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Electrical properties of water saturated basalt
Preliminary results to 506K (233°C)

by

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This brief report describes the preliminary results of measurements of the electrical resistivity of a Hawaiian tholeiitic basalt as a function of temperature while water saturated under hydrostatic pressure. The sample is a core from 4.6 meters deep in the ERDA KI-76-1 hole drilled into the solidified crust of the Kilauea-Iki lava lake. It has a dry bulk density of 2.695 kg/dm^3, specific gravity of 3.137, water accessible porosity of 13.6%, and a total porosity (by helium pycnometry) of 14.1%.

The sample was saturated with a 1.7 ohm-m (298 K) NaCl aqueous solution (about 0.1m), and was found to have a resistivity variation with frequency of less than 14% between 0.01 Hz and 1 kHz, so all measurements as a function of temperature were performed at 1 kHz. The sample was tightly press-fit into the bottom quarter of a teflon cylinder and the cylinder was oriented vertically within a vertical mullite ceramic cylinder. The upper three-quarters of the teflon cylinder was filled with a 1.7 ohm-m solution to become the "top" solution reservoir, while the space between the bottom of the teflon cylinder and the mullite cylinder (bottom end closed) was the "bottom" reservoir. The two reservoirs did not connect (except through the sample pores), thus insuring no conducting path around the sample. Four terminal measurements were performed using platinum electrodes and the U.S. Geological Survey Petrophysics Laboratory automated data acquisition system. A pair of platinum electrodes (one current and one potential) were in each solution reservoir with the potential electrodes nearest the sample. All four electrodes were used to measure the sample resistivity followed by each pair in the reservoirs used to measure the solution resistivity. Typical measurement accuracies were $\pm 1\%$ or better in resistivity ($\pm 2.5\%$ worst case). Temperature was measured with S-type thermocouples while pressure was measured with an electronic strain gauge pressure transducer. The entire mullite and teflon sample holder was encased within an Inconel hydrothermal pressure vessel with argon gas as the pressurizing medium.

As no variation in resistivity was observed with change in current density or pressure (as long as the solution remained in the liquid state), all measurements reported here are at approximately 0.5 A/m^2 and at 11 MPa.

Figures 1 through 4 illustrate the heating and cooling curves for the basalt sample and the solution resistivity. The circles are the data points while the asterix-lines are the least squares fit with the equation shown (a simple Boltzmann equation). Note that the statistical parameter, R^2, illustrates a fit of 0.996 or better to the basalt resistivity versus temperature whereas the solution resistivity only shows an R^2 of 0.97. Thus, the form of the temperature dependence is slightly different for the pore water than for the water saturated basalt sample. Also (and more significantly), note that the activation energies of the basalt resistivity with temperature are about 0.2 eV and nearly double those of the pore solution. Thus, the volume conduction through the pore water is not the only contributor to the basalt resistivity change with temperature. Figure 5 is a plot of the solution reservoir resistivity versus the basalt sample resistivity with a straight line for comparison. The water saturated basalt has about the same temperature dependence as the reservoir solution up to 80°C (353 K) whereas above that temperature the resistivity of the sample is decreasing faster than that of the pore water. It is very likely that the resistivity dependence upon temperature in the basalt is influenced strongly by the pore wall rock/water interaction and a strong surface conductance as well as the volume conductance through the pore water. These factors effectively negate the use of Archie's law for this basalt above 80°C (353 K). A more comprehensive relation will have to be developed as more data become available.

