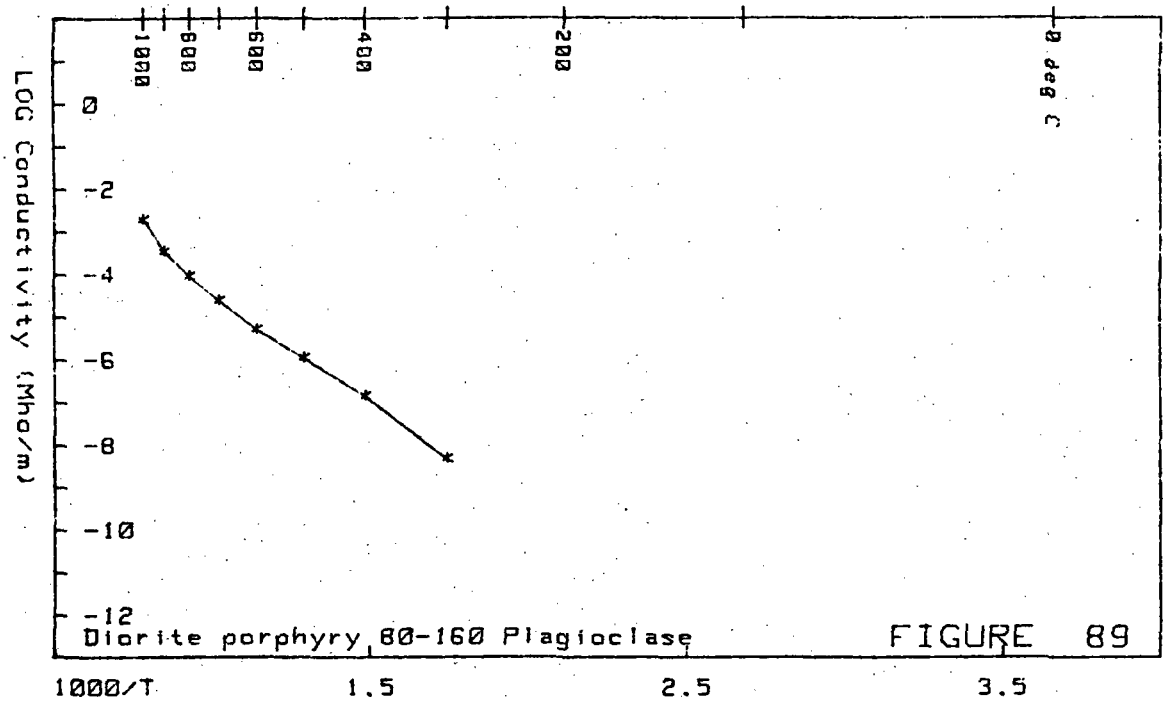












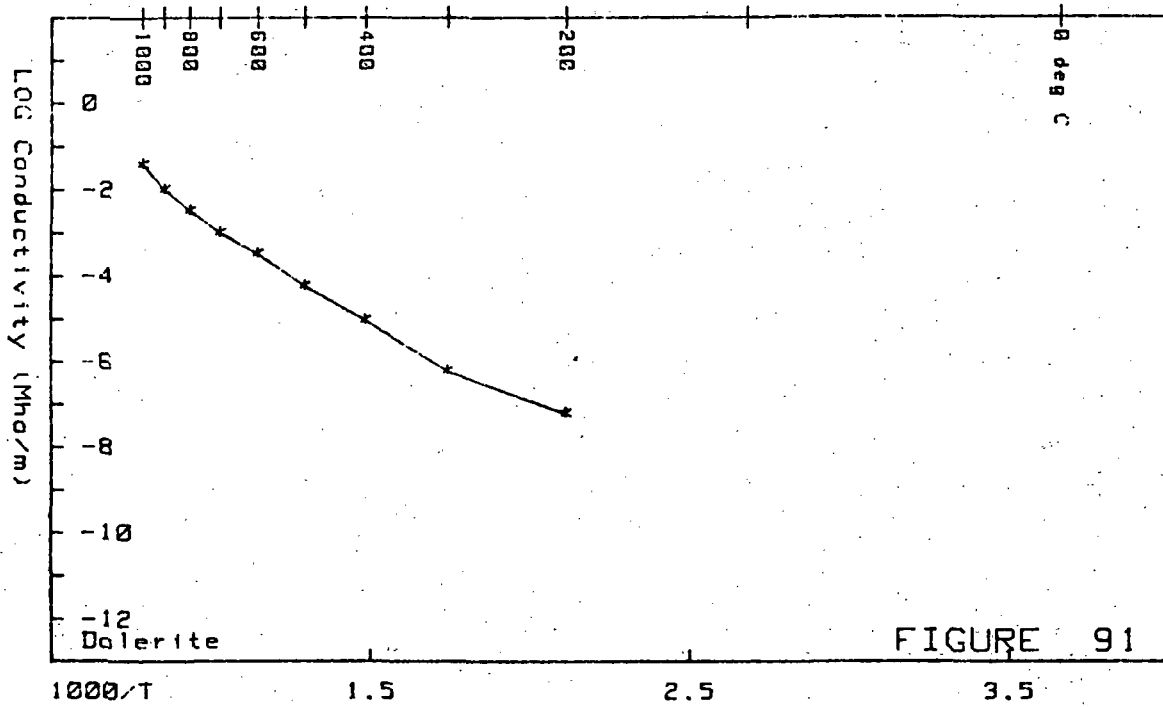


FIGURE 91

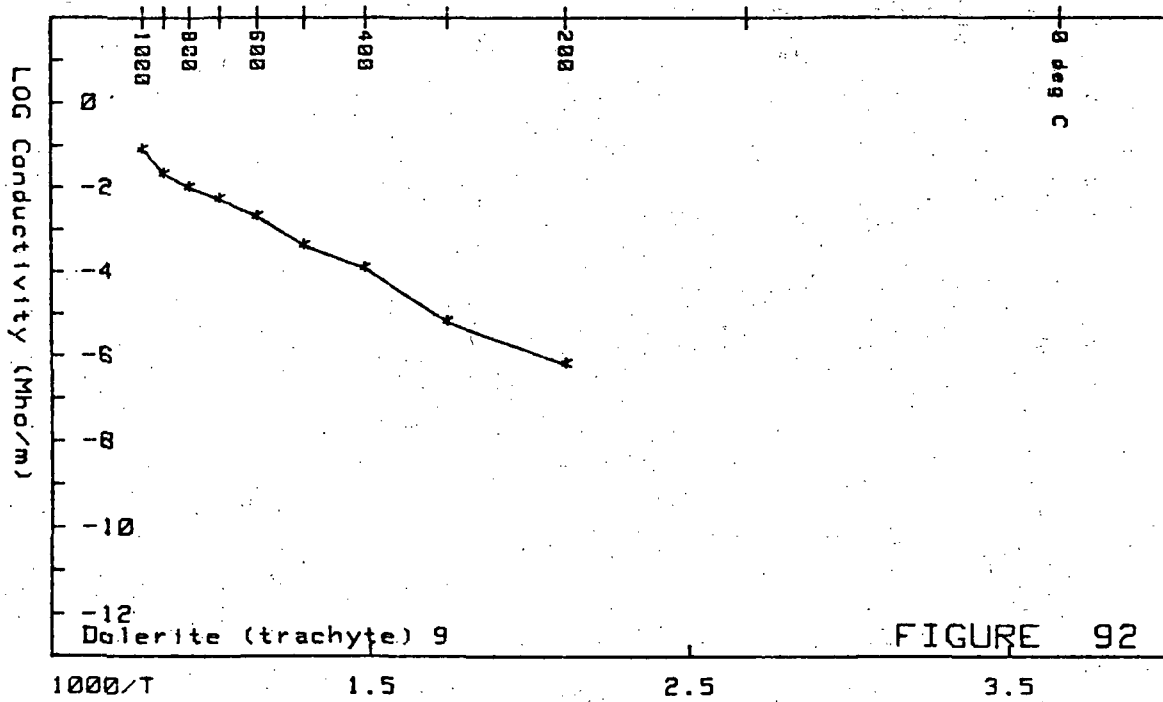
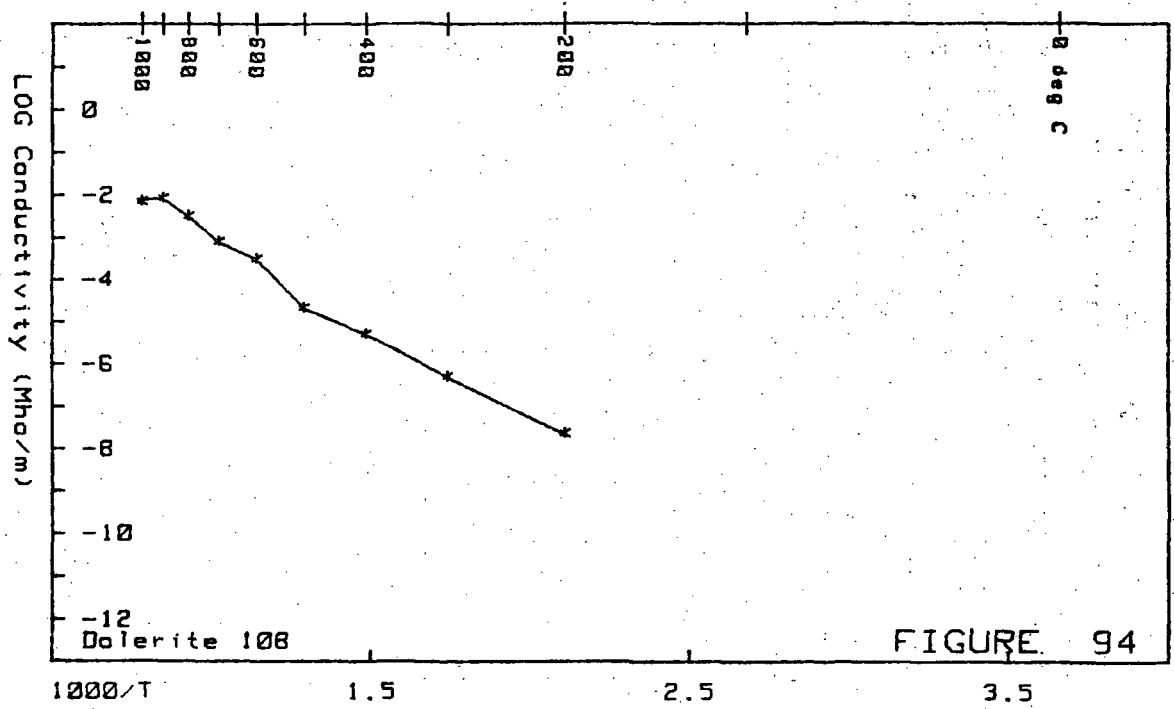
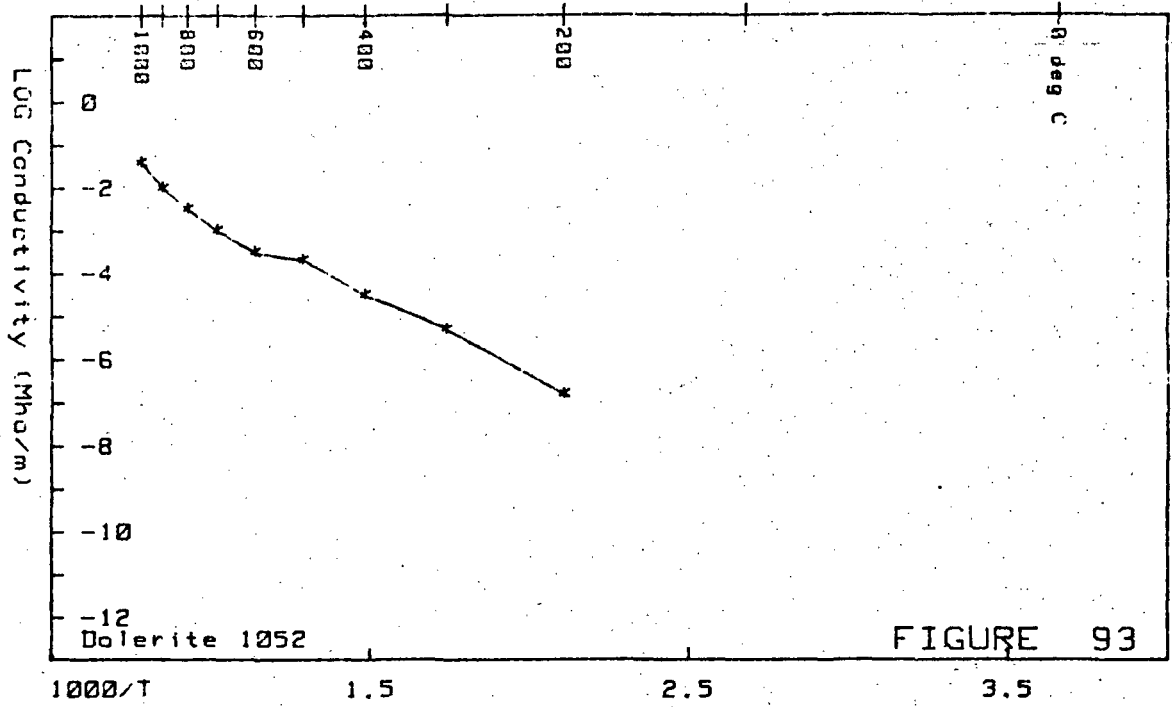
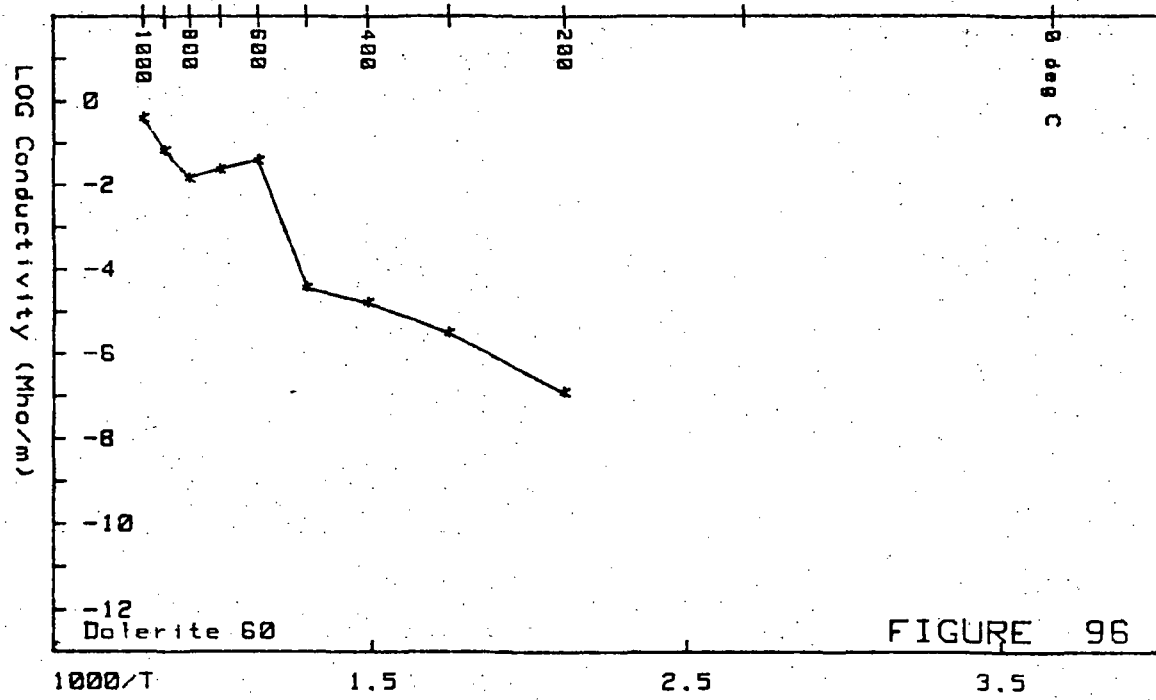
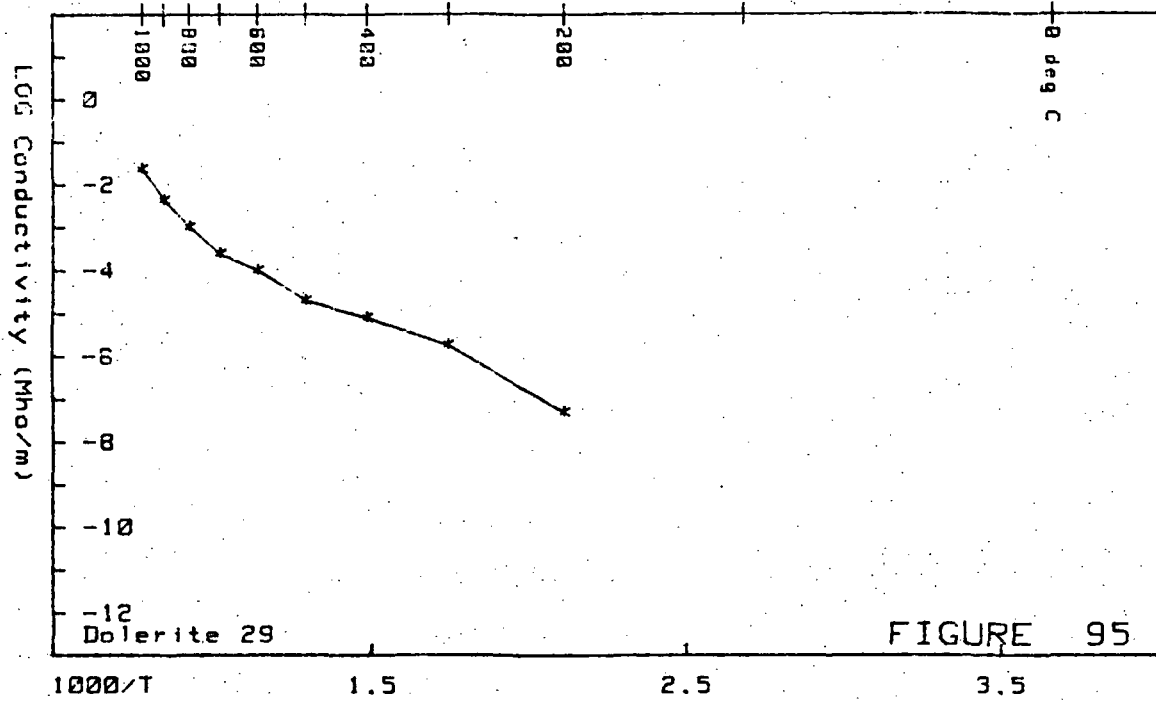
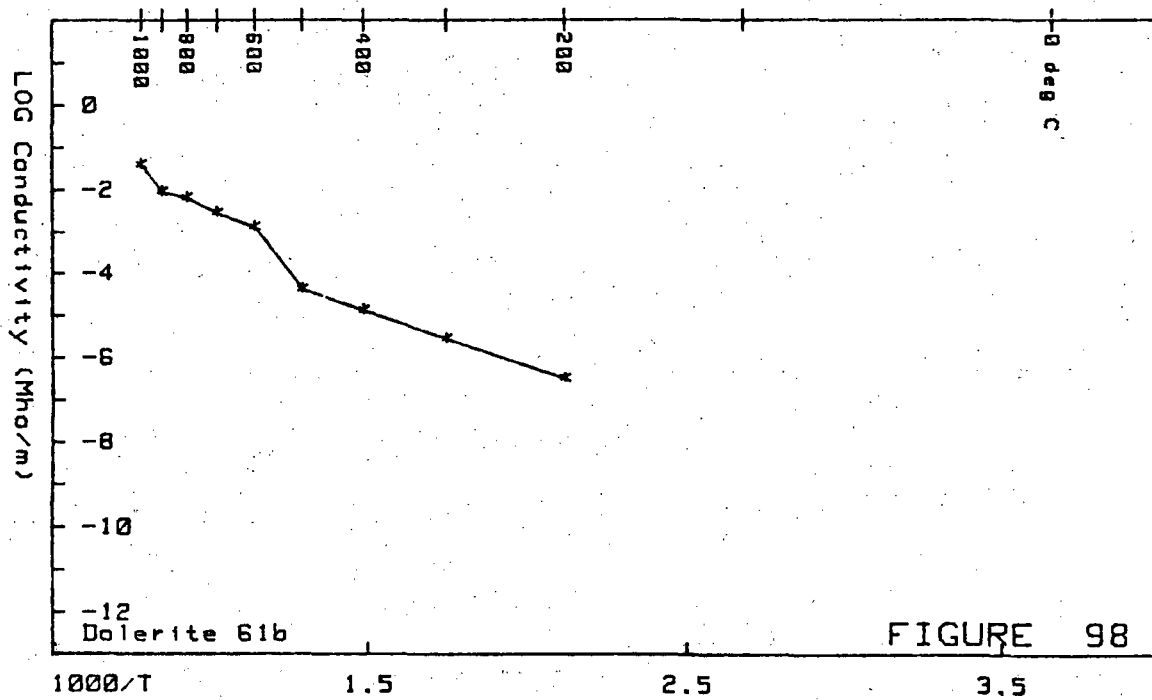
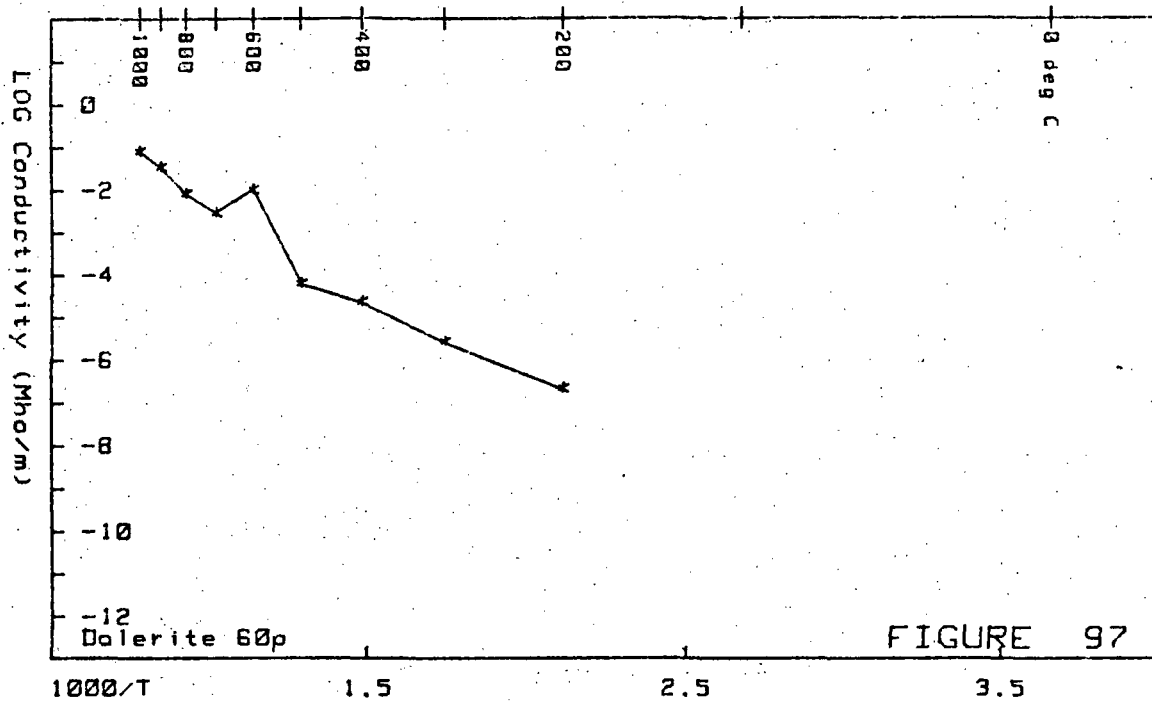
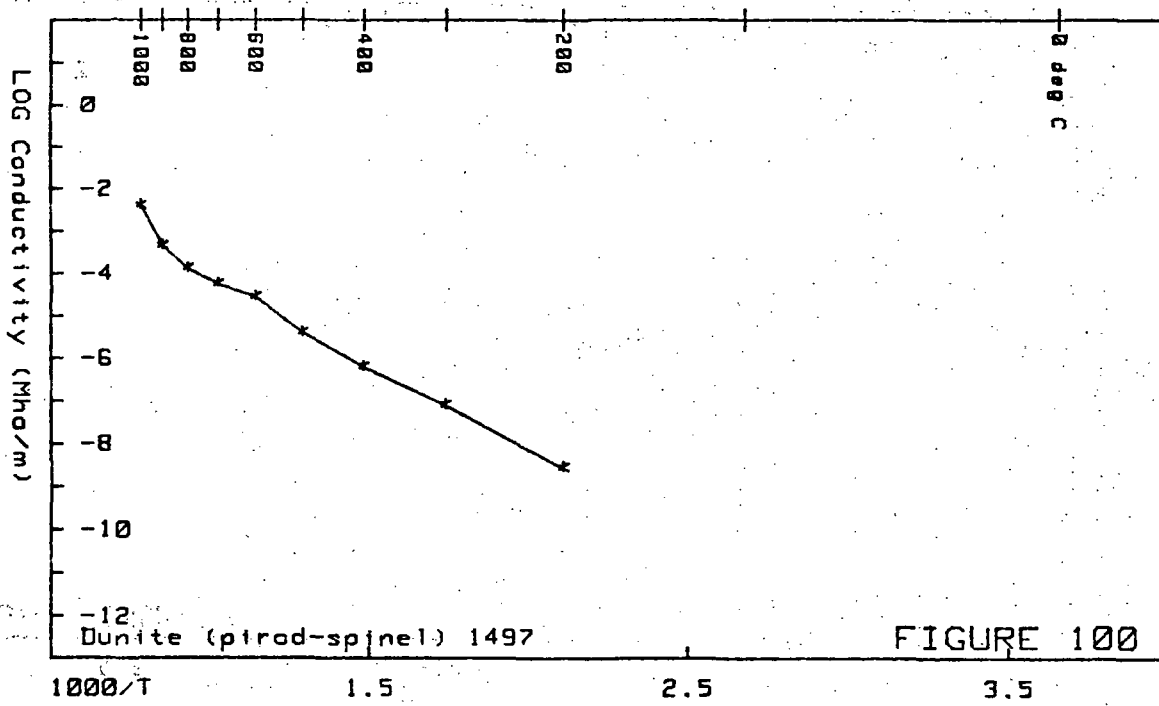
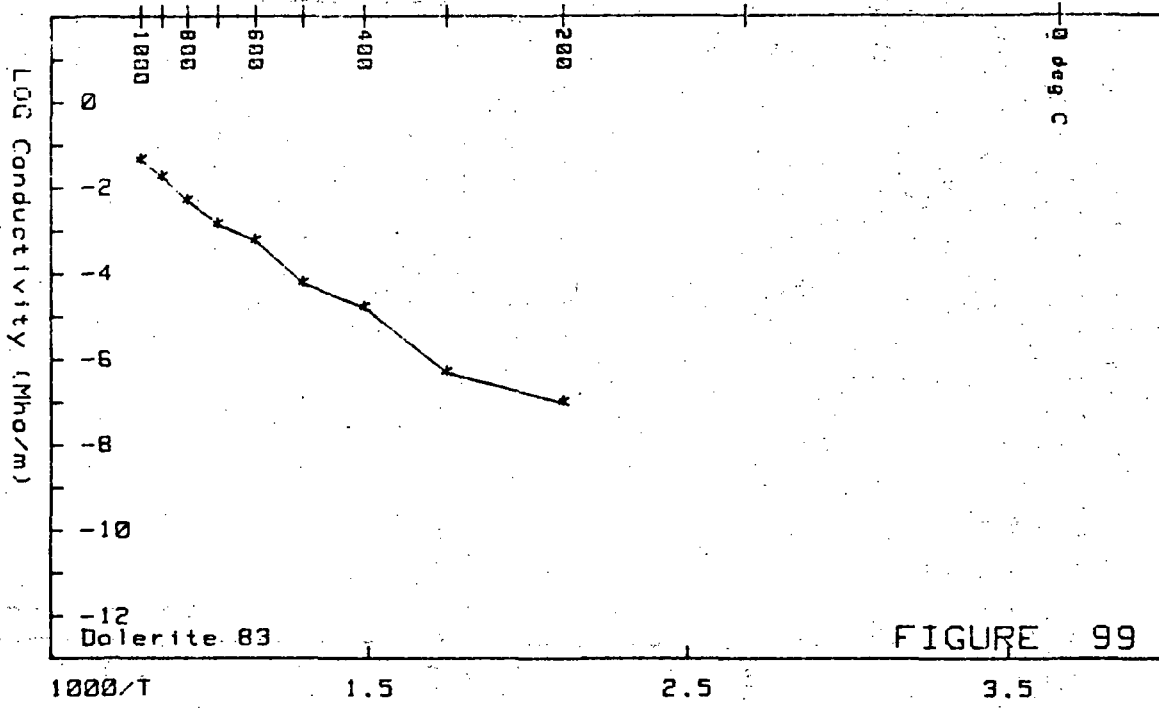


