LA-UR-86-2137

MASTER

CONF-860746--1

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--86-2137

DE86 012401

7 1986

TITLE: MAGNETORESISTANCE AND UPPER CRITICAL MAGNETIC FIELD OF UBe_{13} UNDER PRESSURE

AUTHOR(S): J. O. Willis, J. D. Thompson, J. L. Smith, Z. Fisk

SUBMITTED TO: To be presented at the International Conference on Anomalous Rare Earths and Actinides, 7-11 July 1986, in Grenoble, France. To appear in Journal of Magnetism and Magnetic Materials.

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

MAGNETORESISTANCE AND UPPER CRITICAL MAGNETIC FIELD OF UBe_{13} UNDER PRESSURE

J. O. Willis, J. D. Thompson*, J. L. Smith, and Z. Fisk

Materials Science and Technology Division, Mail Stop G730,
Los Alamos National Laboratory, Los Alamos, New Mexico 87545
* Physics Division, Los Alamos National Laboratory, Los Alamos, NM 87545

ABSTRACT

We have investigated the effects of pressure on the magnetoresistance and the upper critical magnetic field of the heavy electron compound UBe_{13}. Both the superconducting transition temperature and the upper critical field decrease under hydrostatic pressure. The low temperature magnetoresistance remains large and negative under pressure. The temperature region over which the resistivity has a T^2 temperature dependence increases with both magnetic field and with pressure. At a fixed magnetic field, the coefficient of the T^2 term in the resistivity decreases strongly with pressure. UBe_{13} is found to have a pressure independent intrinsic residual resistivity of 18 μΩ-cm.

Keywords: Heavy electron superconductor, Critical magnetic field, Magnetoresistance

Running Title: Magnetoresistance and Critical Field of UBe_{13}

UBe_{13} [1] is one of the three heavy electron superconductors characterized by large values of the dc susceptibility at zero temperature and of the electronic specific heat coefficient γ (=C/T), which taken together imply electron masses of several hundred times the free electron value. This intermetallic compound is superconductive below T_c=0.9 K and has extremely large values of $B_{c2}' \equiv -dB_{c2}/dT|_{T=T_c}$ of 42 T/K or possibly larger, and extrapolated values of B_{c2} (T=0) in excess of 9 T [2]. Such values reflect the large electron mass and the high normal state resistivity at T_c of about 130 $\mu\Omega$-cm. UBe_{13} also exhibits a very large negative magnetoresistance, amounting to 35% at T_c^+ and 5 T [2].

In addition to the striking response of UBe_{13} in both the normal and superconducting state to magnetic fields, the effects of impurity substitution are unique [3,4]. Dilute thorium substitutions for uranium show a nonmonotonic depression of T_c with concentration. A second large anomaly appears in the specific heat data well below T_c and then vanishes again as the Th concentration is increased. In general, impurity substitutions may affect both the interatomic spacing and the number of conduction electrons. In contrast, hydrostatic pressure may be used to vary the interatomic spacing with no other perturbing effects. Because of the many interesting and unusual properties of UBe_{13} noted above, we have here investigated the effects of pressure on T_c, B_{c2}', and $\rho(T,B)$ of UBe_{13}. Pressure has been shown to reduce the C/T value by 30% at pressures of about 9 kbar [5]. Recent measurements above 1 K at Los Alamos [6] show that the position and magnitude of the 2.5 K resistivity peak in UBe_{13} both show a strong positive correlation with pressure. In addition, for pressures greater than $\sim$9 kbar, the resistivity exhibited a T^2 temperature dependence over a limited temperature interval above 1 K that increased with pressure. Such temperature dependences had only been observed previously below 1 K in the presence of a large magnetic field (B>2 T) [7].

In this work we have measured the magnetoresistance and the upper critical magnetic field of polycrystalline UBe_{13} between 0 and 9 T, at pressures from 0 to 19 kbar, and at temperatures down to approximately 150 mk, below which thermal equilibrium times in the self-clamped Cu-Be cell employed became excessive. The measurements were performed using a conventional four-terminal ac resistance technique with transport currents of 0.07 A/cm^2 or smaller to avoid joule heating effects. The transport current was roughly parallel to the applied magnetic field. The pressures were determined from the T_c of a tin manometer.