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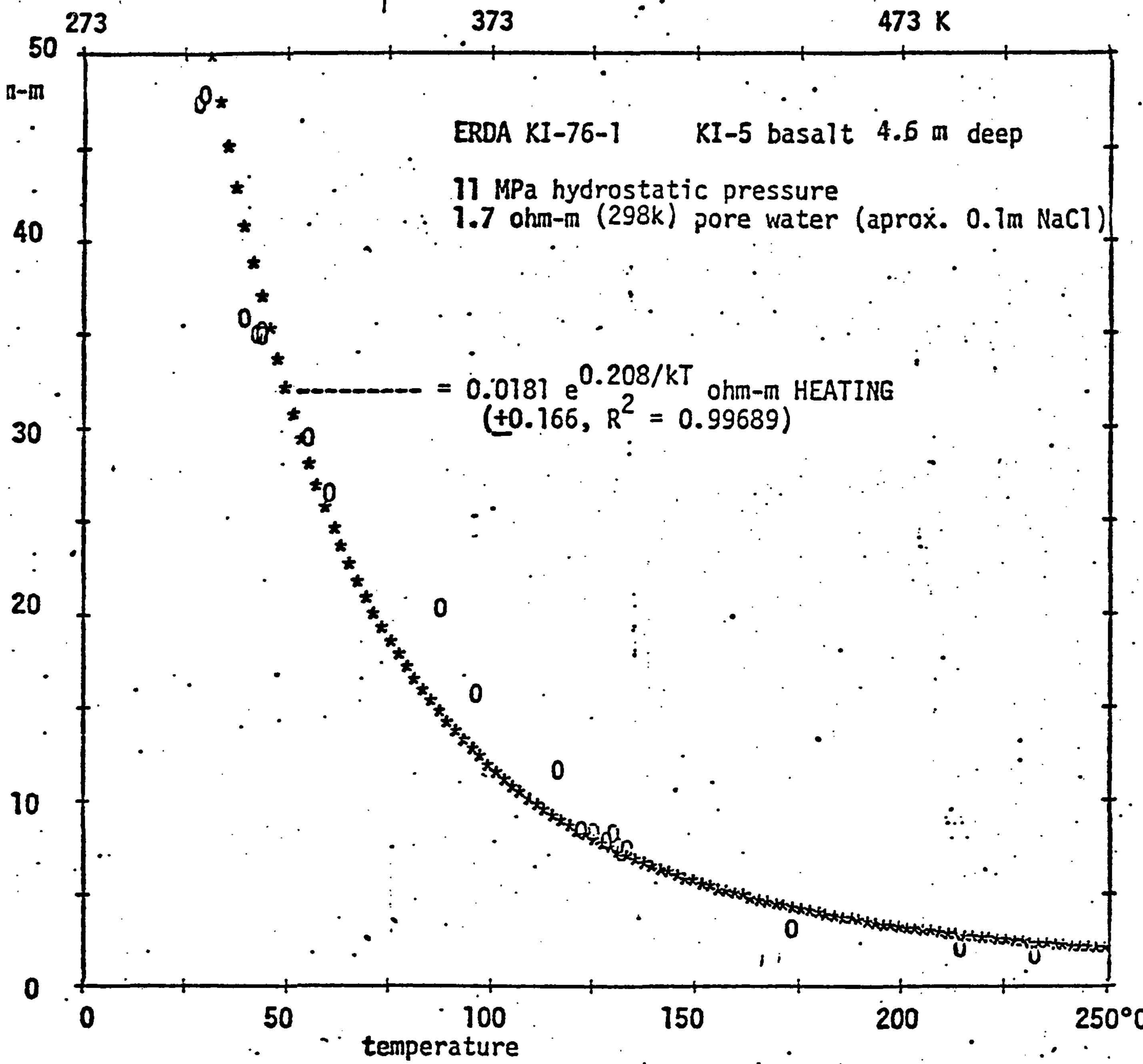

Figure 1 - Basalt resistivity versus temperature.