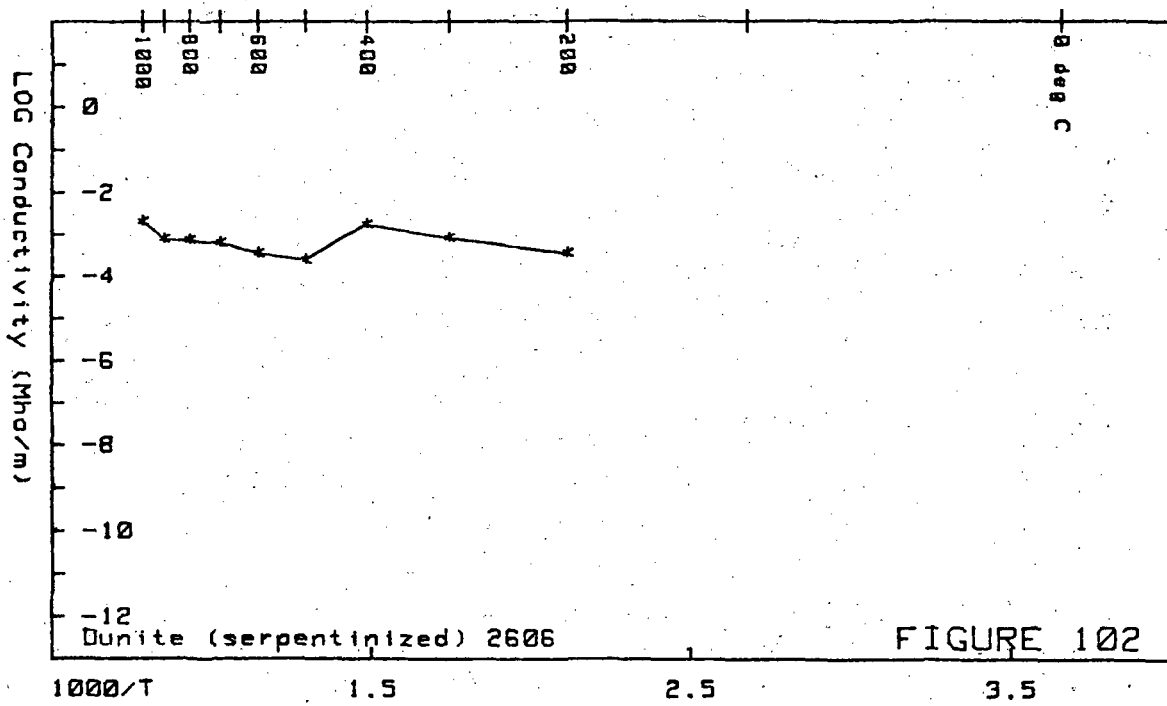
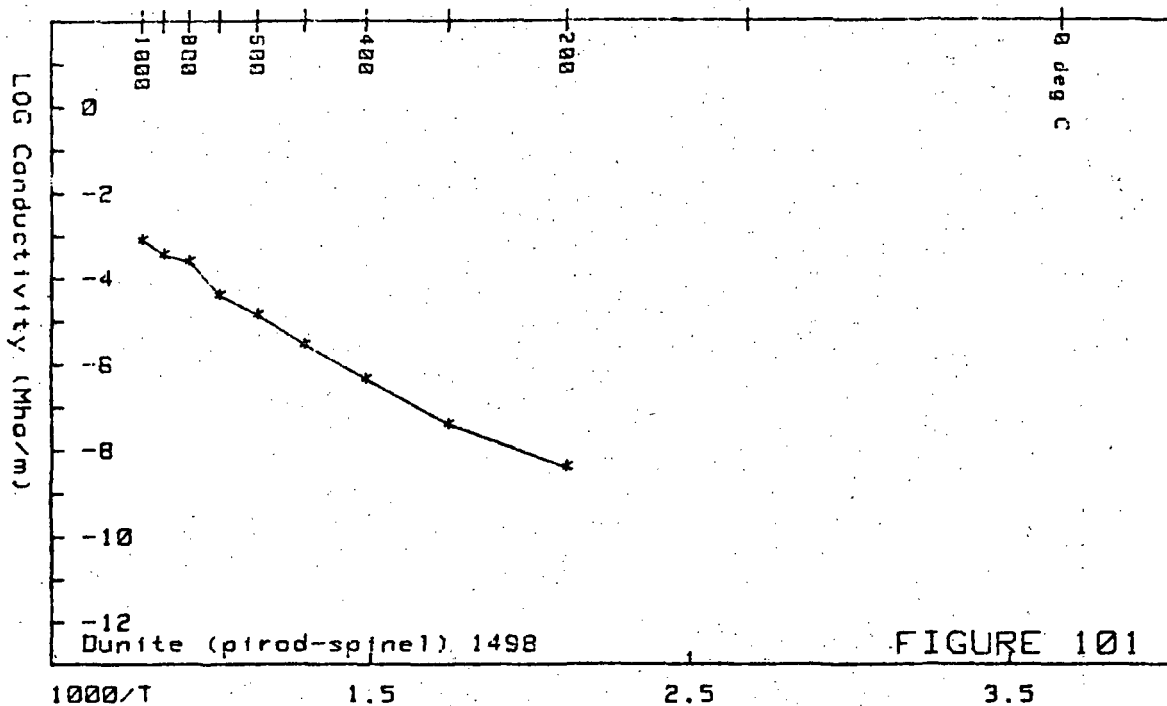
FIGURE 92

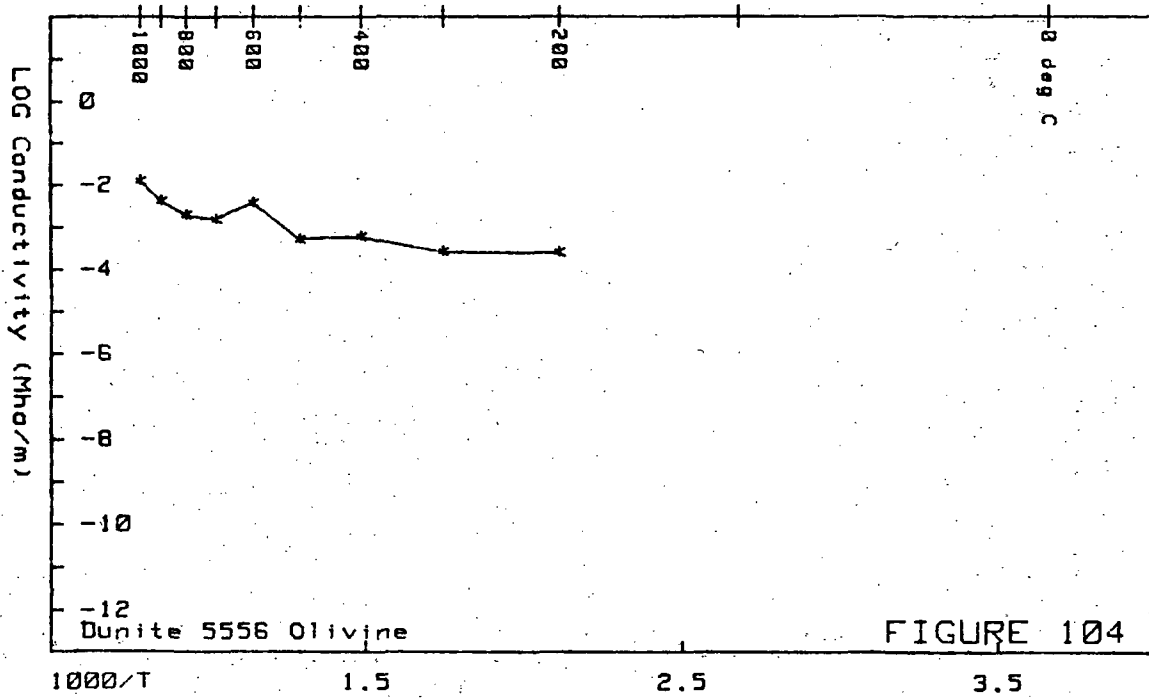
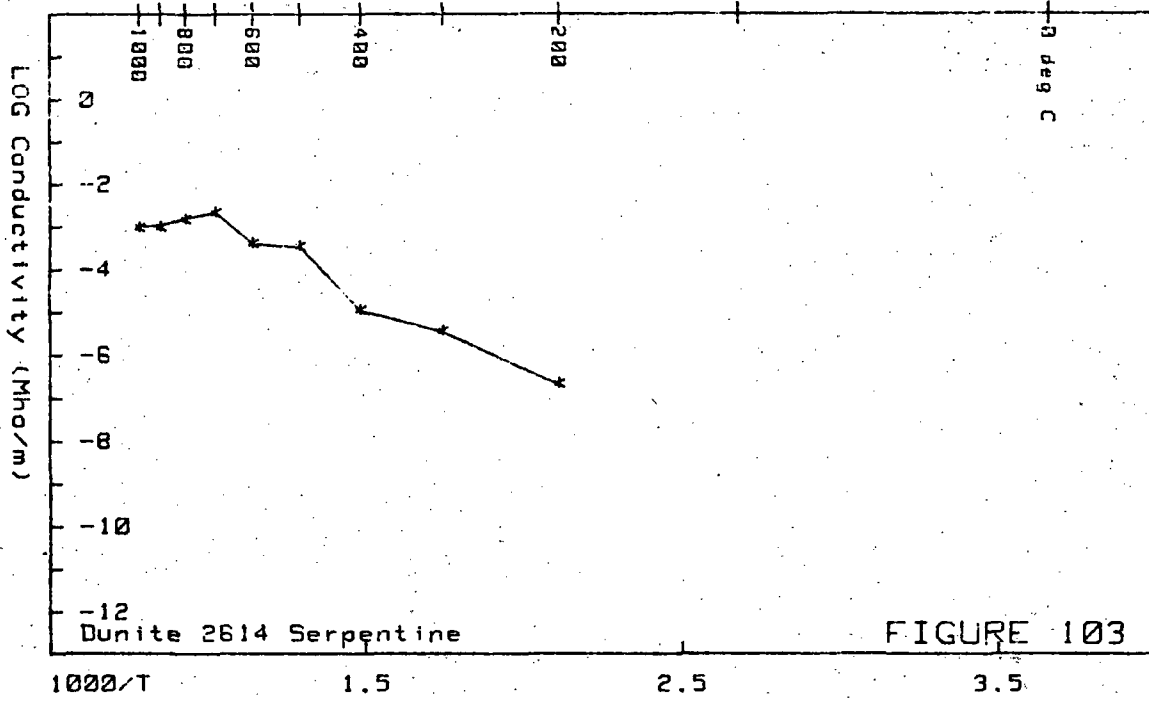