Results are shown for representative pressures of 0 and 19 kbar in figs. 1 and 2 respectively, where it is immediately apparent that for T<4 K the resistivity at 19 kbar is strongly depressed relative to its zero pressure value. The superconducting transition temperature T_c was found to decrease at the rate of about 16 mK/kbar -see fig. 3. This value is slightly larger than that found previously by ac susceptibility measurements [8] on a polycrystalline sample with a T_c of 0.85 K versus the present value of 0.905 K. The upper critical magnetic field B_{c2} (T) is strongly depressed by pressure, as seen in fig. 4. We have extrapolated the critical field linearly to T=0 as there is no evidence that B_{c2} (T) approaches the temperature axis with zero slope, as has been noted previously [2]. The values of $B_{c2}(0)$ so obtained decrease linearly with pressure at the rate of 0.29 T/kbar, with a P=0 value of 11.5 T, somewhat larger than that reported previously [2,9]. Additionally, we find that B_{c2}' decreases dramatically with pressure in correspondence to the large decrease in C/T [5] and the normal state resistivity at T_c.

Examining now the normal state properties, we observe that the large negative magnetoresistance persists at 19 kbar. As is evident from figs. 1 and 2, the magnetoresistance is a complex function of temperature and magnetic field, and it cannot be determined explicitly below T_c (B=0). The normal state resistivity is decreased with both pressure and magnetic field, and we find an intrinsic resistivity ρ_o of 18 μΩ-cm that is independent of pressure. This is an important result in that previous measurements above 1 K [6] exhibited a tendency toward a constant ρ_o but were not able to extract a precise value.

Figure 5 shows the resistivity versus temperature-squared for UBe_{13} at 19 kbar. There are large regions over which the temperature dependence is indeed quadratic at the higher fields, with the coefficient A in $\rho = \rho_o + AT^2$ decreasing for fields of 3 T and larger. There may be smaller ranges over which a T^2 dependence occurs at lower fields, but they are somewhat obscured by a high temperature tail of the superconducting transition. The coefficient A has a value of about 13 μΩ-cm/K^2 at 19 kbar and B=9T, which is much lower than the value of 34 μΩ-cm/K^2 for the same field at P=0. If A is assumed to be proportional to $1/T_f^2$ where T_f is the Fermi temperature of the heavy mass state, then these results would suggest that the highest attained pressure and magnetic field have increased the degeneracy temperature by roughly a factor of 3 to 4 relative to ambient conditions. Indeed, the region over which a T^2 dependence in ρ is observed at 9 T increases from less than 1 K at P=0, to 1.4 K at P=9.9 kbar, and to 2 K at P=19 kbar.

In conclusion, we find strong effects of pressure on the superconducting transition temperature, on the upper critical magnetic field, the resistance, and the magnetoresistance of UBe_{13}. The results suggest the depression of the mass of the heavy electrons with pressure and with magnetic field and the increase in temperature of the regime in which UBe_{13} exhibits Fermi liquid-like effects, notably a quadratic temperature dependence of the resistivity at low temperatures. Finally our results point to an intrinsic, pressure independent, impurity dominated residual resistivity for UBe_{13} of 18 μΩ-cm in the high magnetic field limit.

Acknowledgement

This work was performed under the auspices of the U. S. Department of Energy.

References

1. H. R. Ott, H. Rudigier, Z. Fisk, and J. L. Smith, Phys. Rev. Lett. 50 (1983) 1595.
2. M. B. Maple, J. W. Chen, S. E. Lambert, Z. Fisk, J. L. Smith, H. R. Ott, J. S. Brooks, and M. J. Naughton, Phys. Rev. Lett. 54 (1985) 477.
3. J. L. Smith, Z. Fisk, J. O. Willis, B. Batlogg, and H. R. Ott, J. Appl. Phys. 53 (1984) 1996
4. H. R. Ott, H. Rudigier, Z. Fisk, and J. L. Smith, Phys. Rev. B31 (1985) 1651.
5. J. A. Olsen, R. A. Fisher, N. E. Phillips, G. R. Stewart, and A. L. Giorgi, Bull. Am. Phys. Soc. 31 (1986) 648.
6. J. D. Thompson, M. W. McElfresh, J. O. Willis, Z. Fisk, J. L. Smith, and M. B. Maple, Bull. Am. Phys. Soc. 31 (1986) 445.
7. G. Remenyi, D. Jaccard, J. Floquet, A. Briggs, Z. Fisk, J. L. Smith, and H. R. Ott, submitted to J. de Physique.
8. J. W. Chen, S. E. Lambert, M. B. Maple, Z. Fisk, J. L. Smith, and H. R. Ott, Proc. 17th Int. Conf. on Low Temp. Physics, ed. U. Eckern, A. Schmid, W. Weber, and H. Wuehl (North-Holland, Amsterdam, 1984) p. 325.
9. U. Rauchschwalbe, U. Ahlheim, F. Steglich, D. Rainer, and J. J. M. Franse, Z. Phys. B60 (1985) 379.