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FIGURE 1

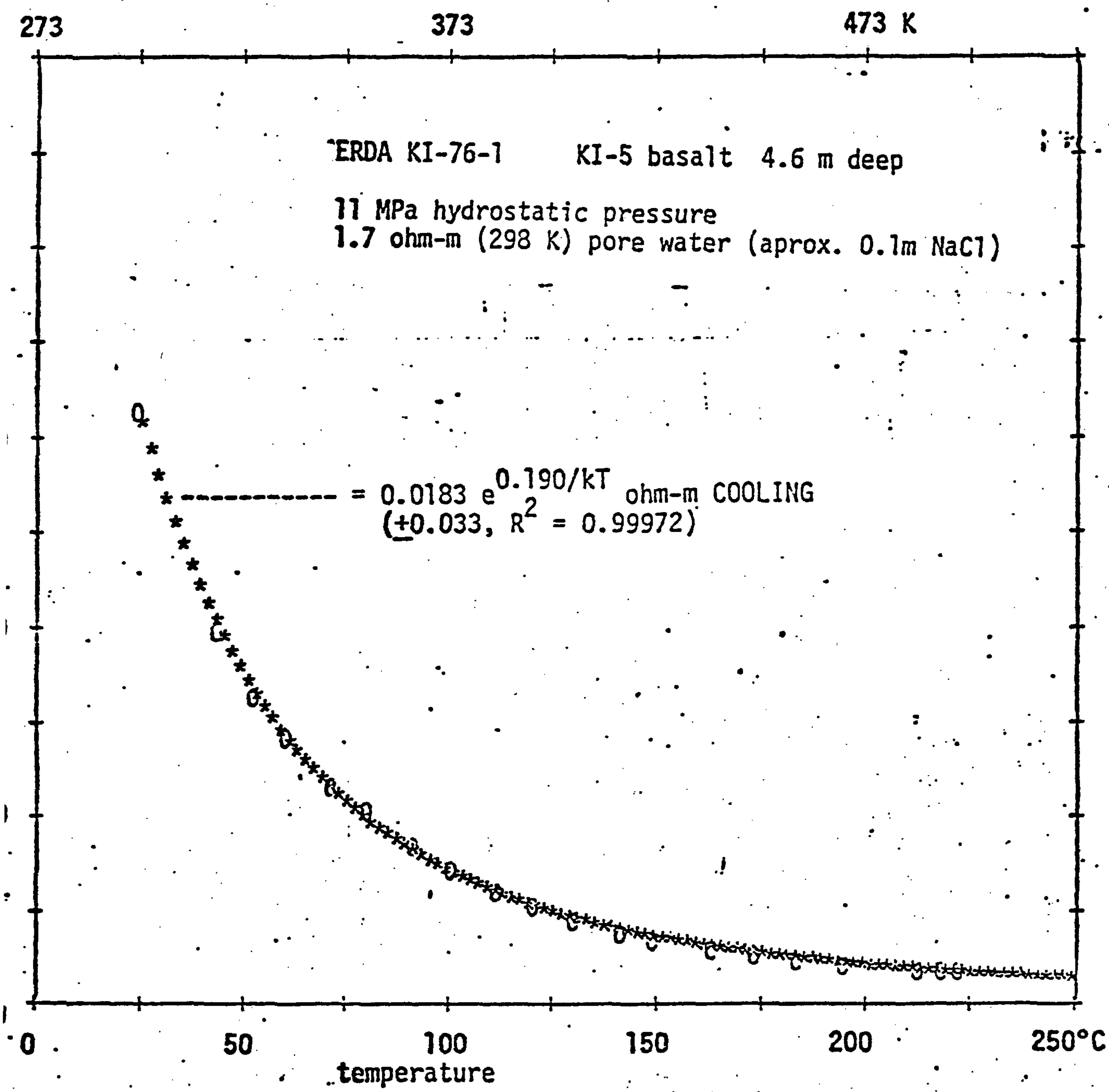

Figure 2 - Basalt resistivity versus temperature.