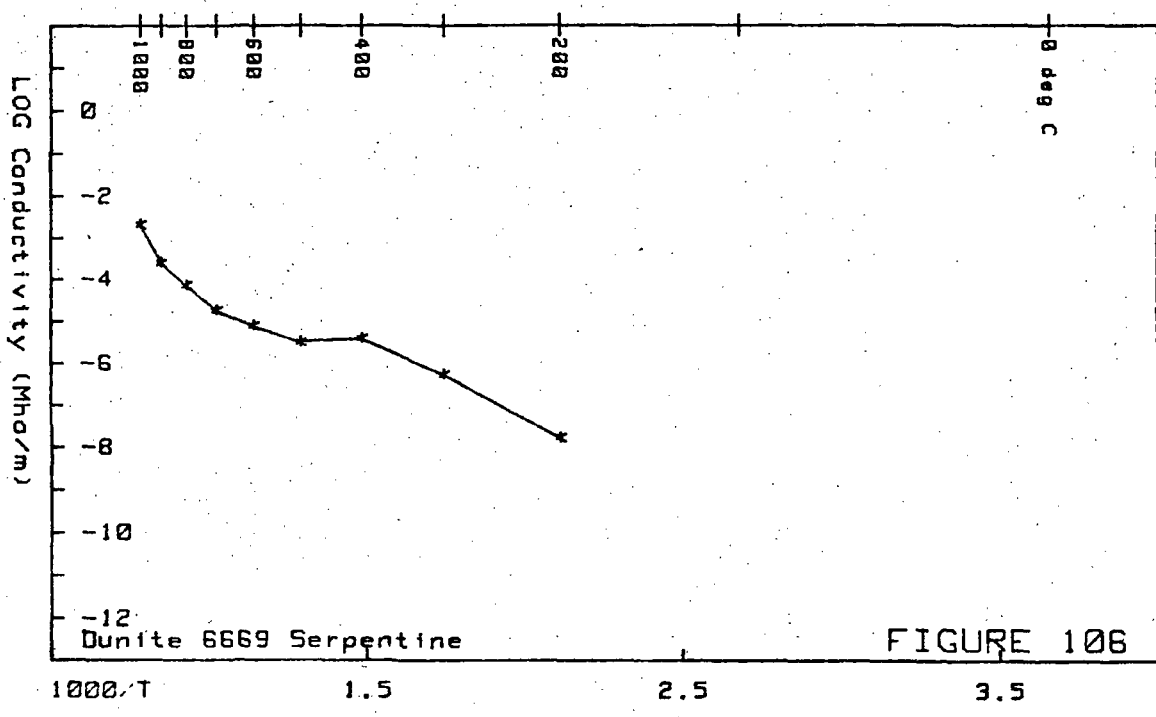
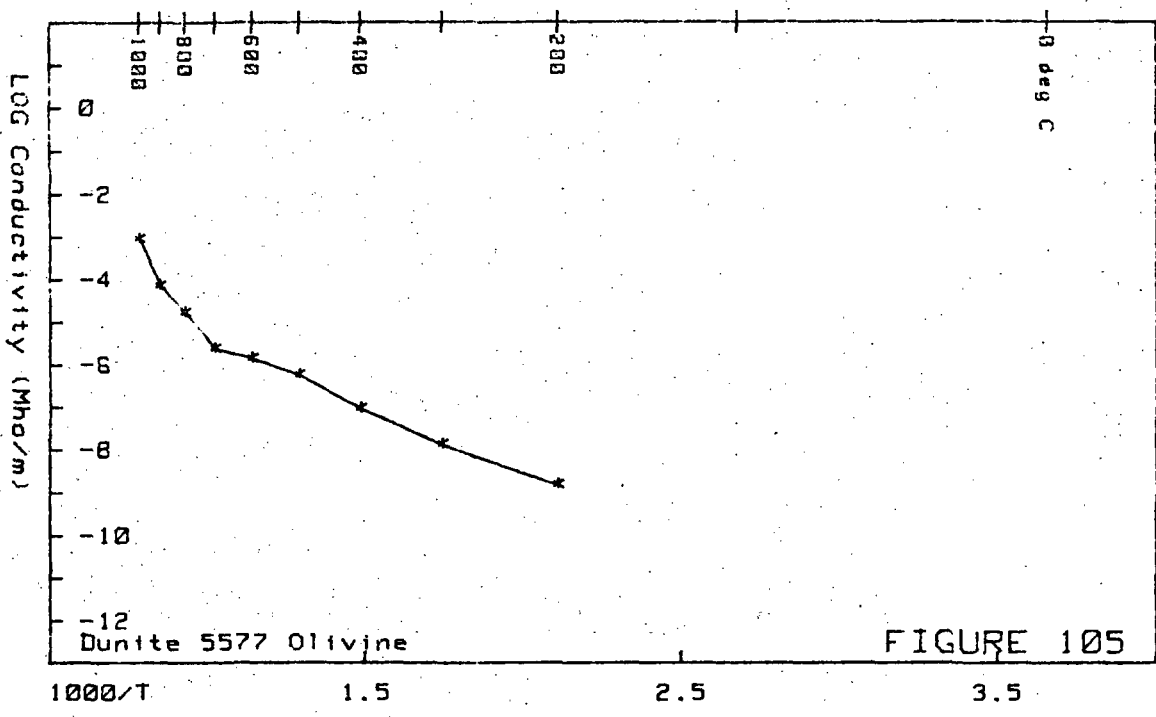


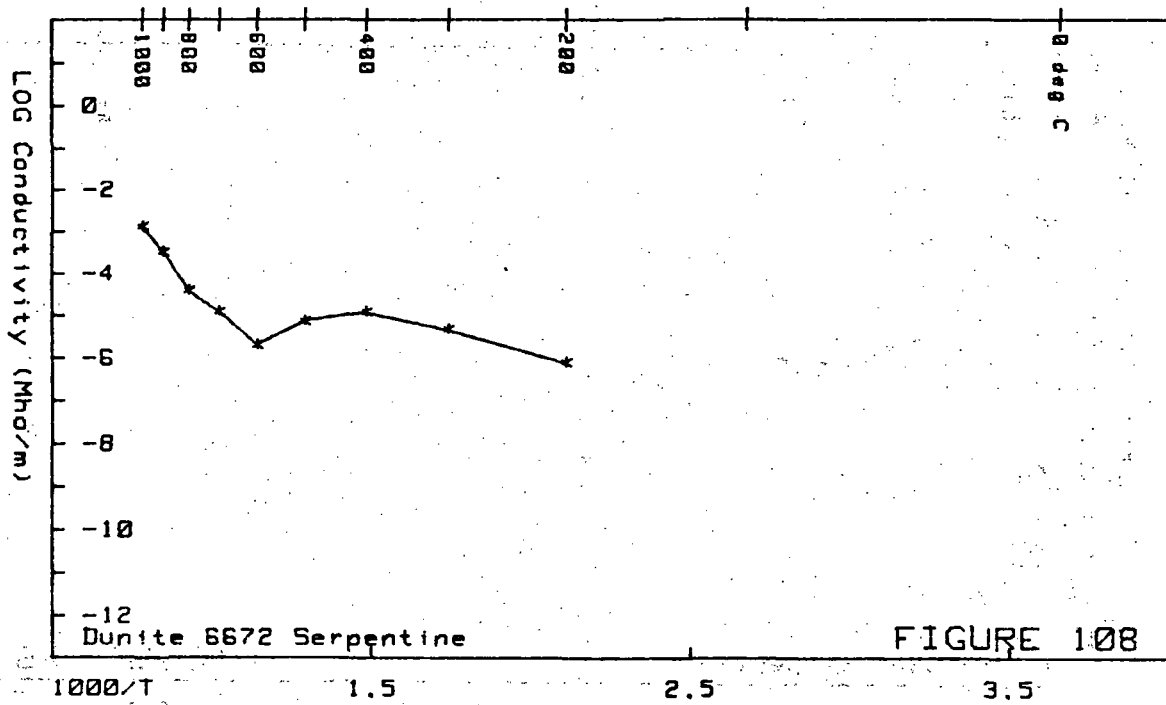
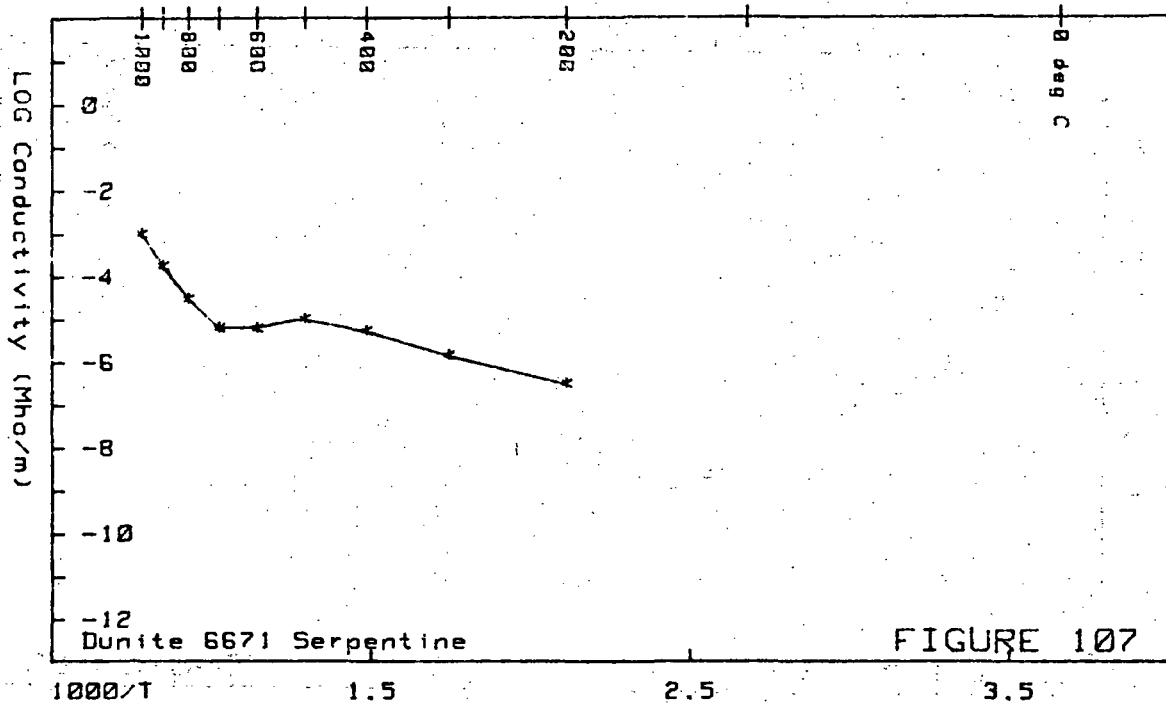


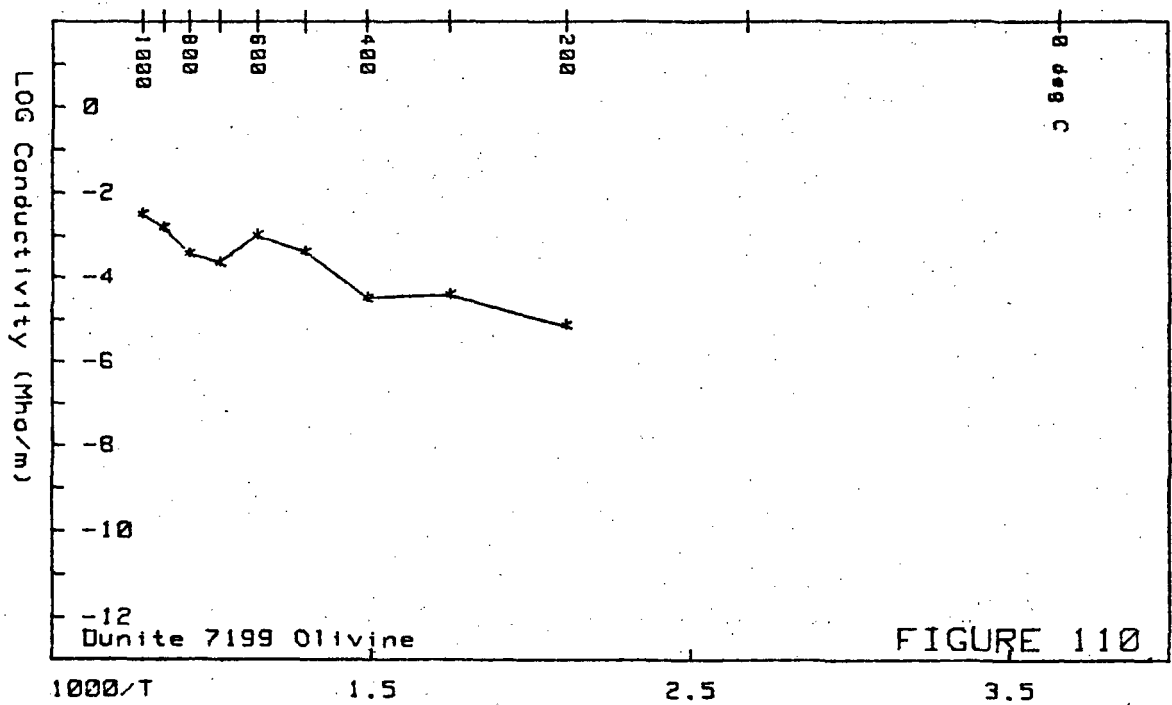
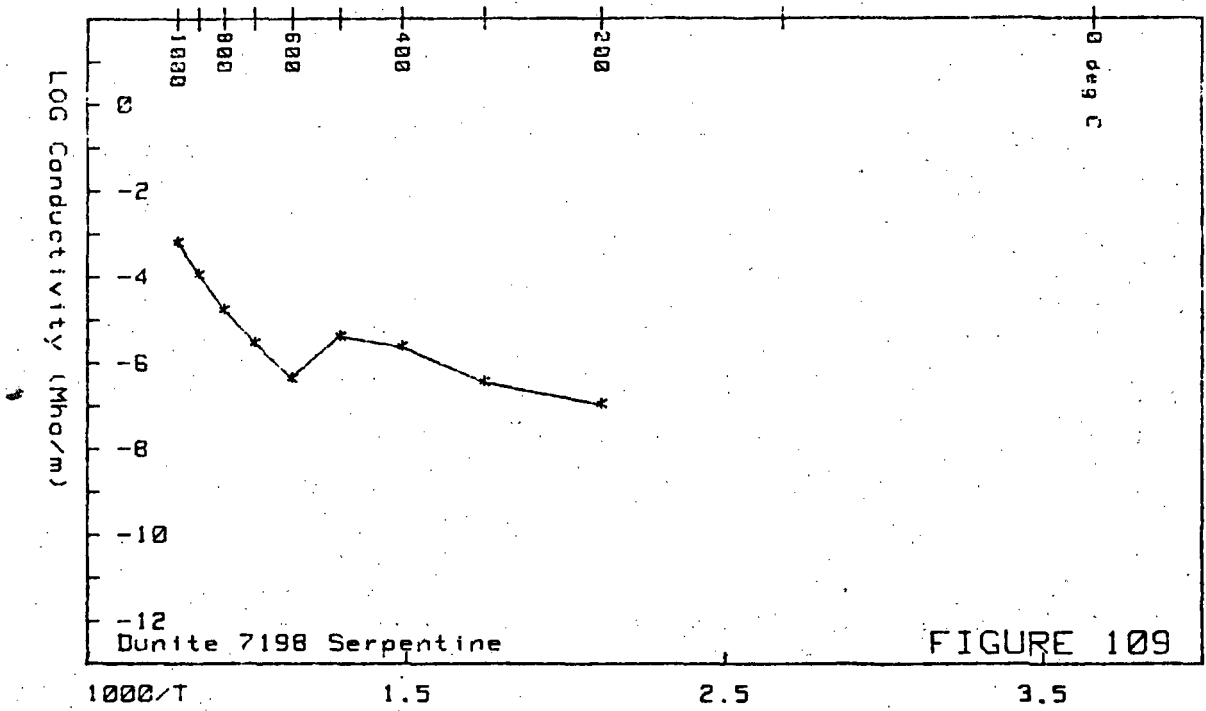


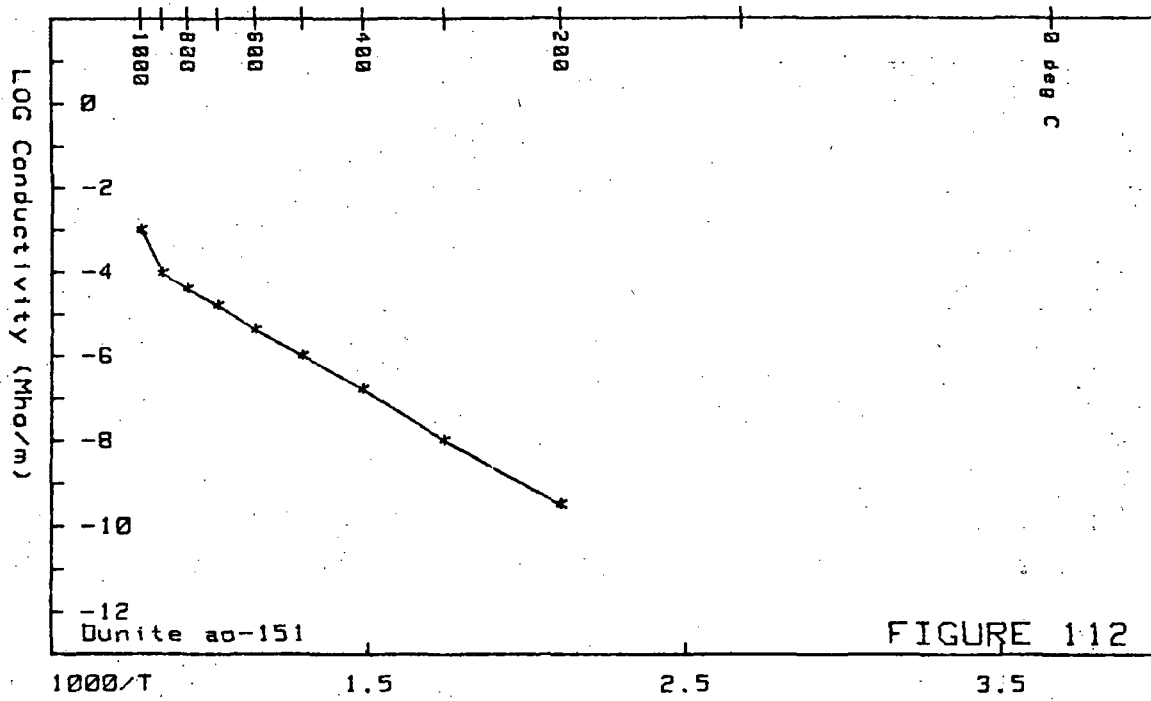
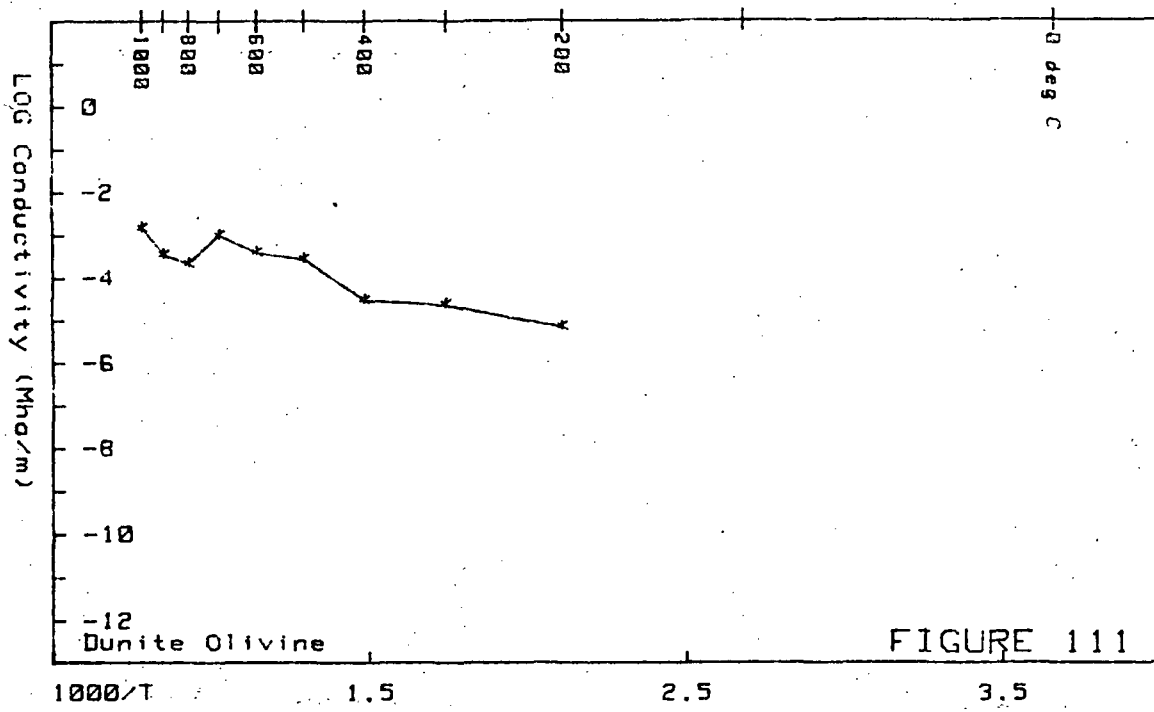