Figure Captions

Fig. 1. Resistivity versus temperature for UBe_{13} at zero pressure and at the magnetic field values indicated.

Fig. 2. Resistivity versus temperature for UBe_{13} at 19 kbar and at the magnetic field values indicated.

Fig. 3. Depression of B_{c2}' and T_c with pressure for UBe_{13}. The lines are only a guide to the eye.

Fig. 4. Upper critical magnetic field versus temperature for UBe_{13} at the pressure values indicated. The lines are only a guide to the eye.

Fig. 5. Resistivity versus temperature-squared for UBe_{13} at 19 kbar and at the magnetic field values indicated.

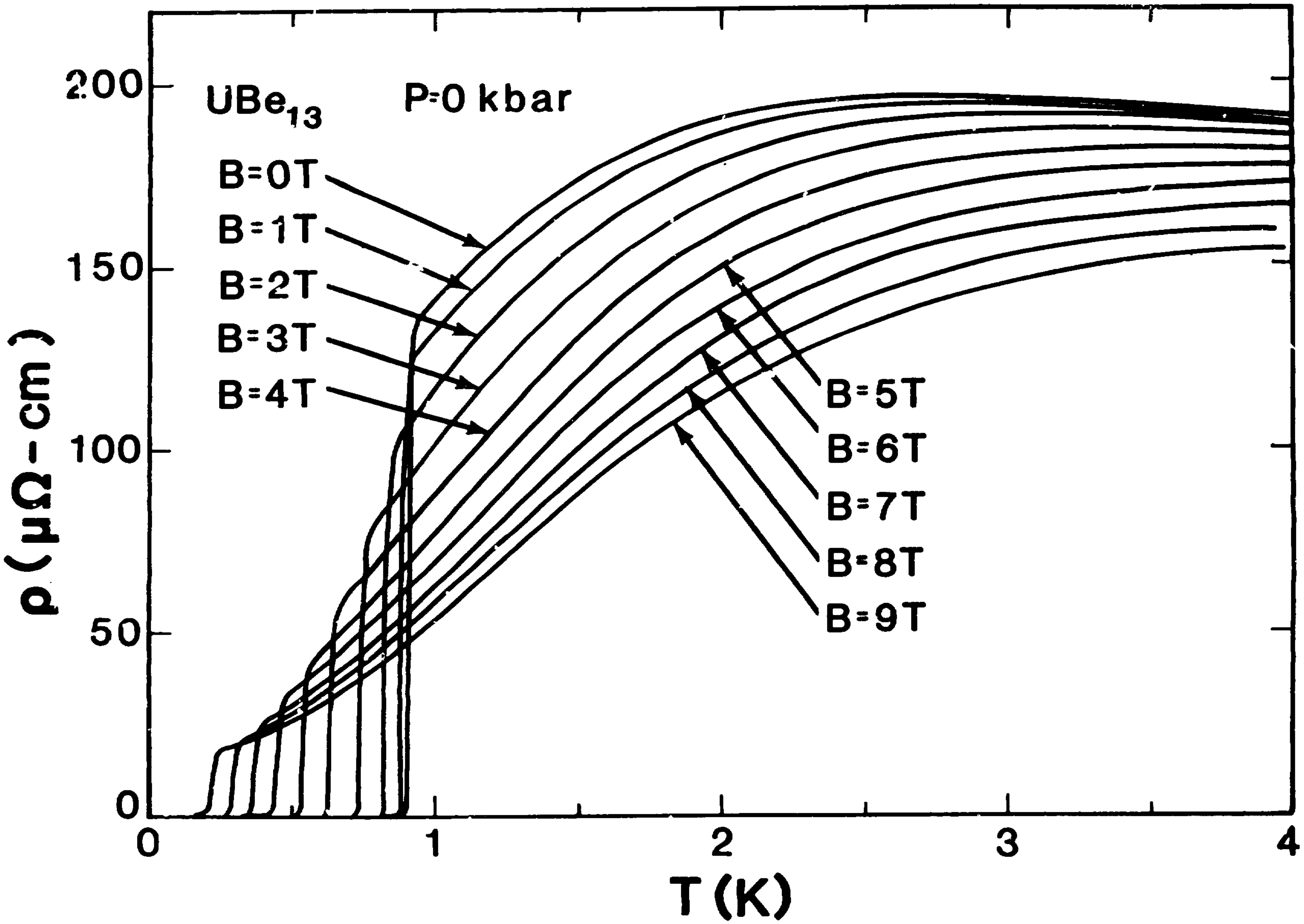

Figure 1
Willis et al.

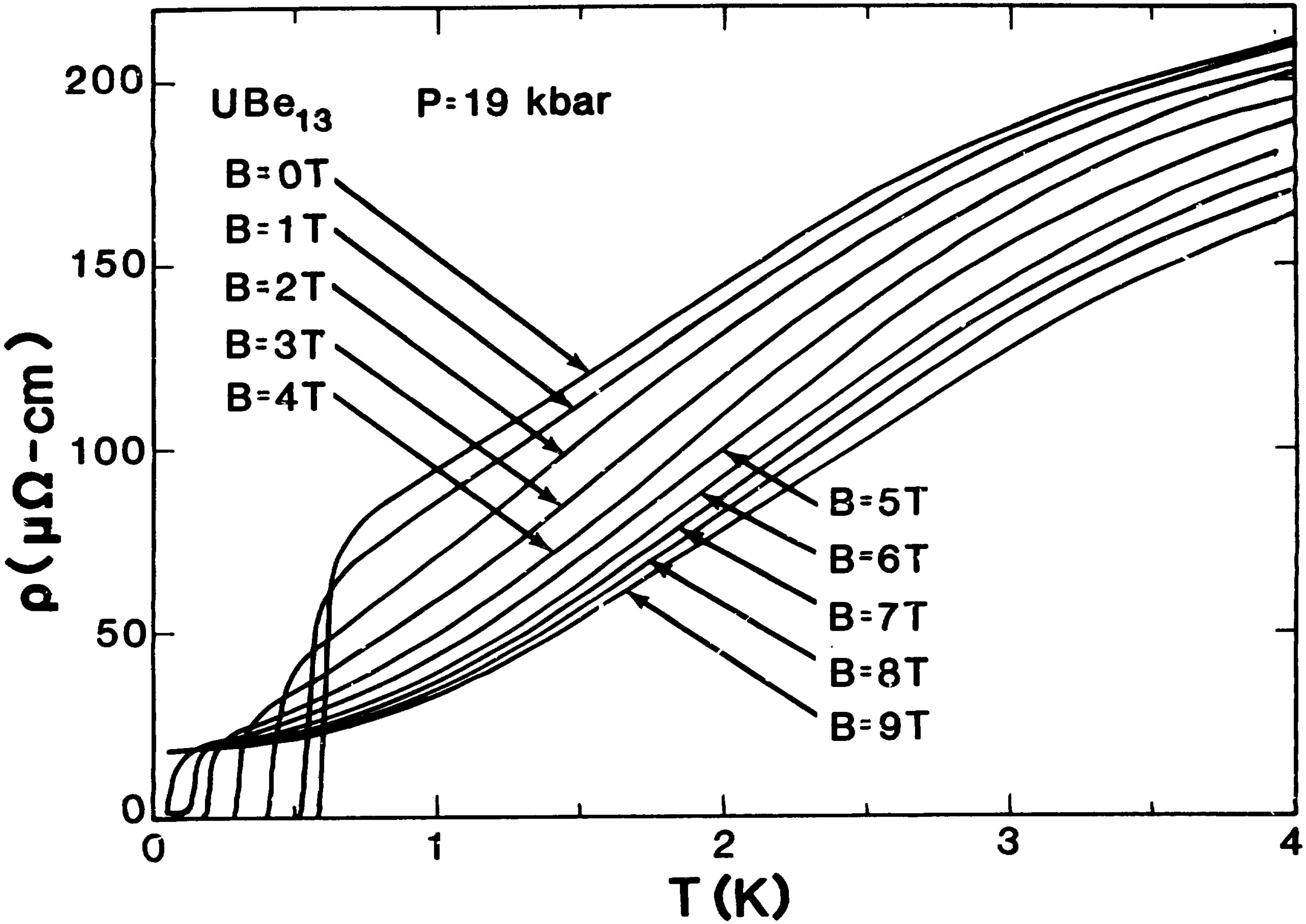

Figure 2
Willis et al.