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FIGURE 2

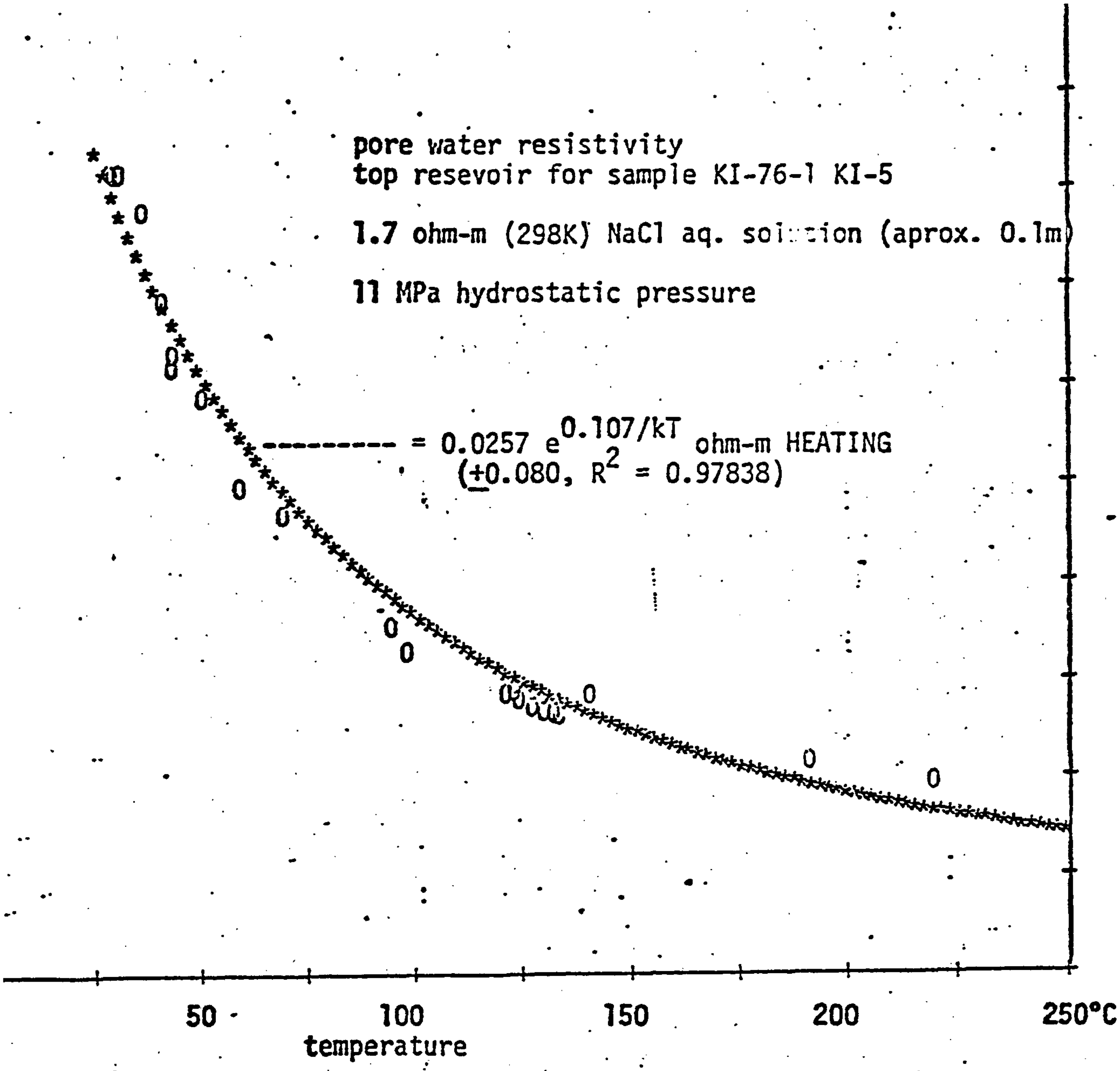

Figure 3 - Top solution reservoir resistivity versus temperature.