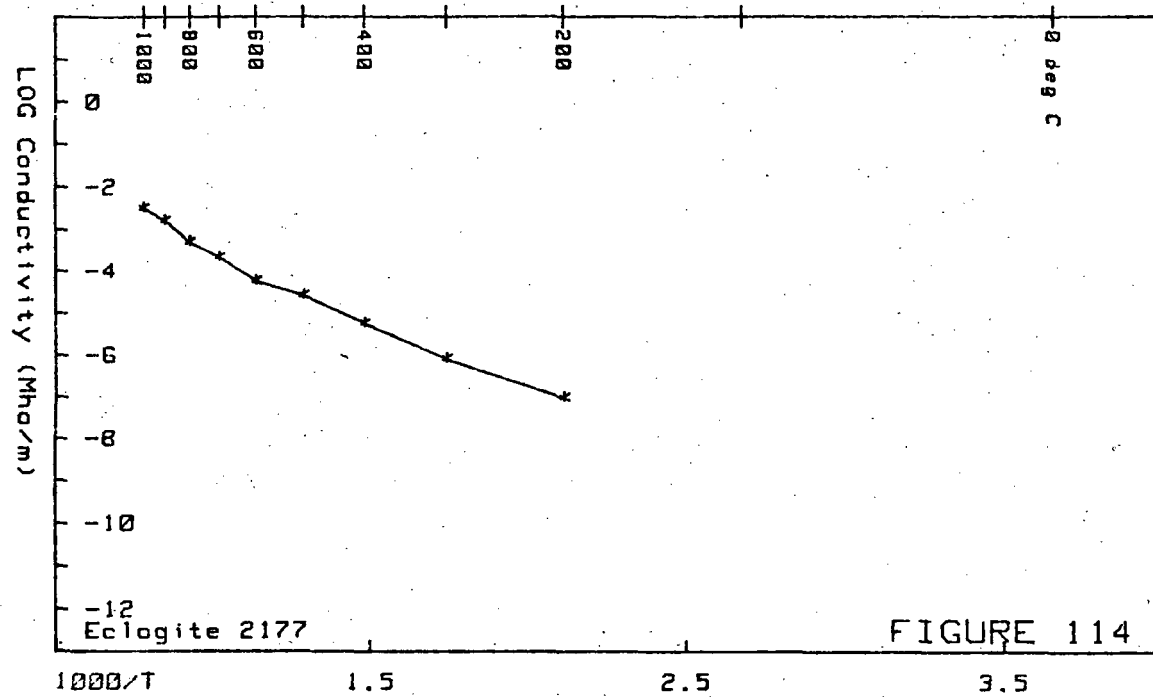
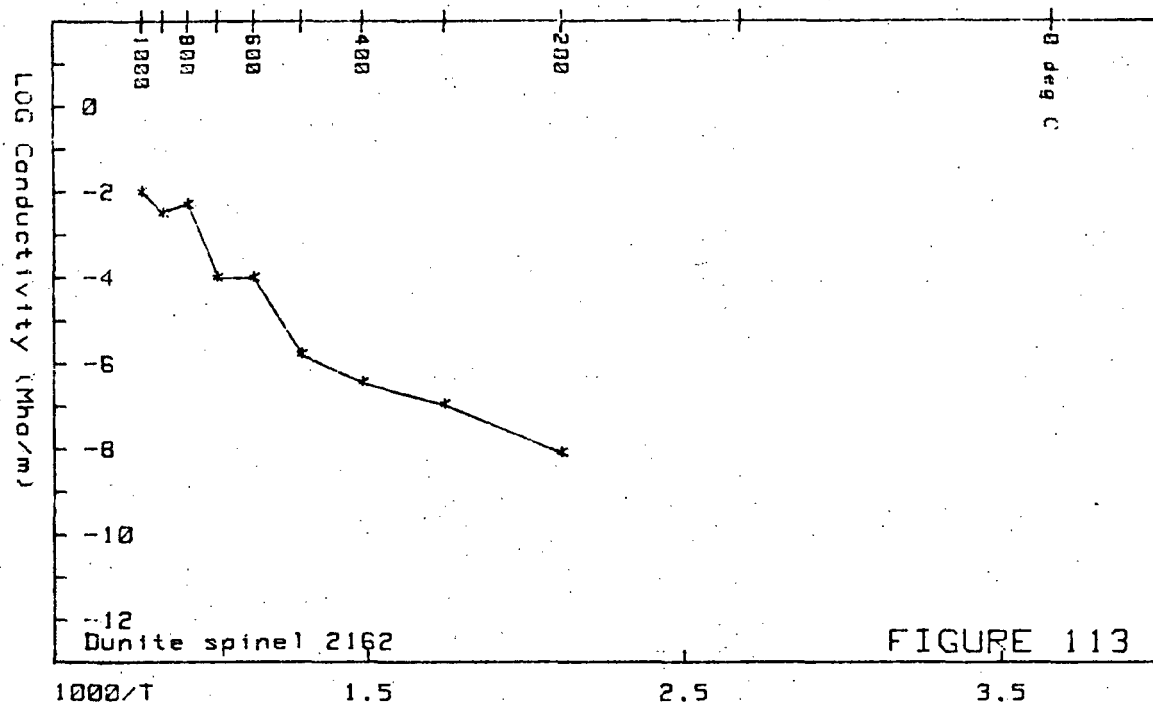


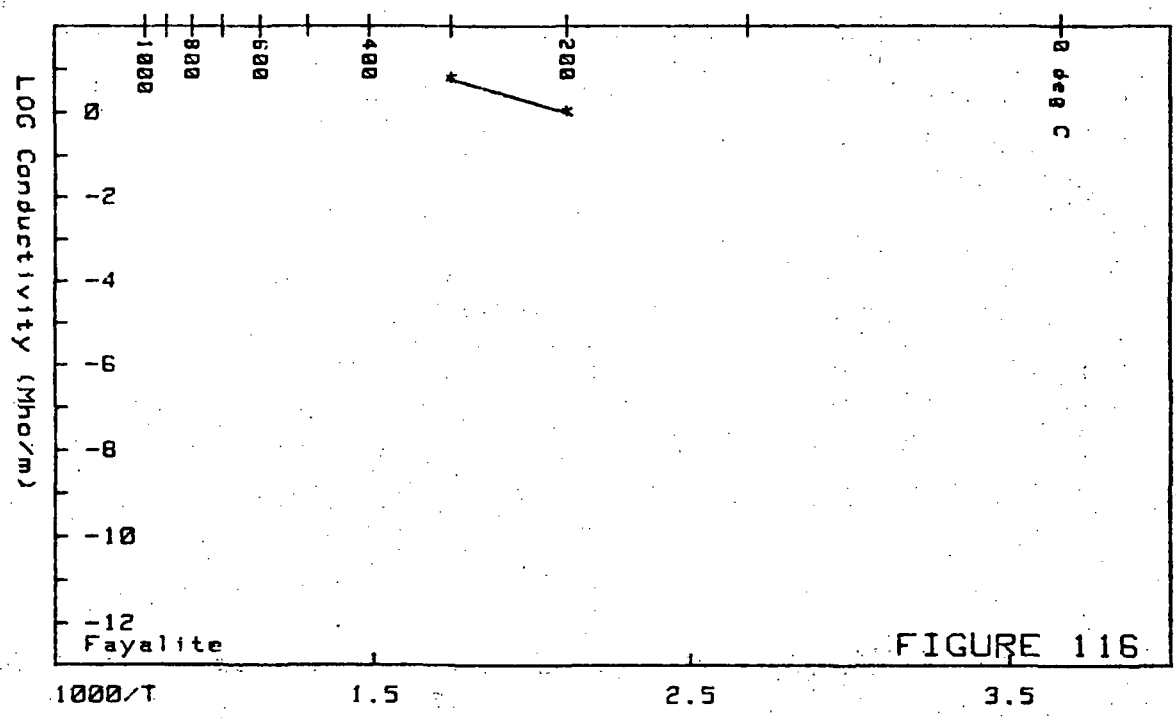
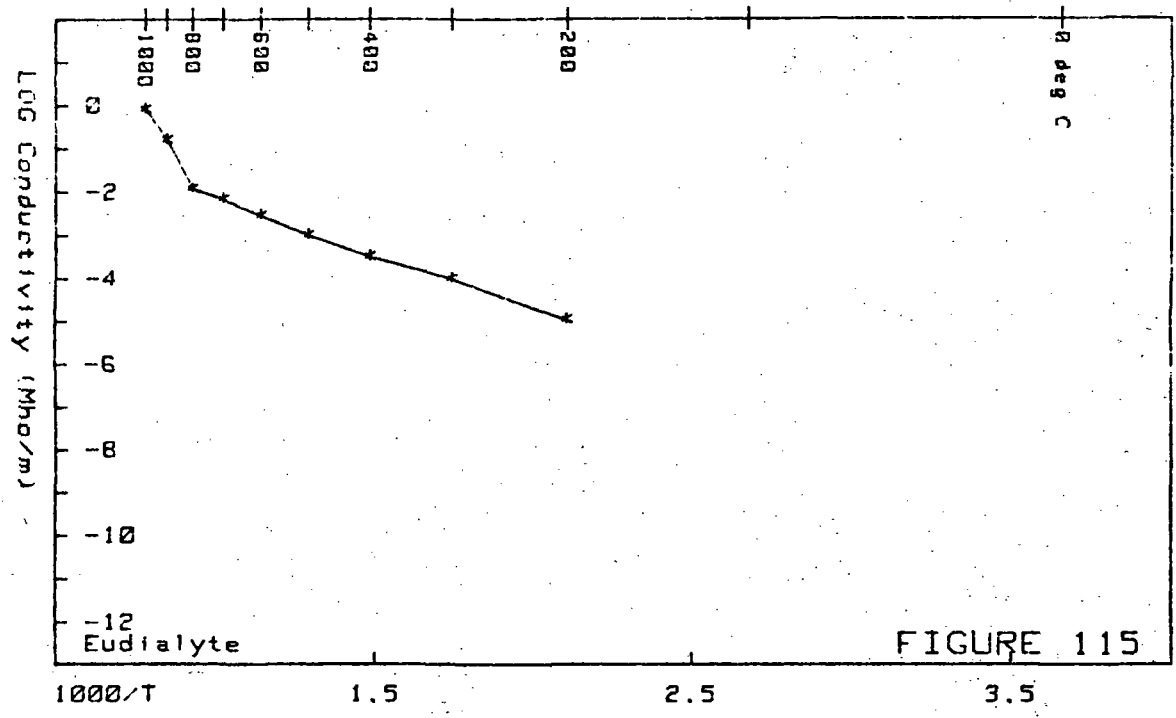












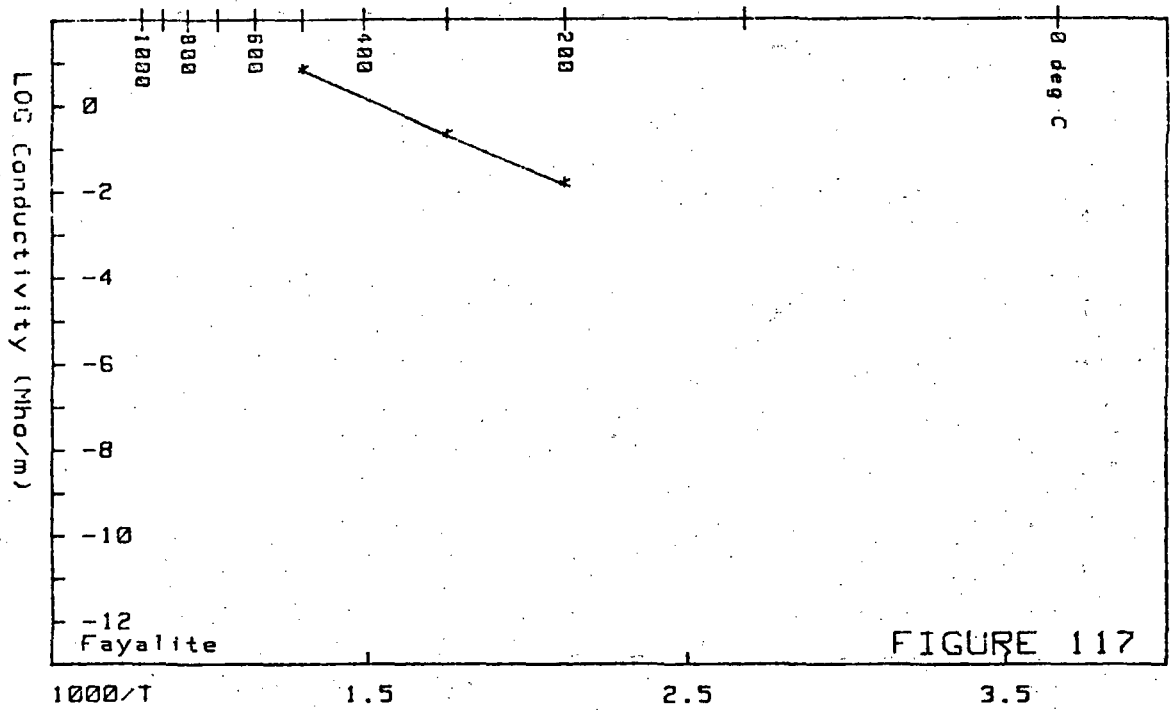


FIGURE 117

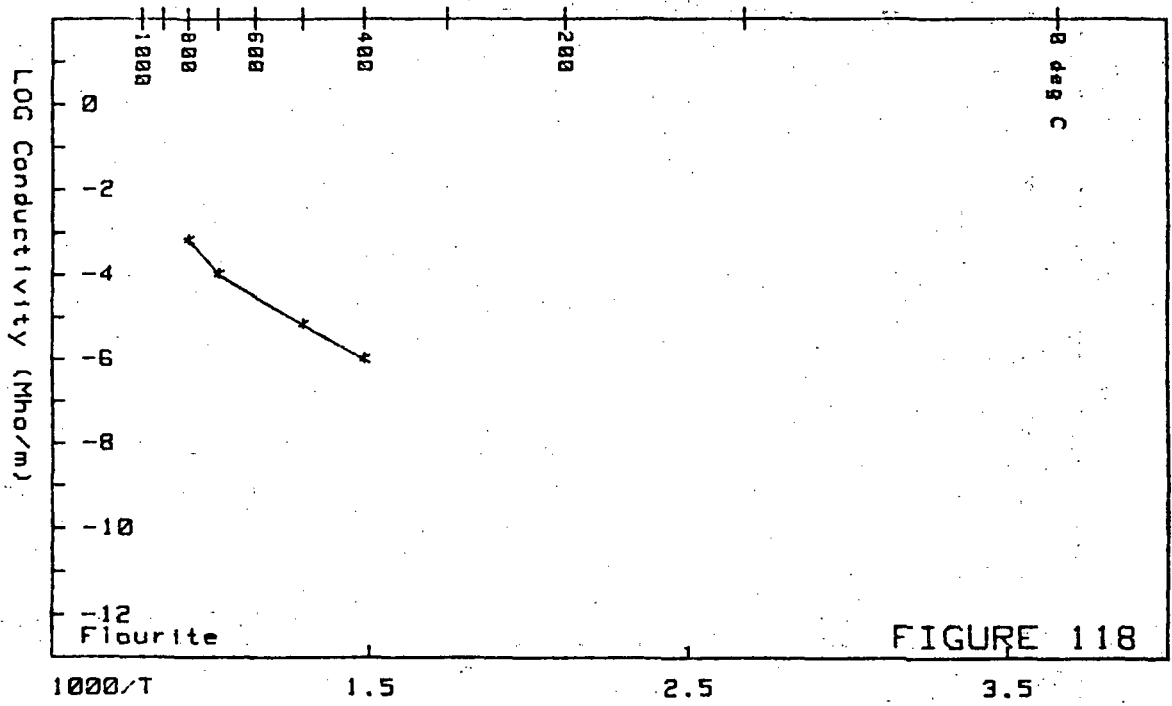
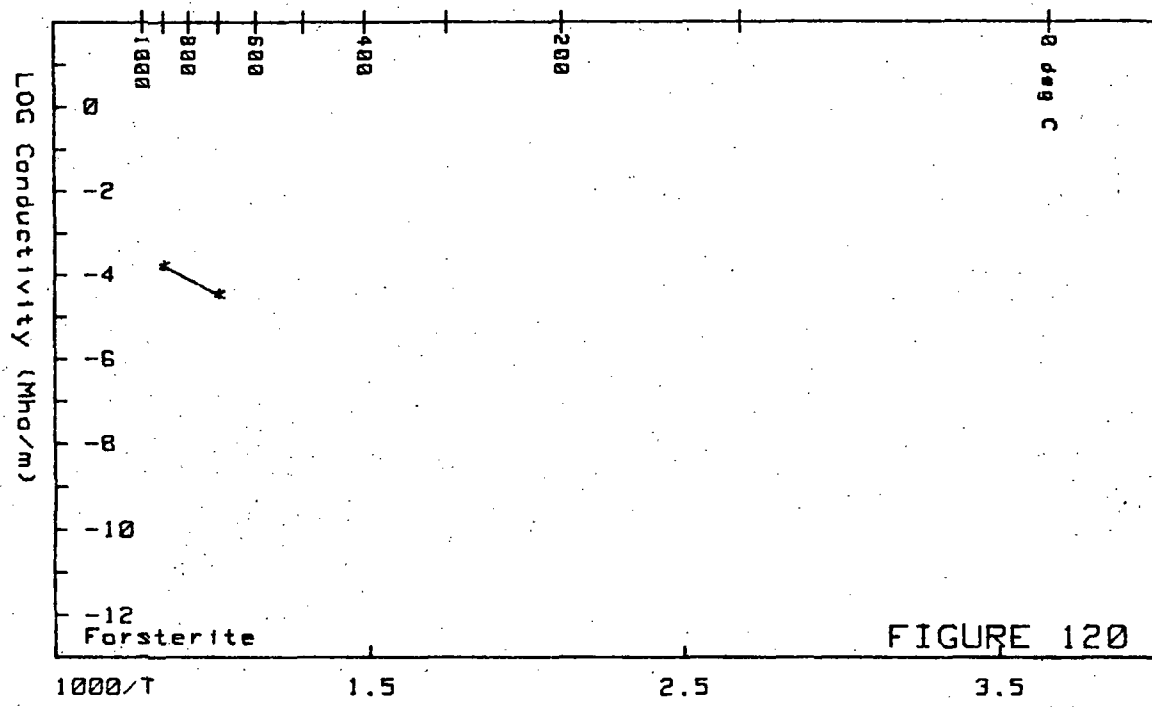
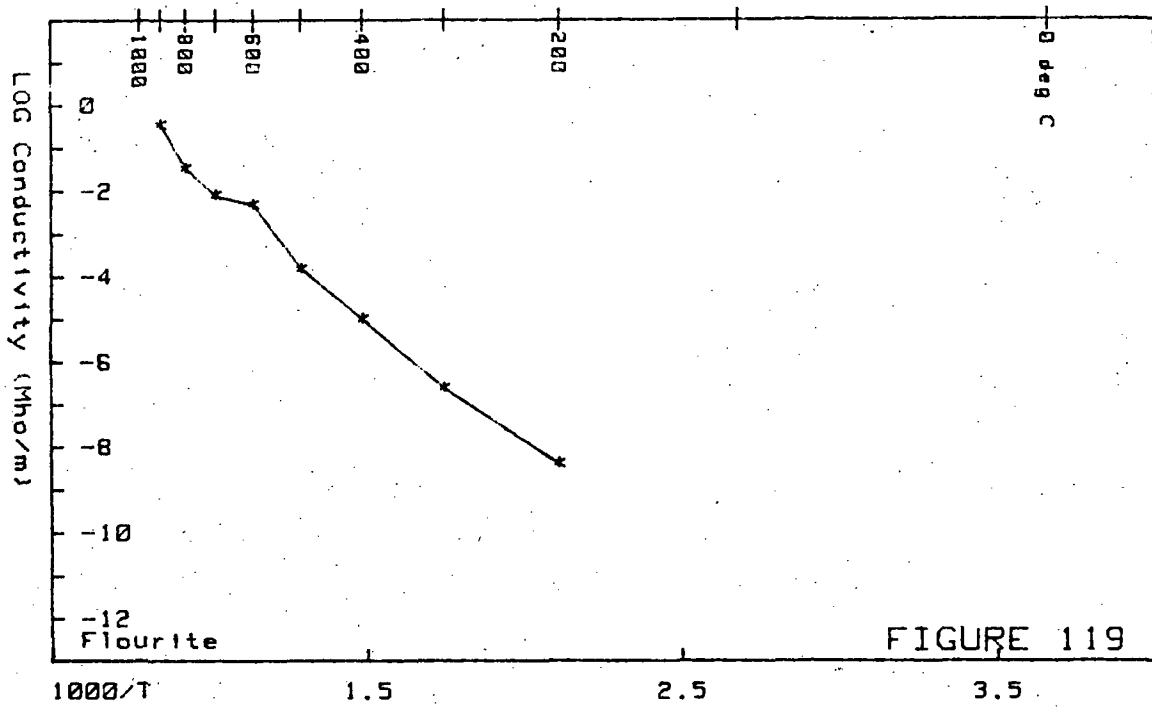
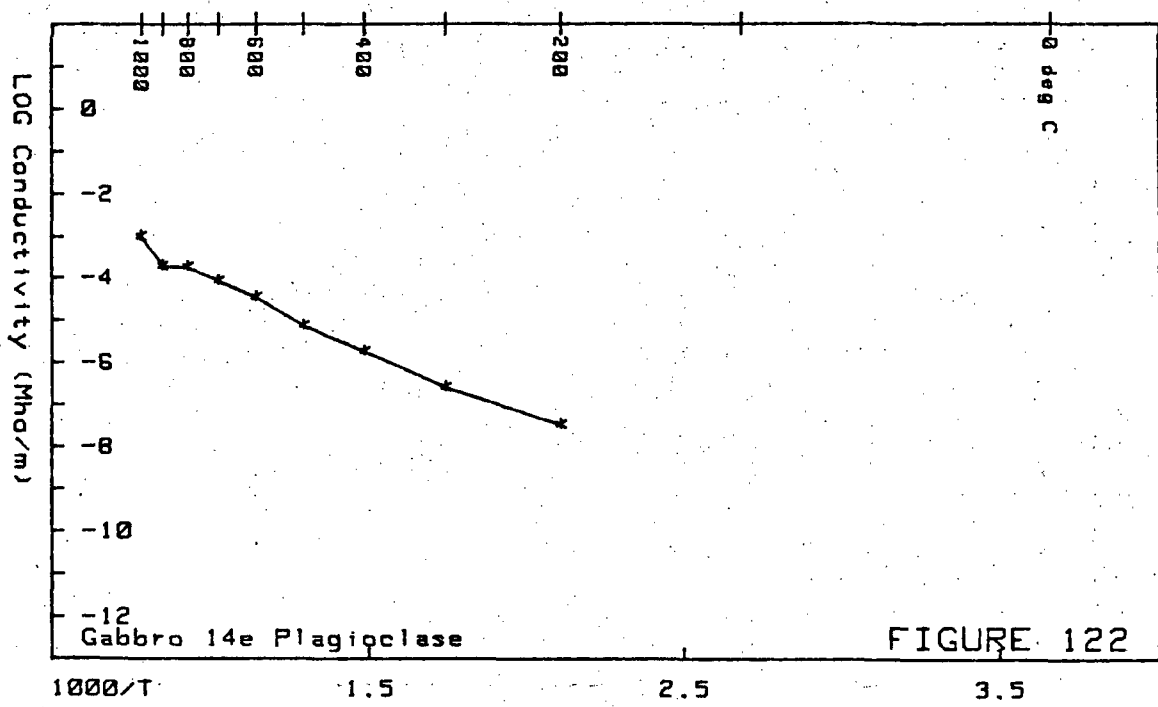
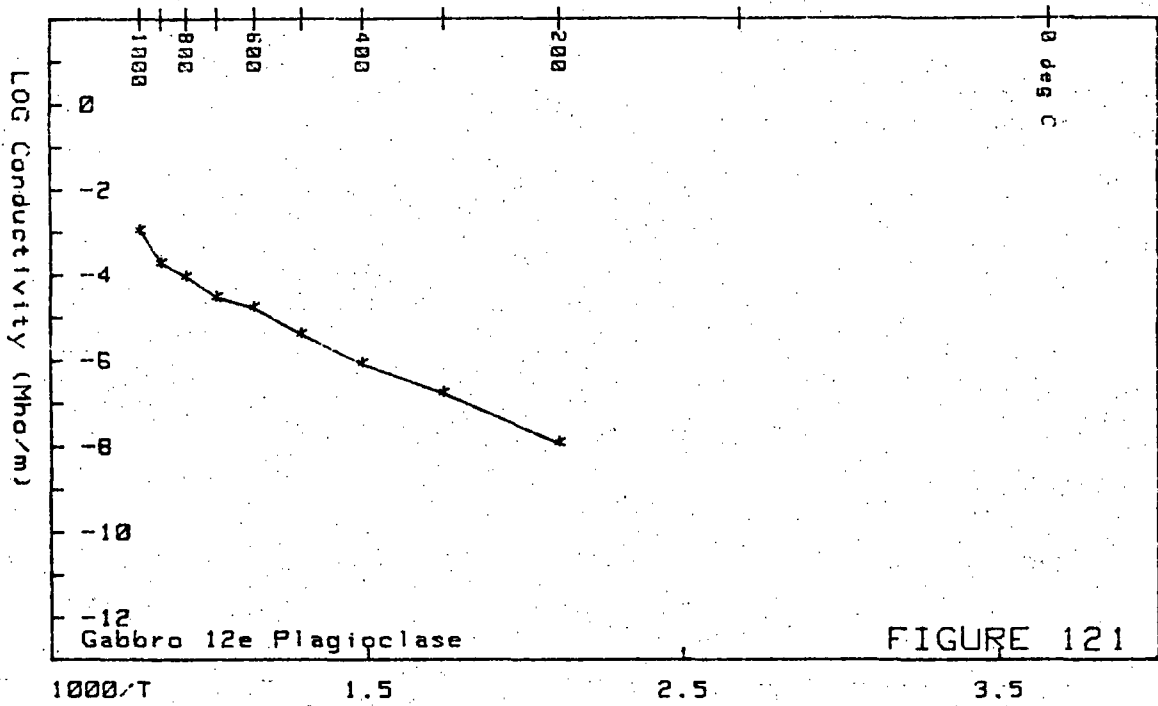
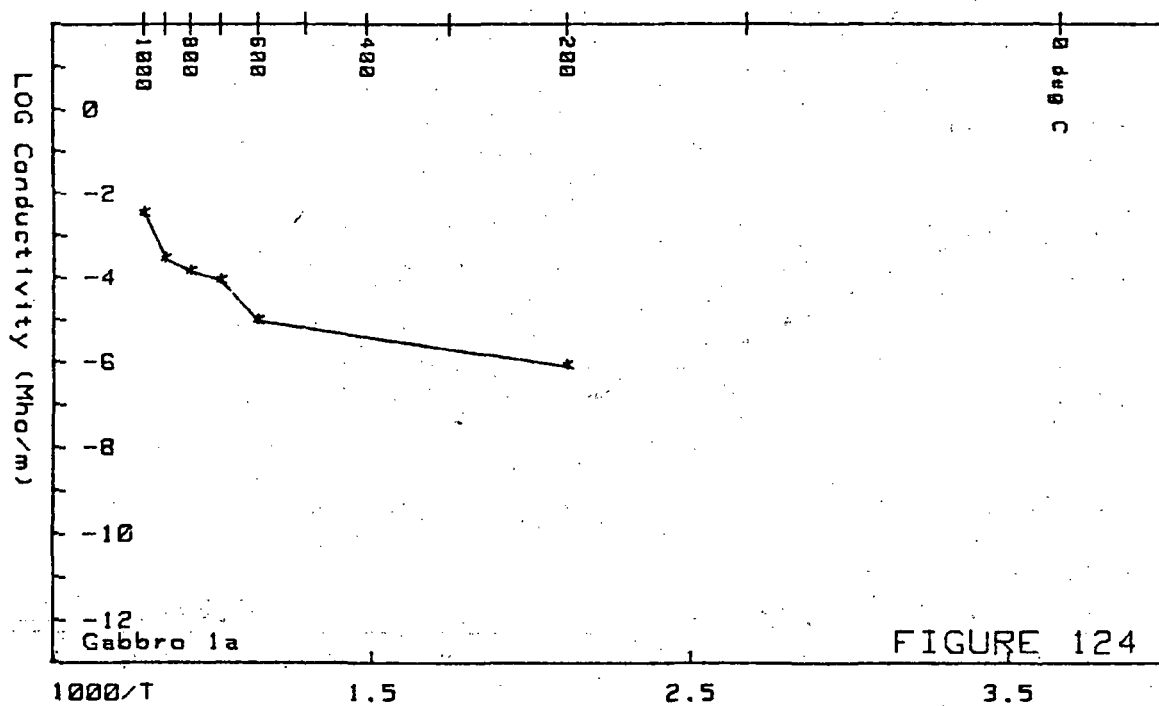
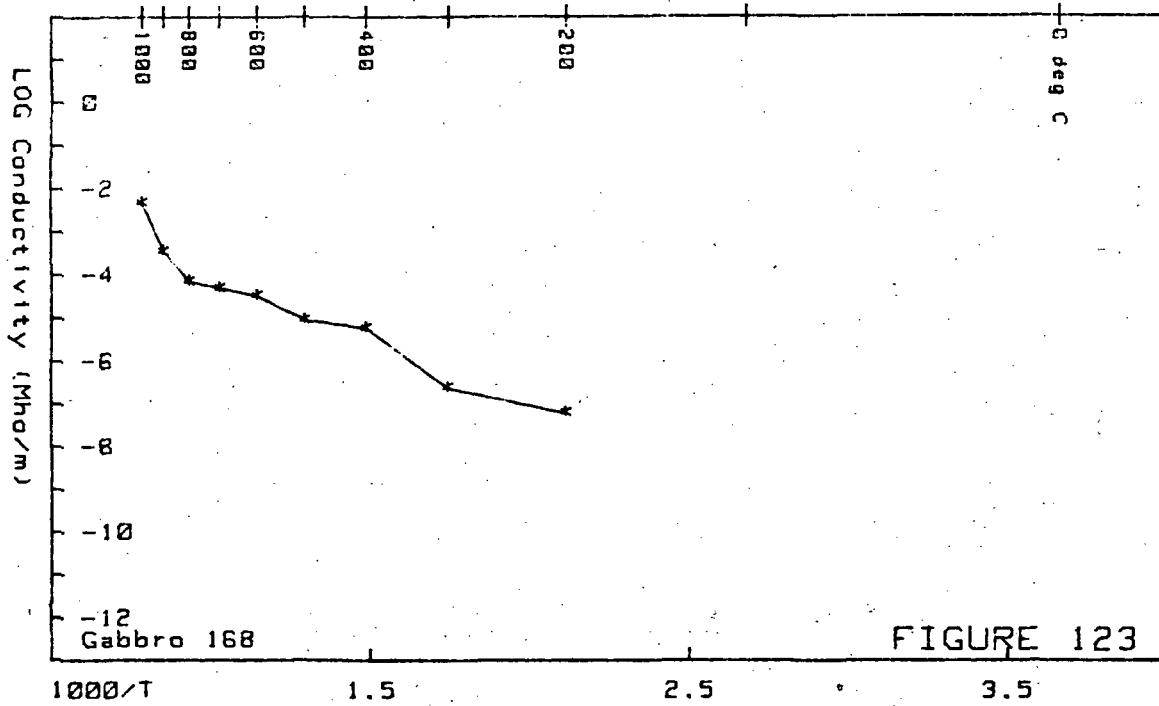


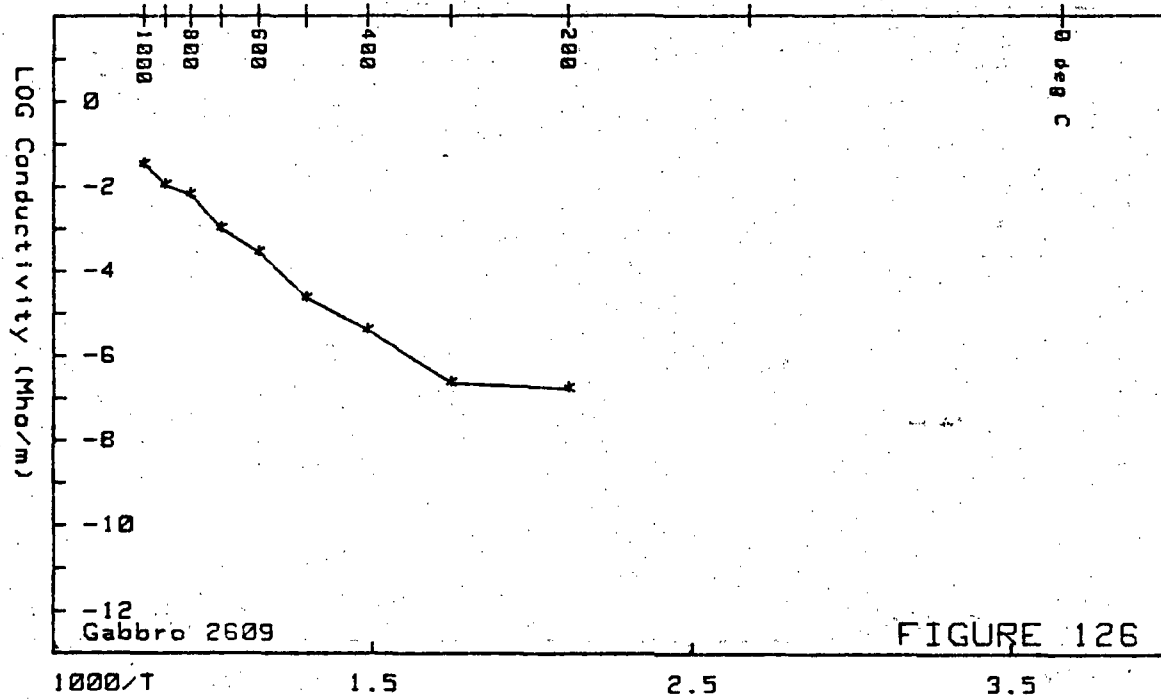
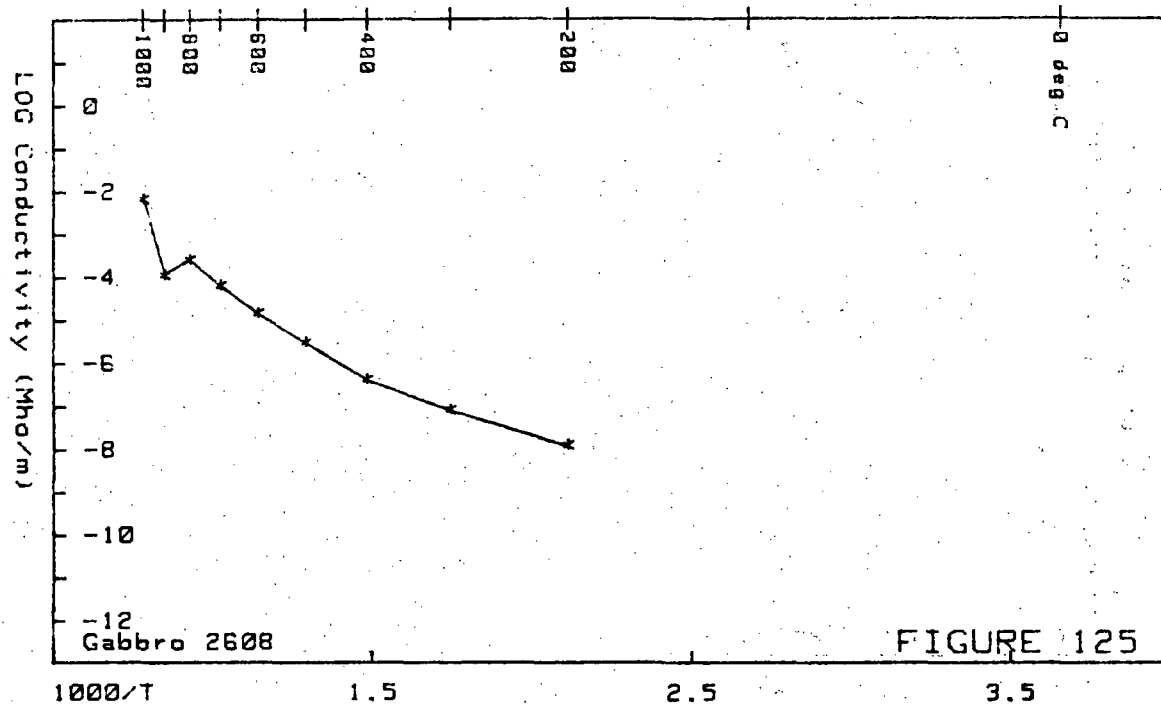
FIGURE 118

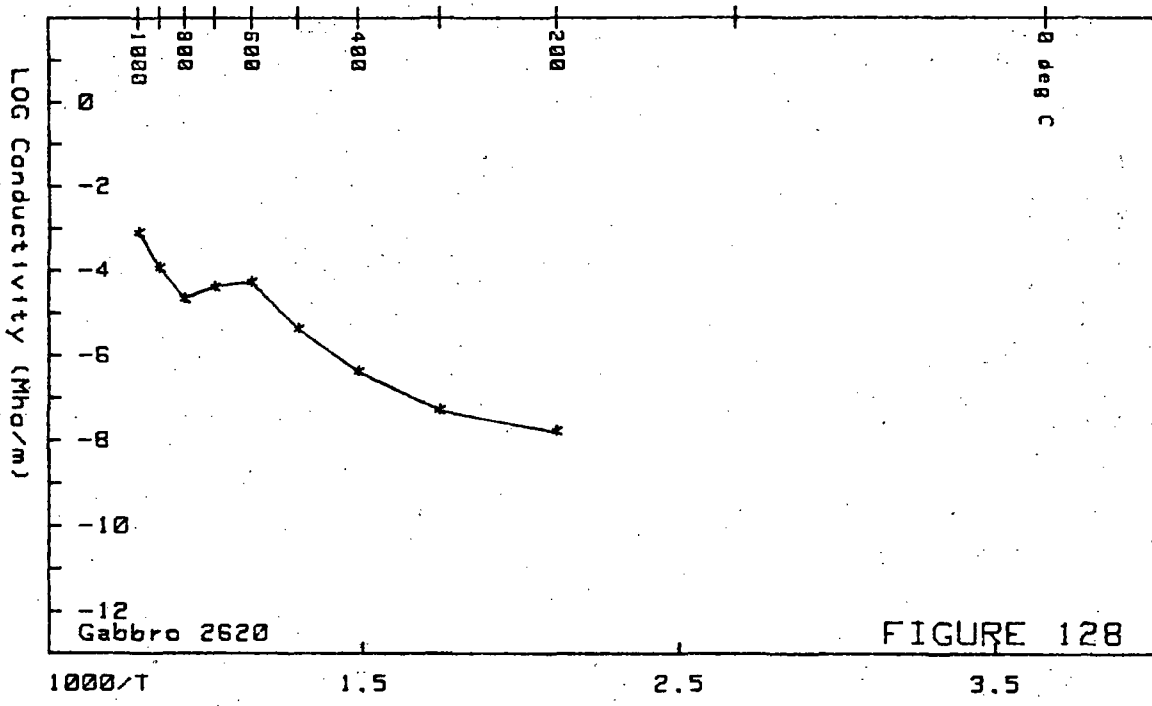
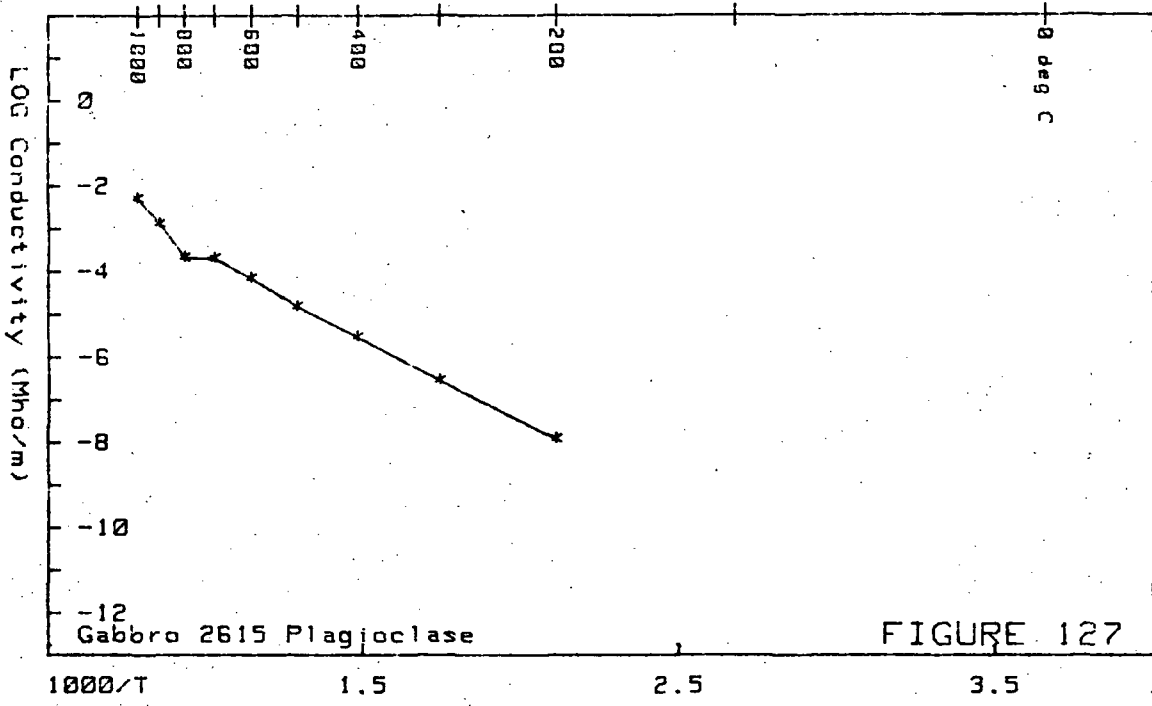