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FIGURE 3

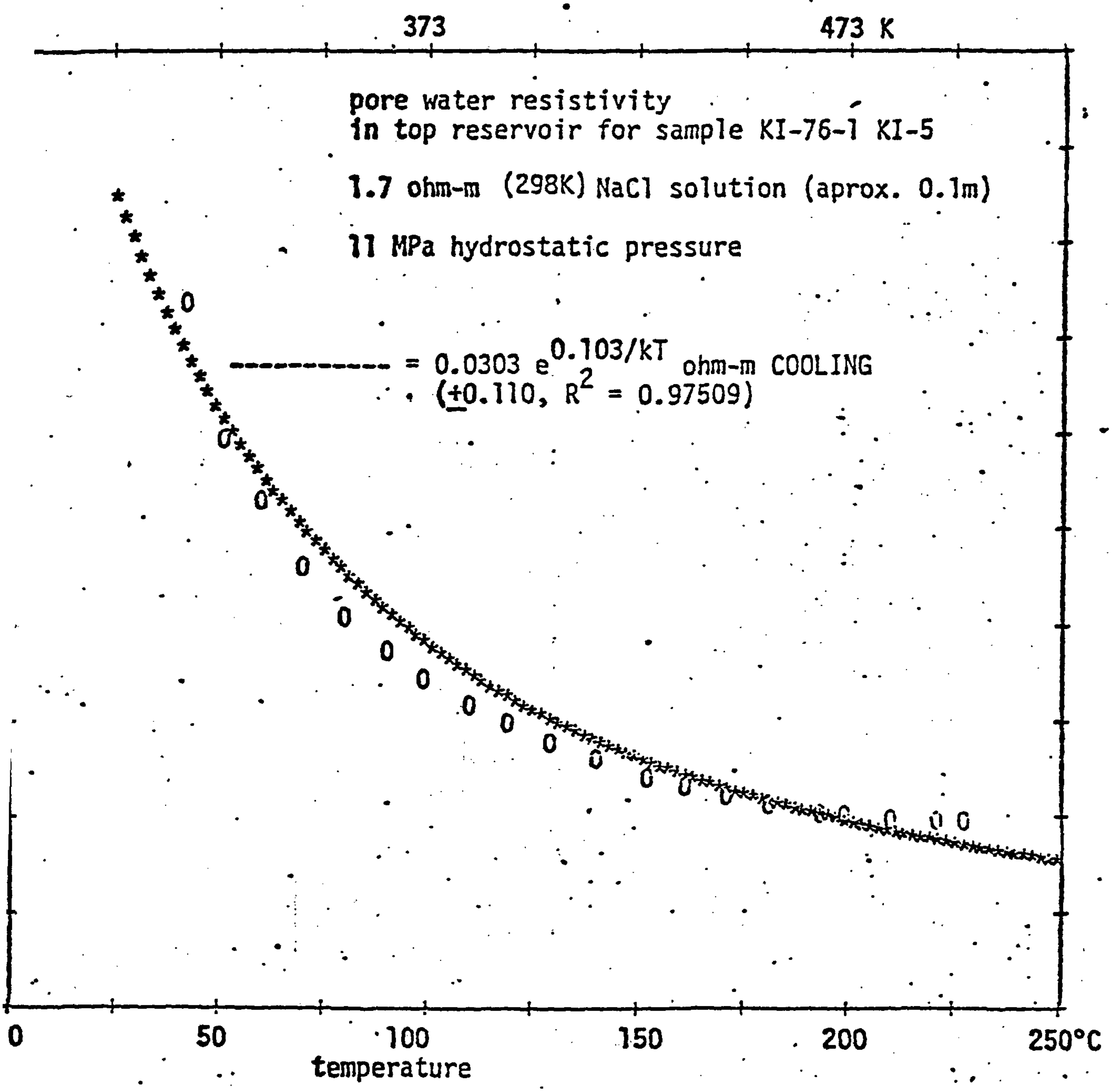

Figure 4 - Top solution reservoir resistivity versus temperature.