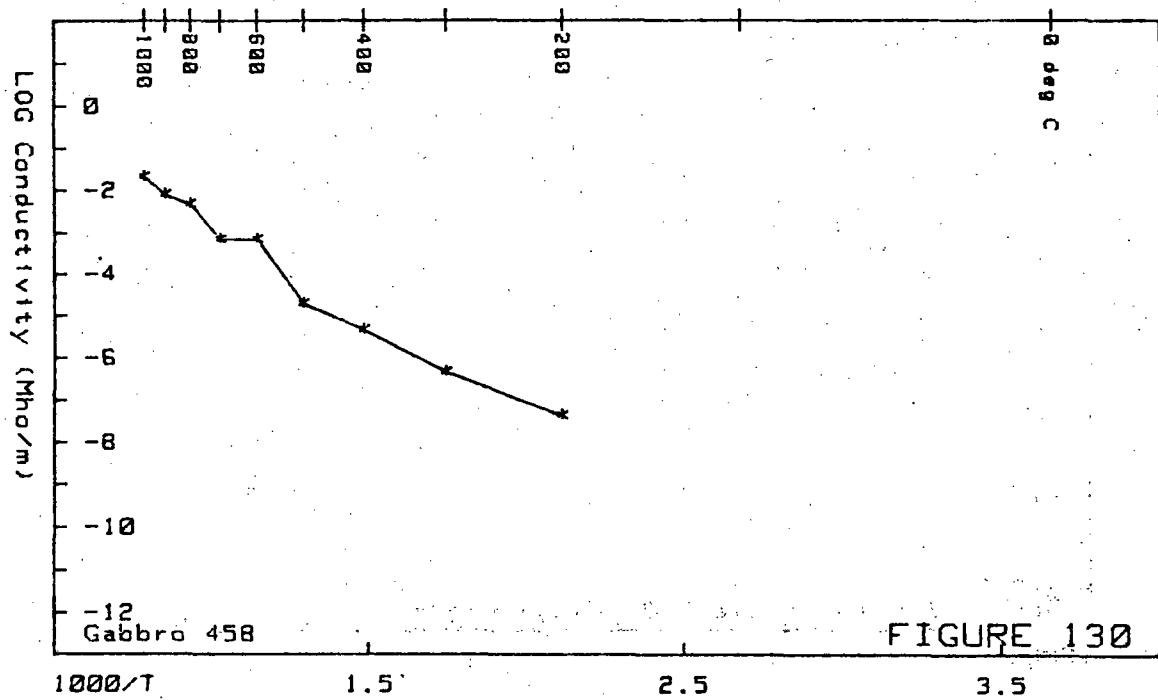
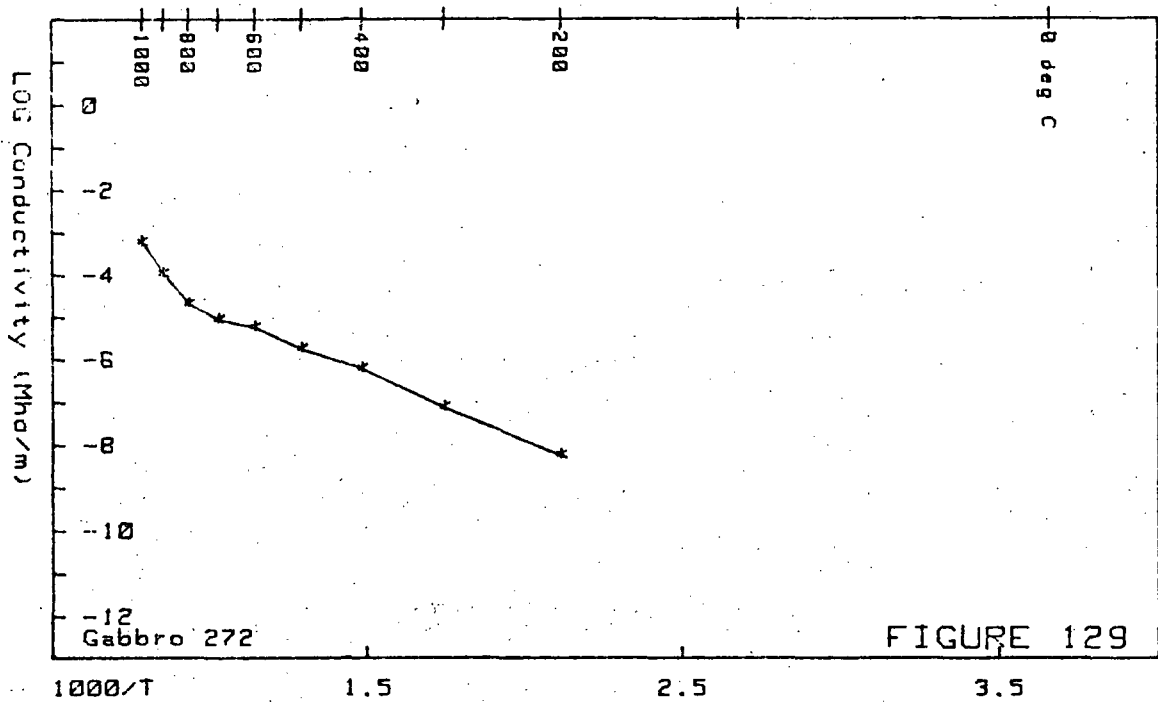


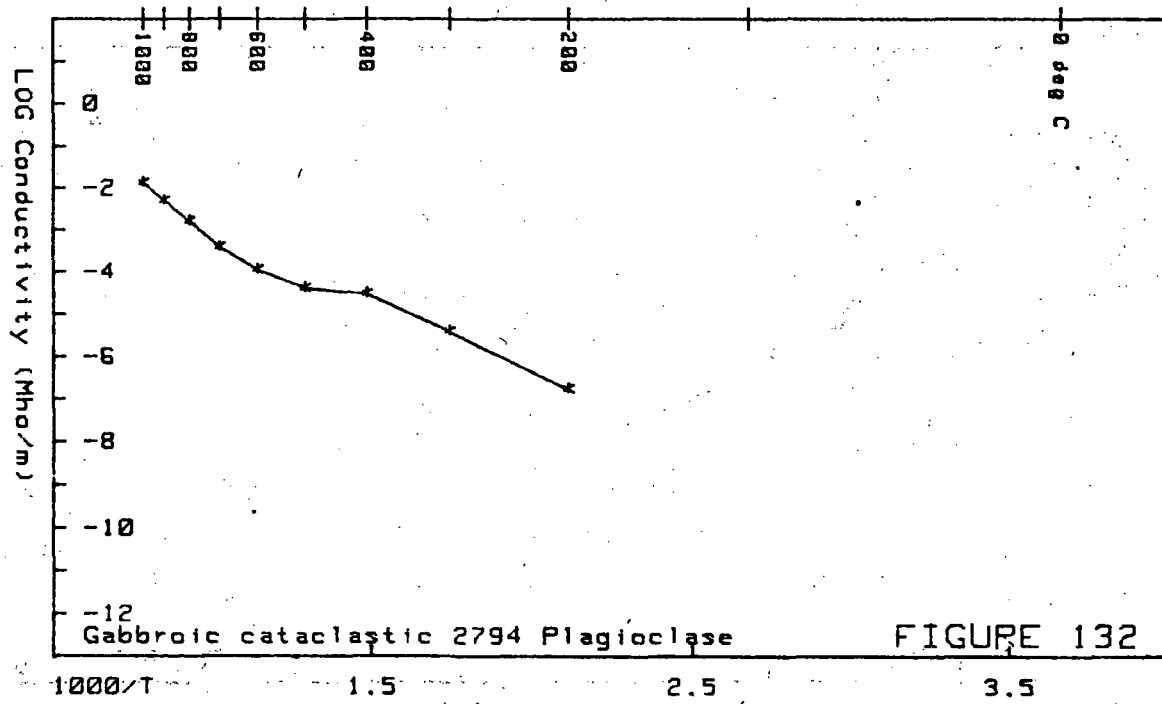
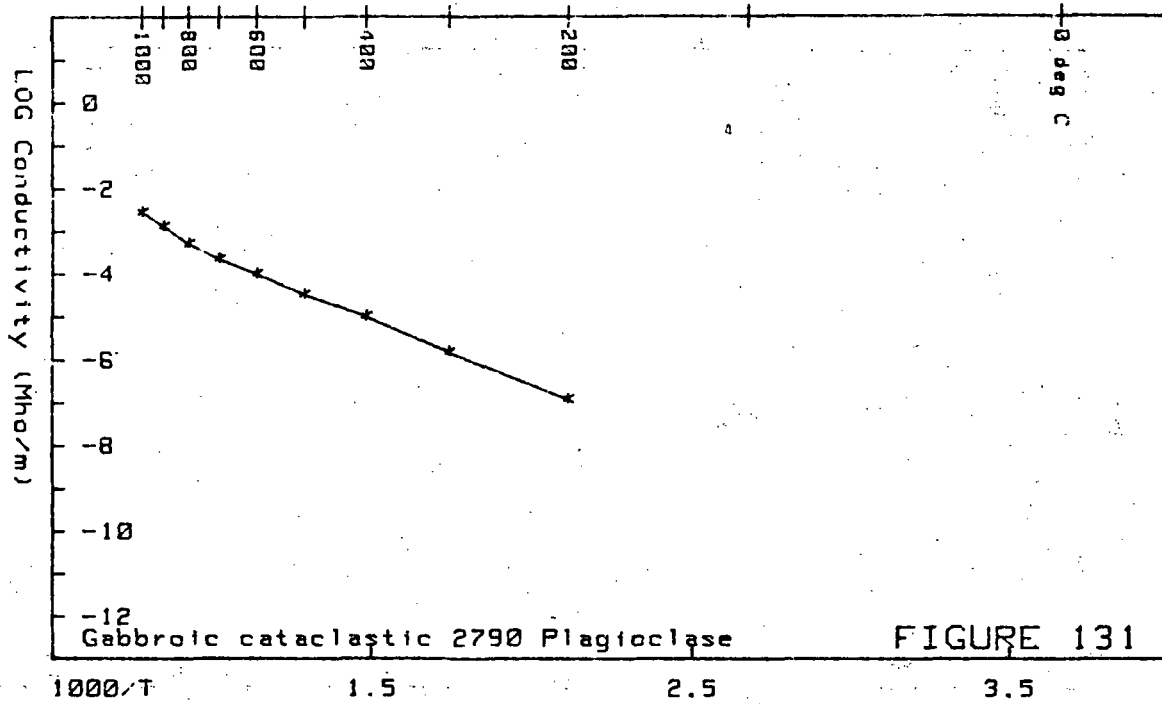


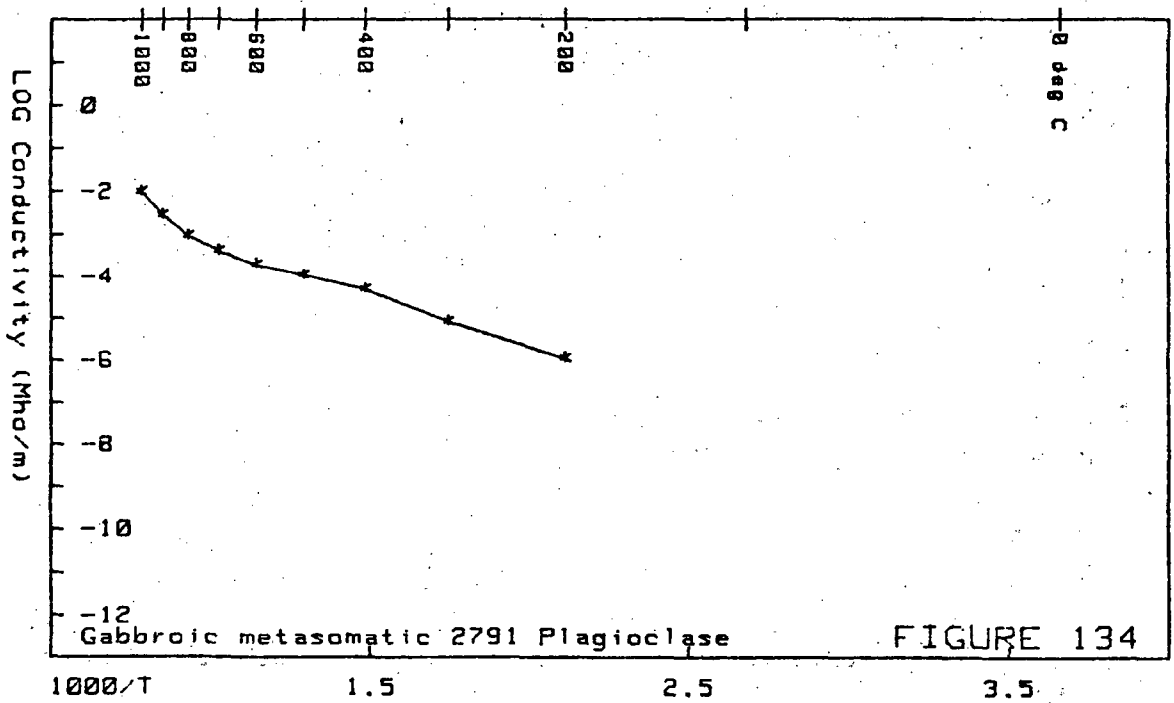
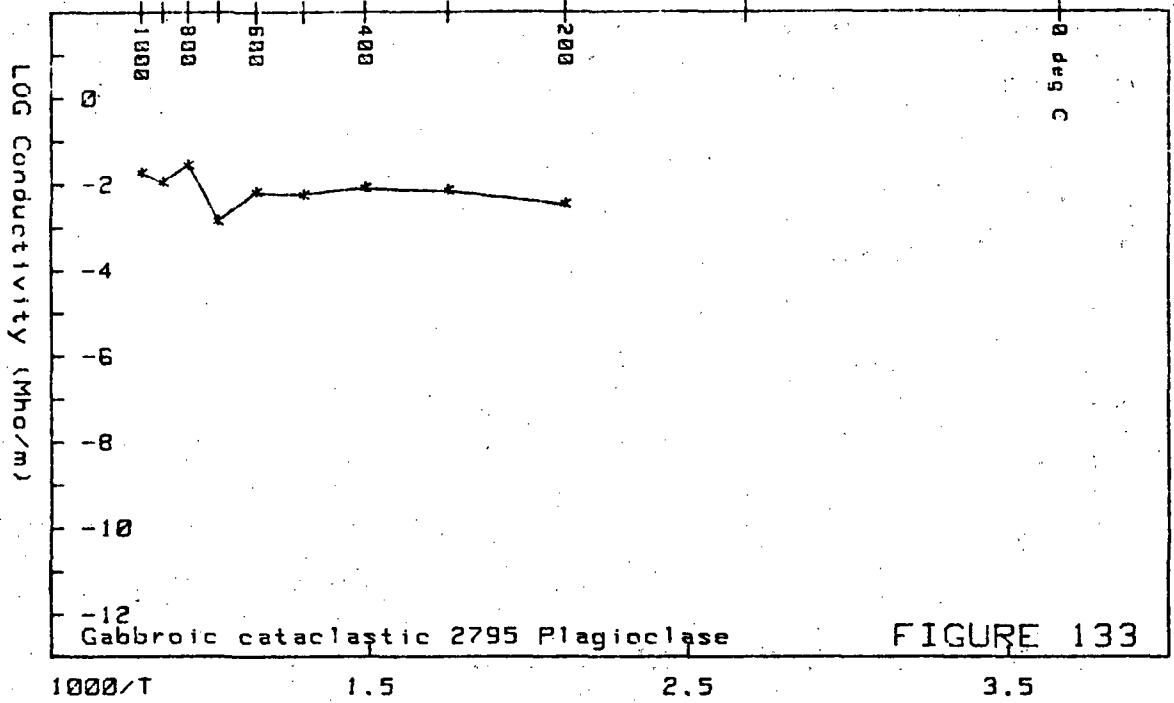


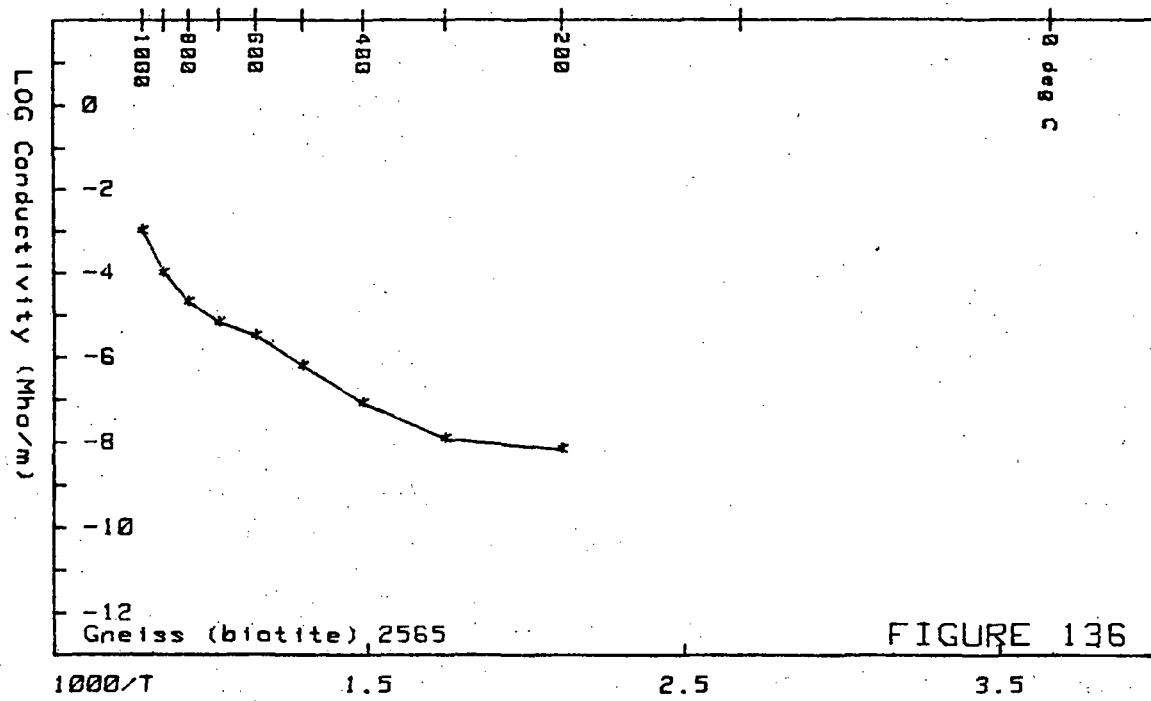
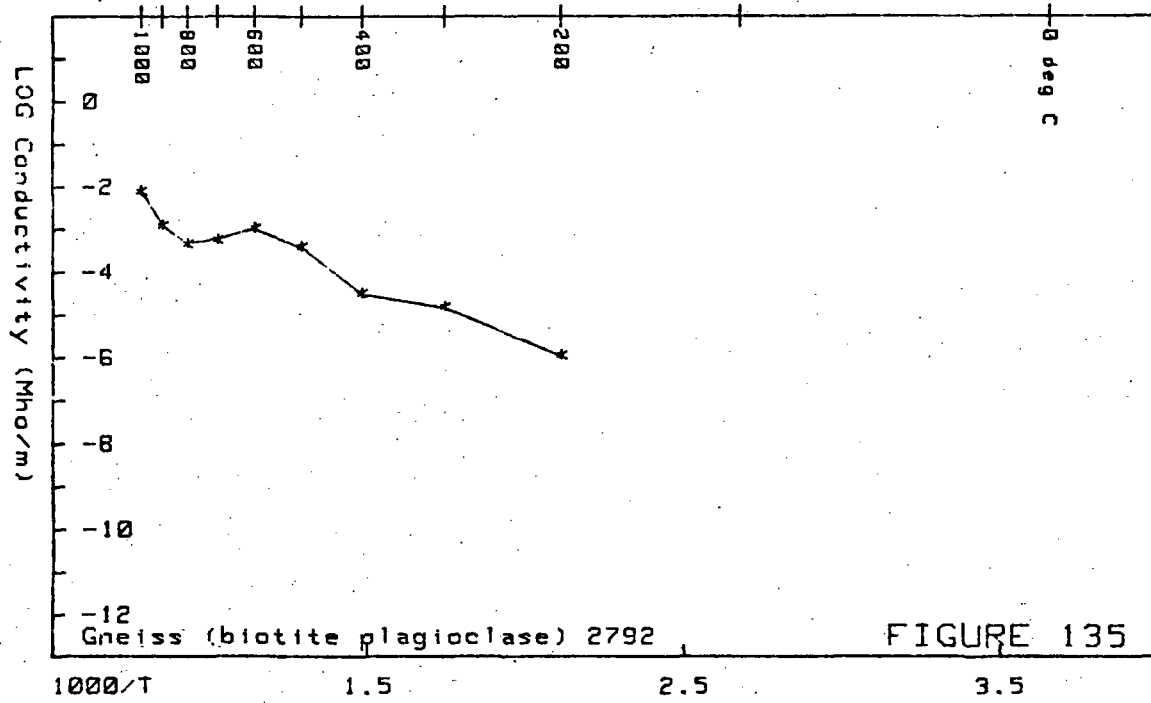




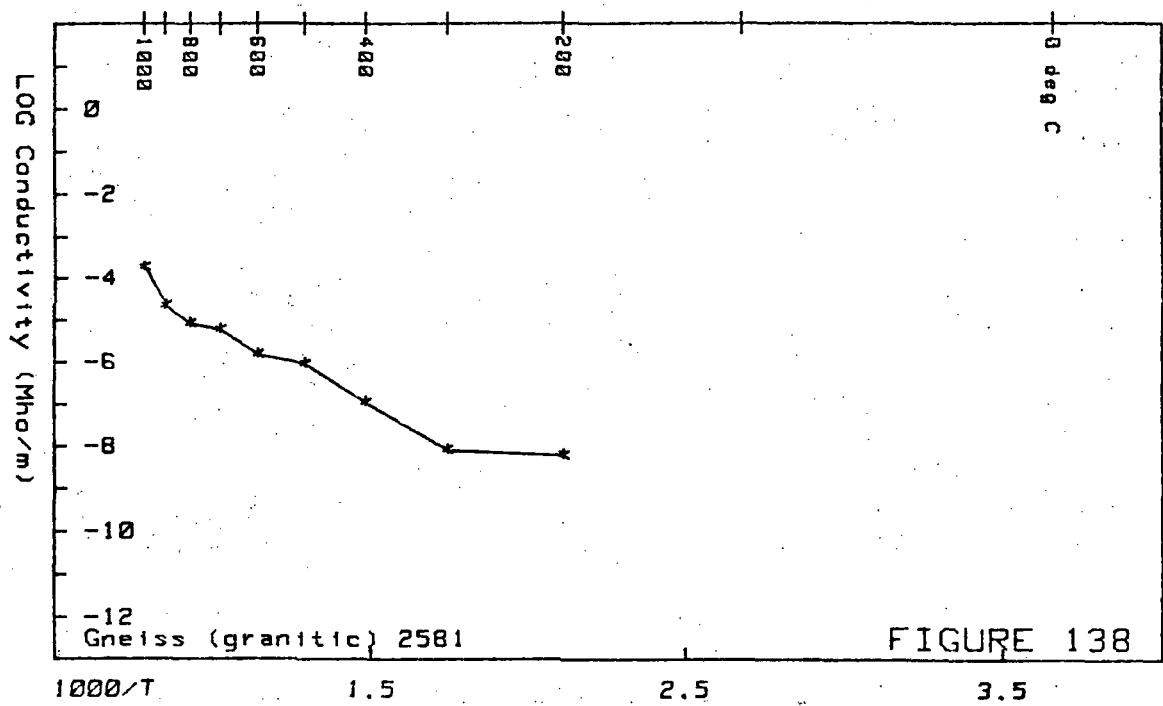
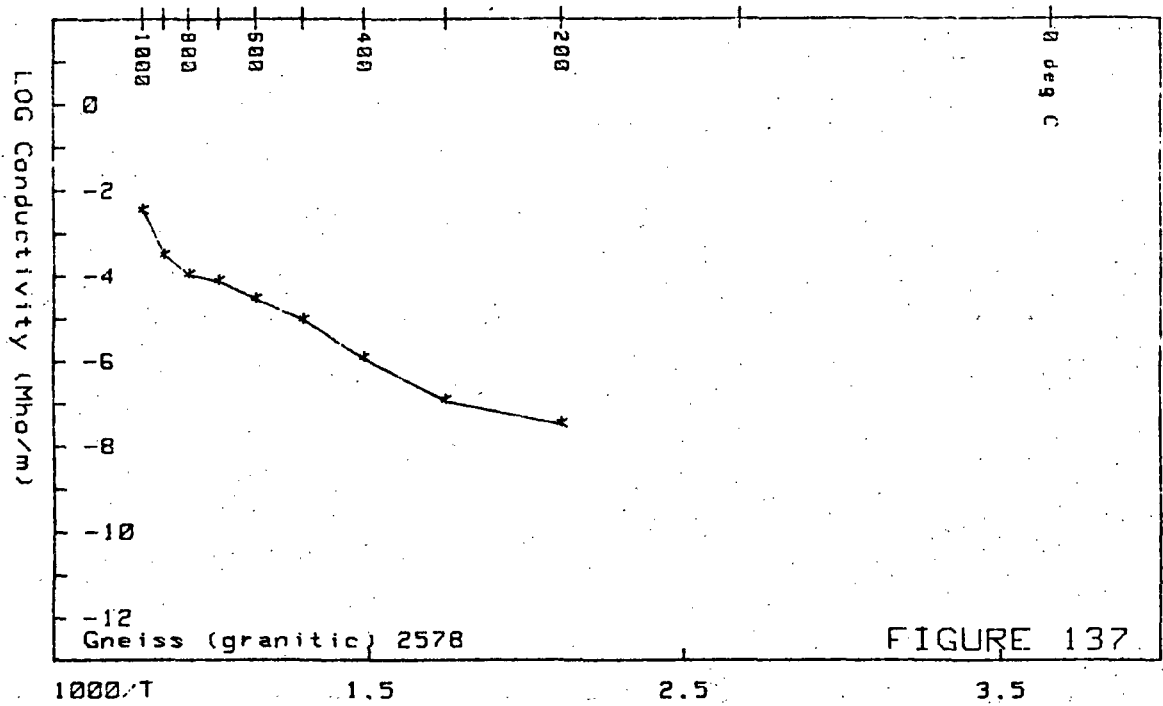


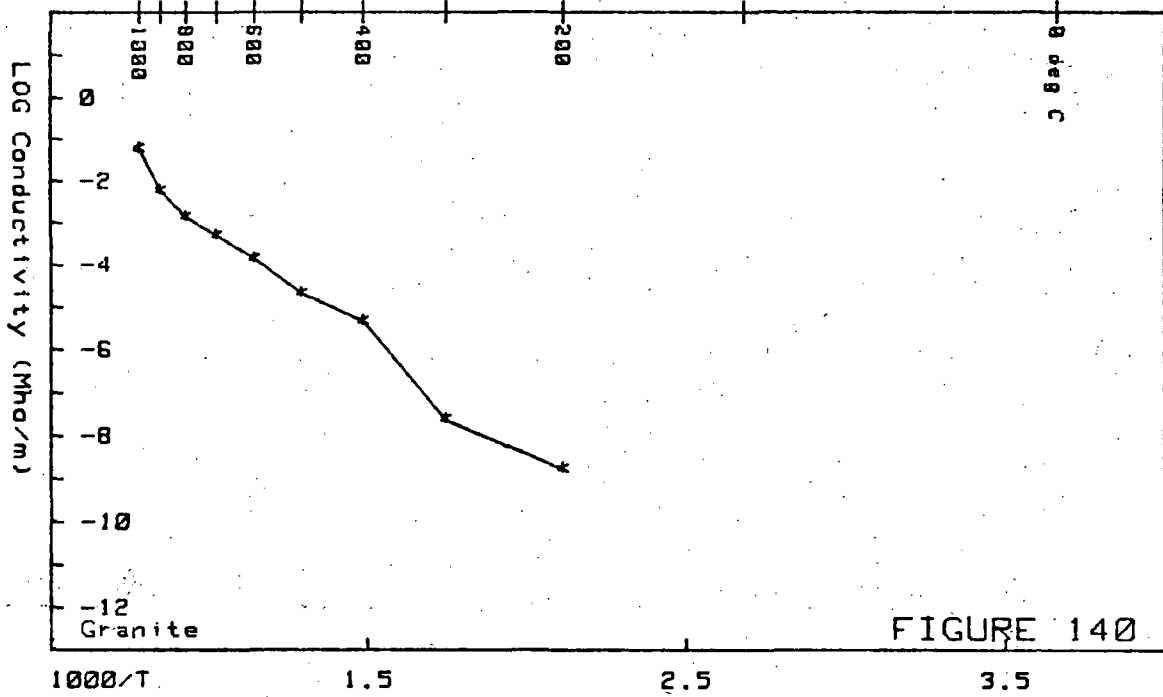
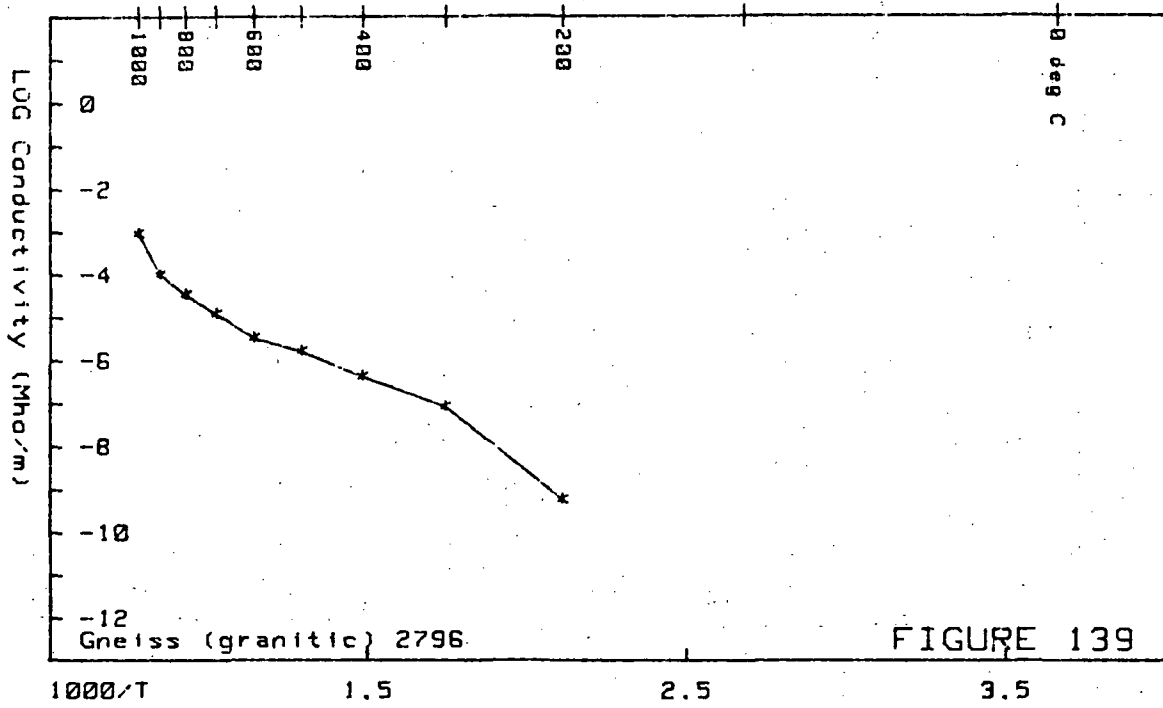


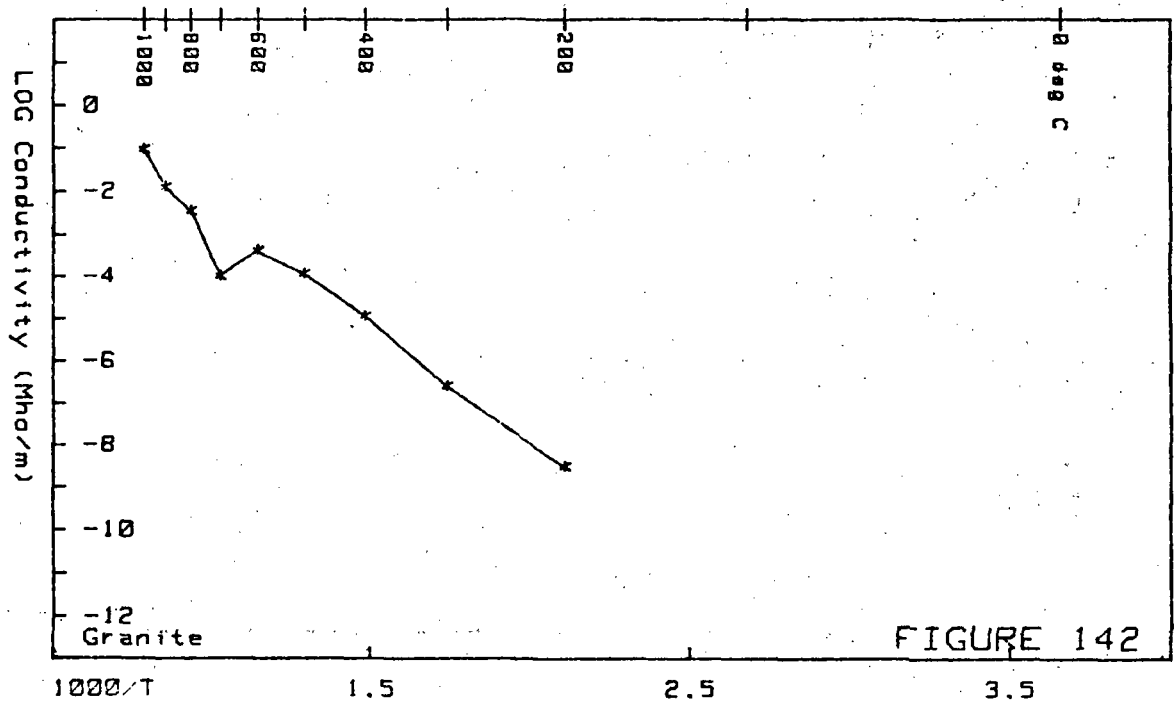
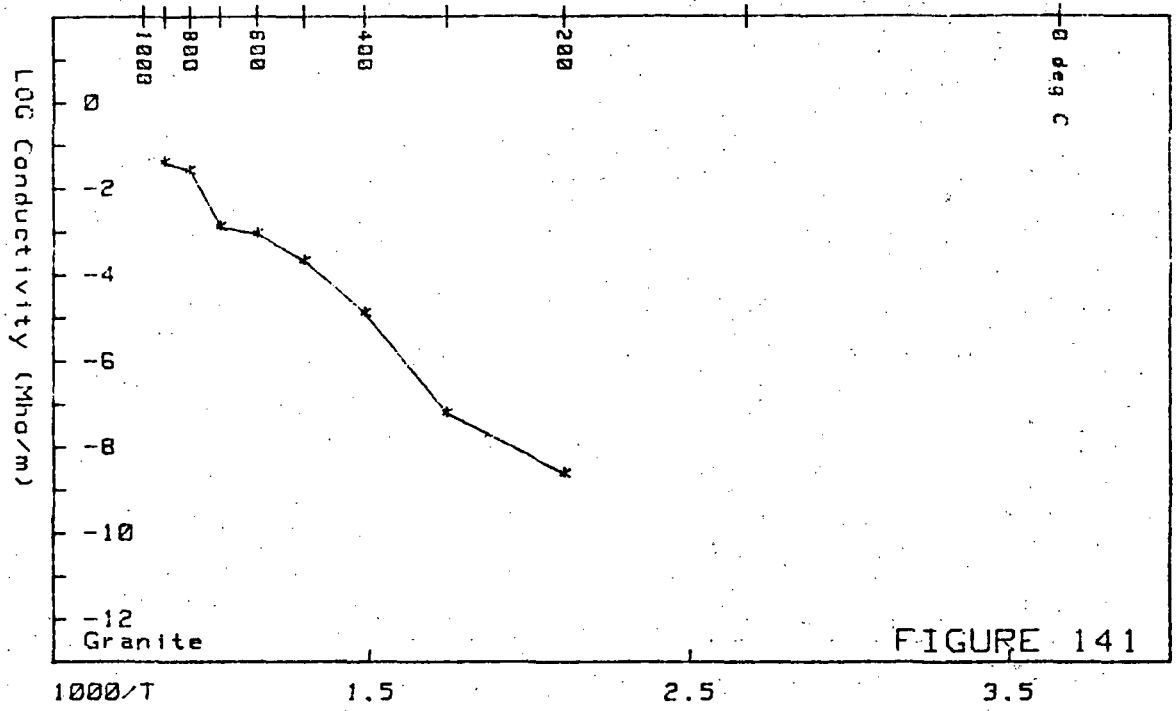