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FIGURE 4

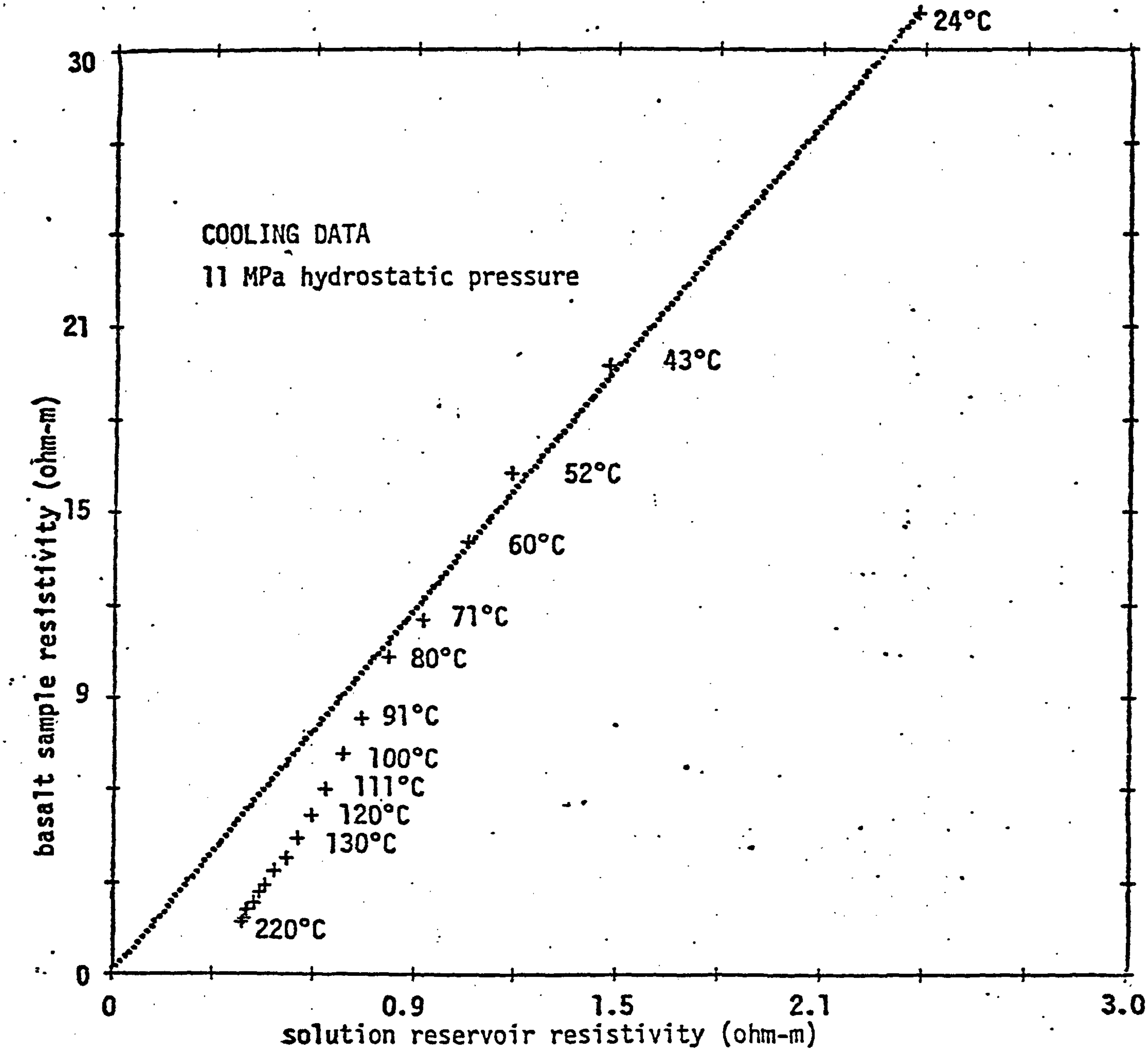

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Figure 5

Figure 5 - Basalt sample resistivity versus solution reservoir resistivity at various temperatures.