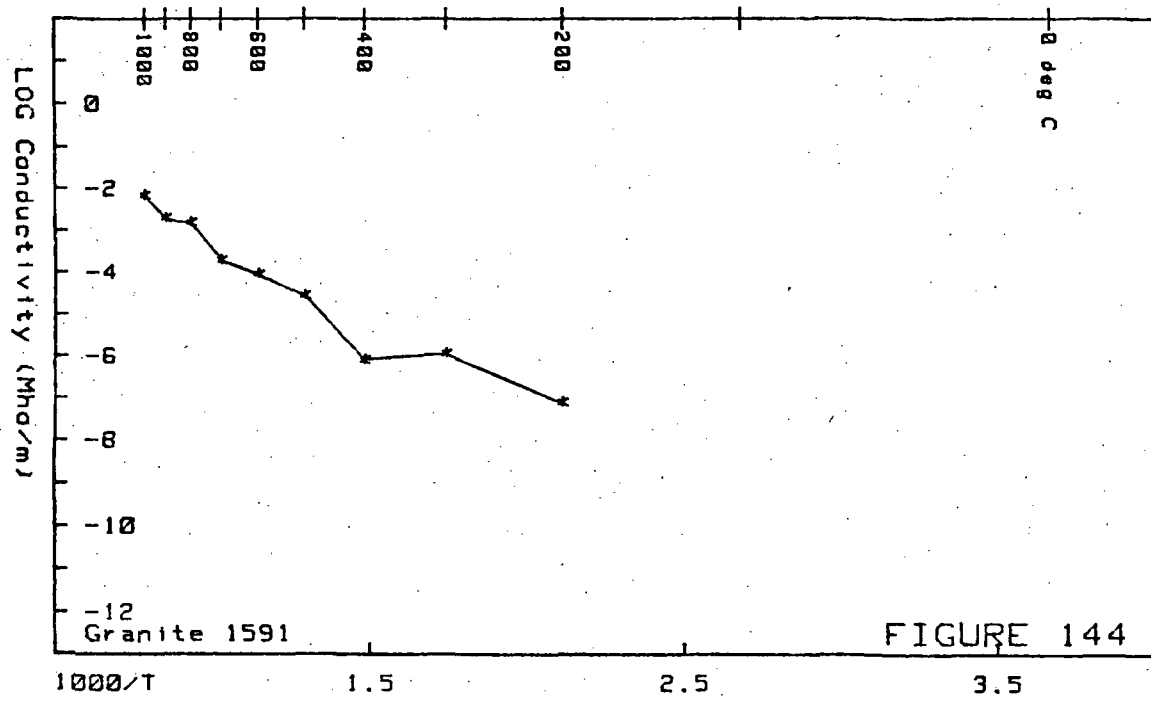
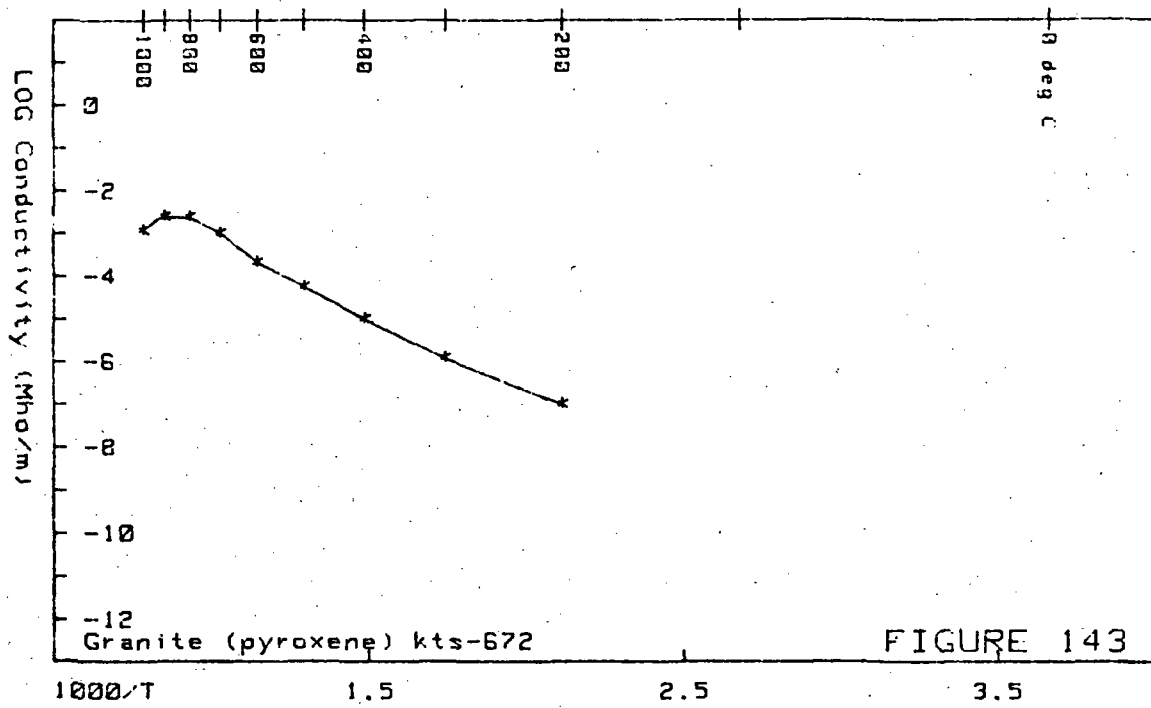


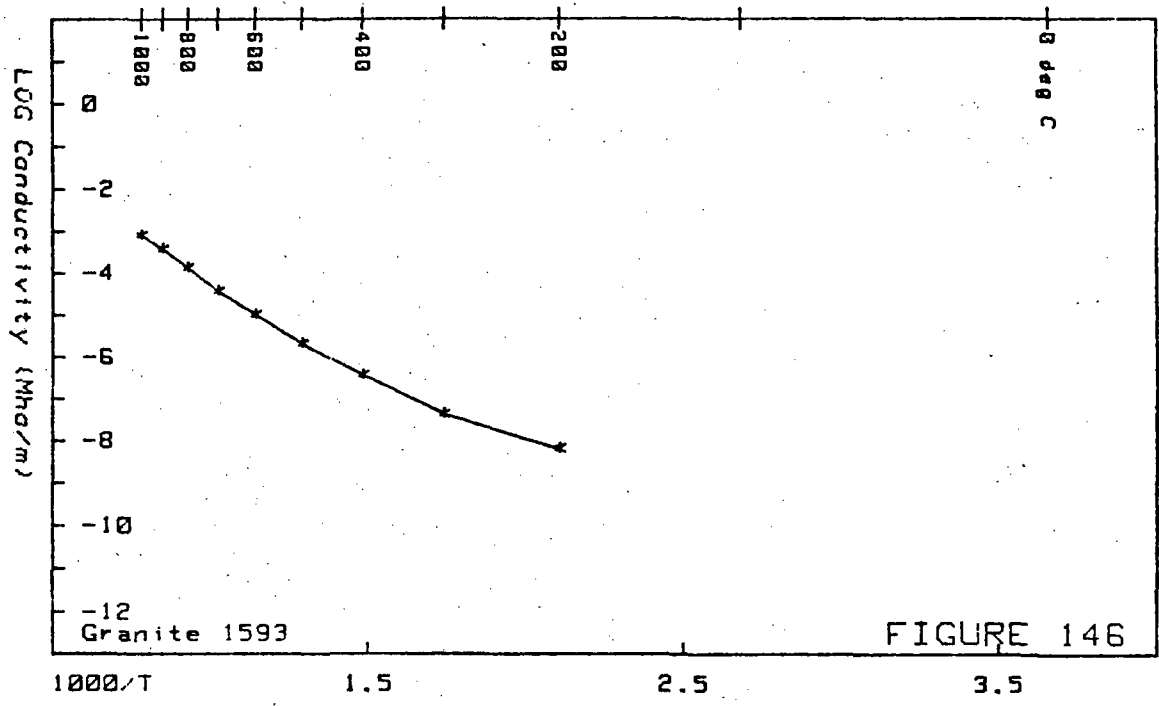
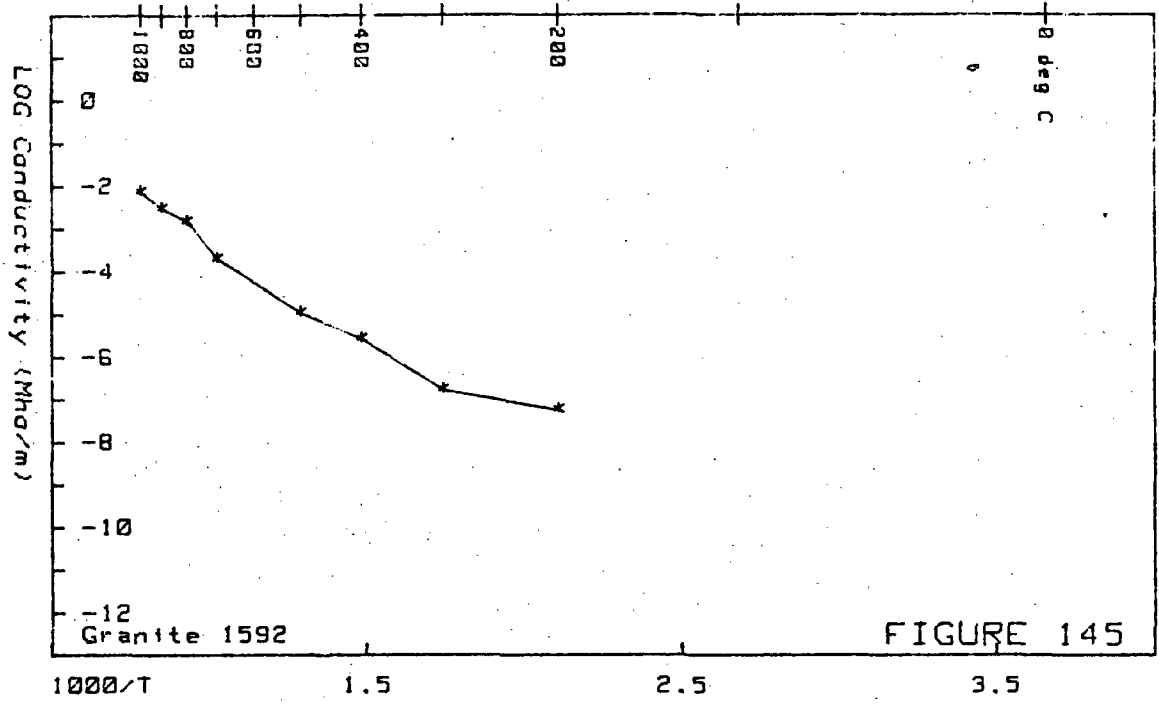


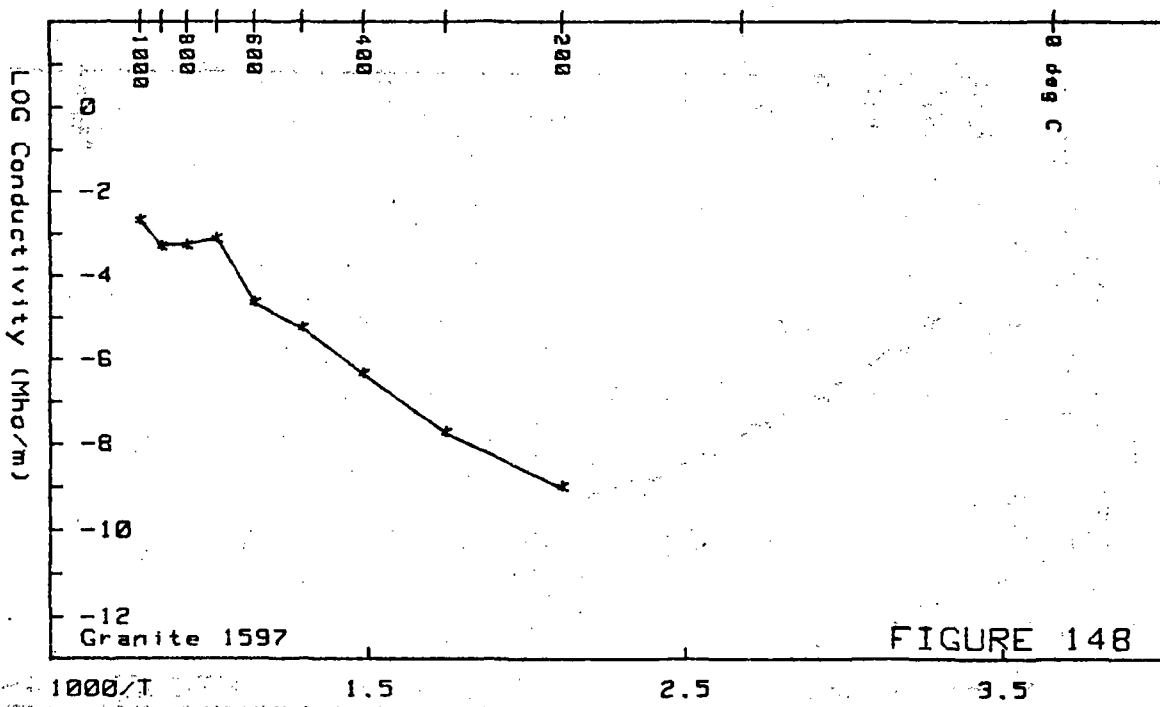
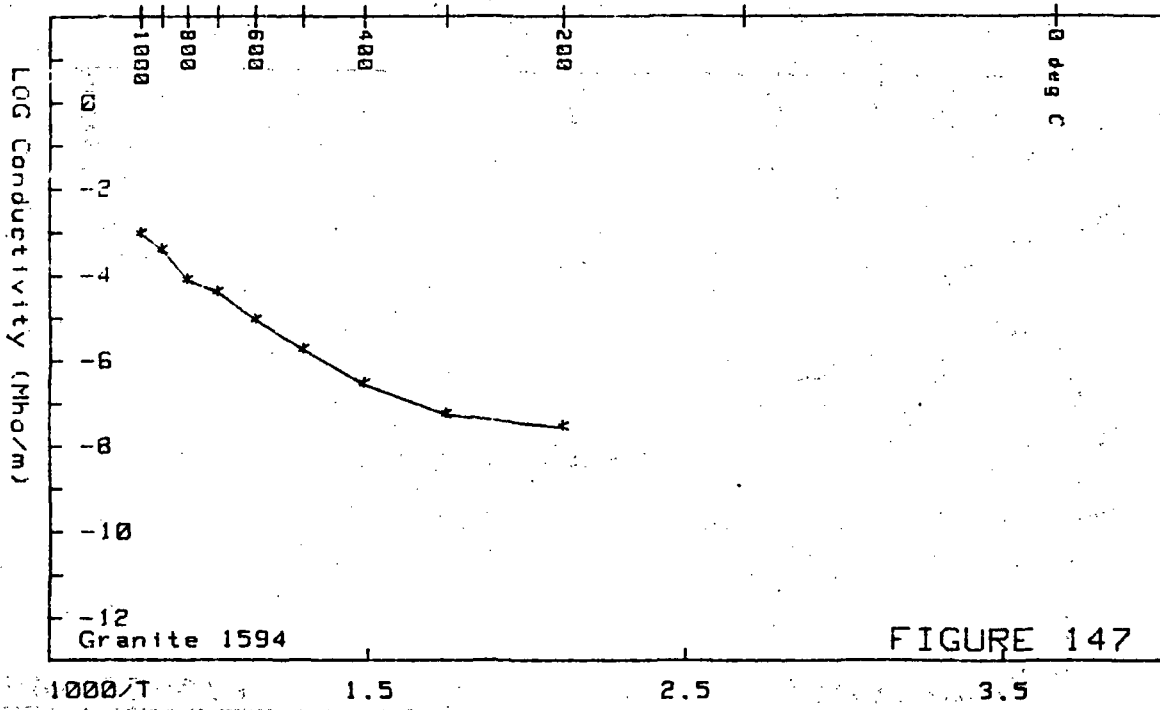












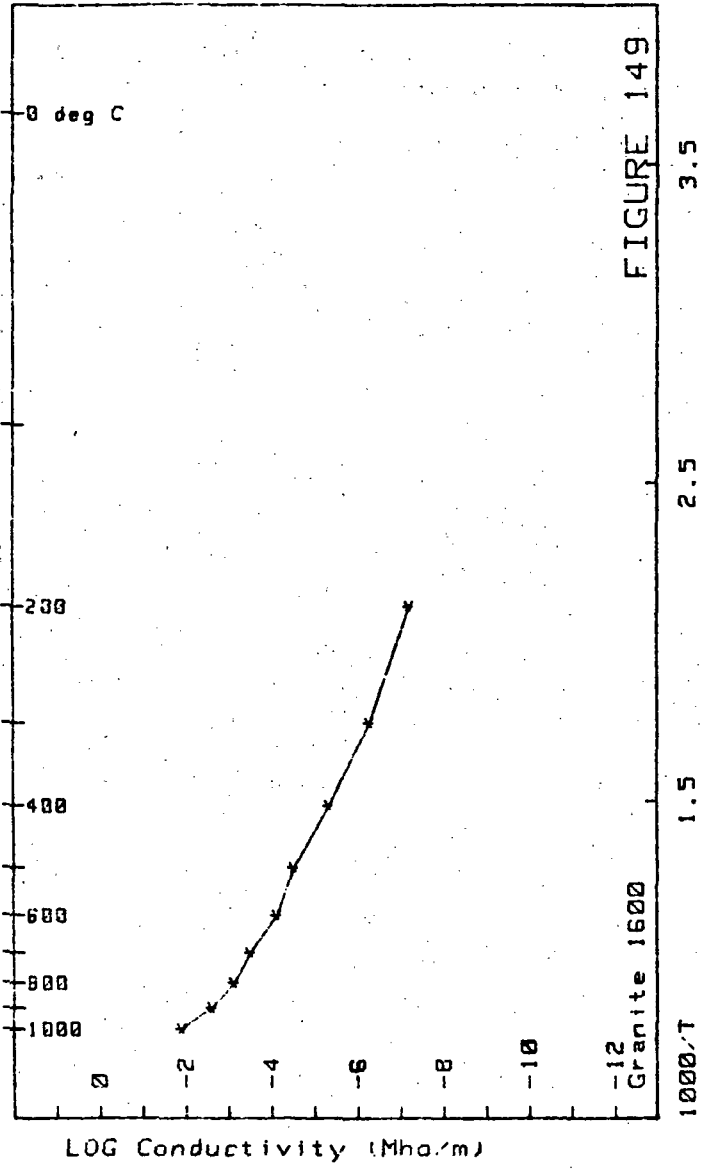


FIGURE 149

Granite 1600

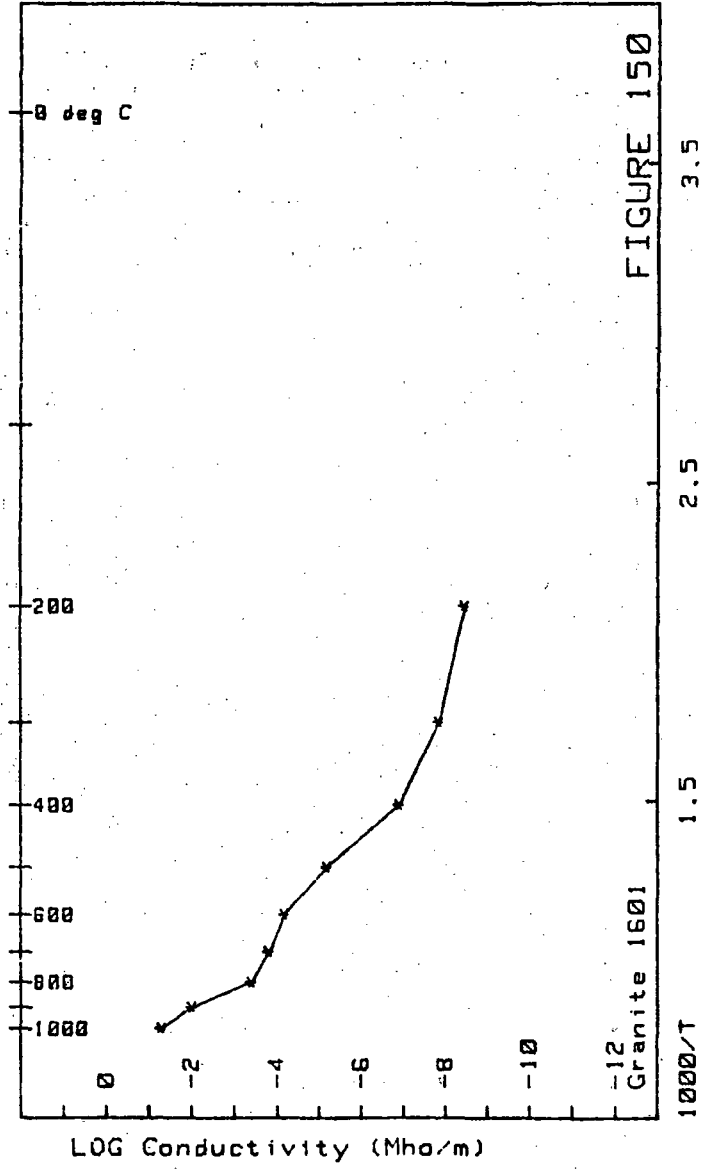


FIGURE 150

Granite 1601