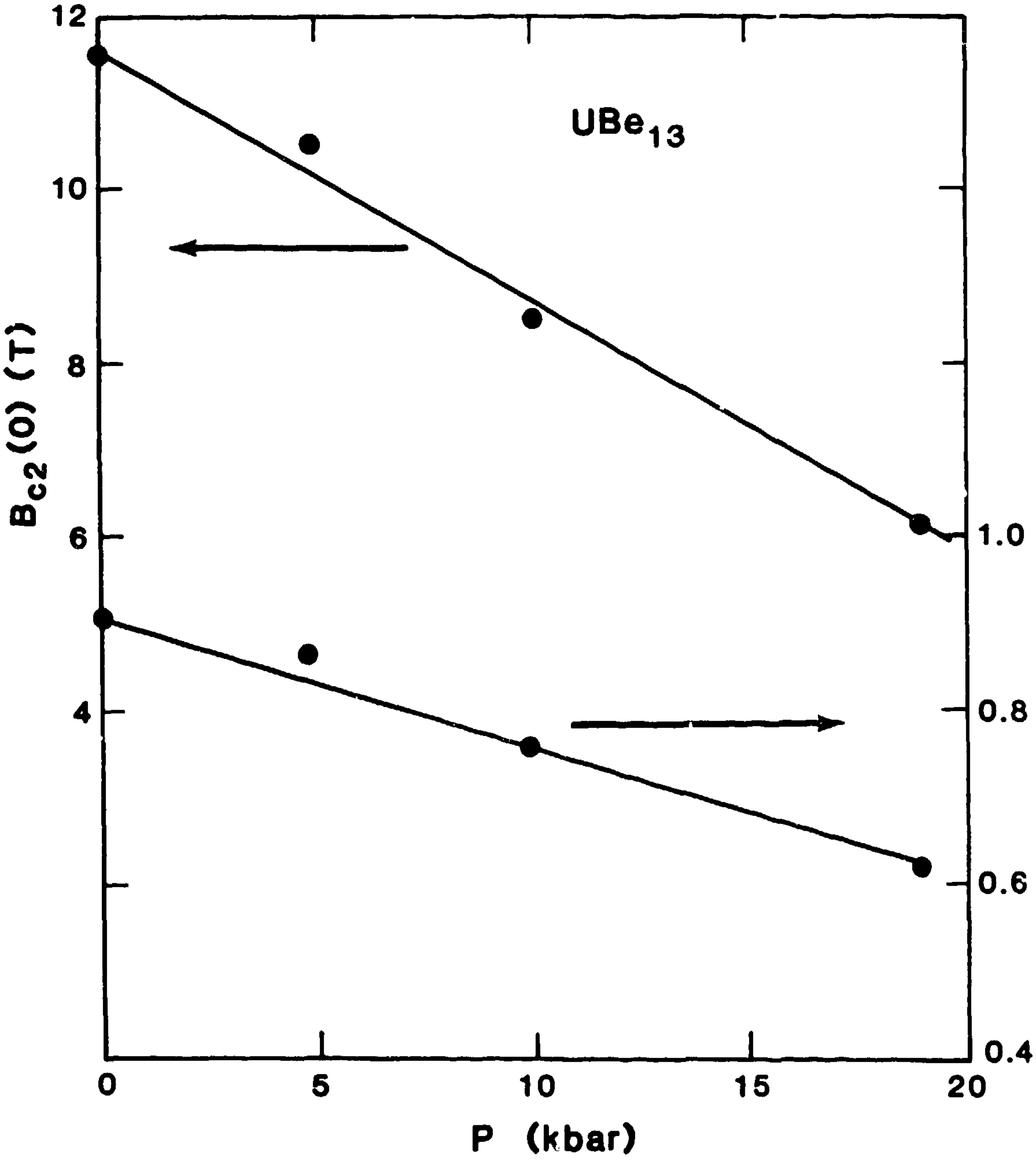

Figure 3
Willis et al.

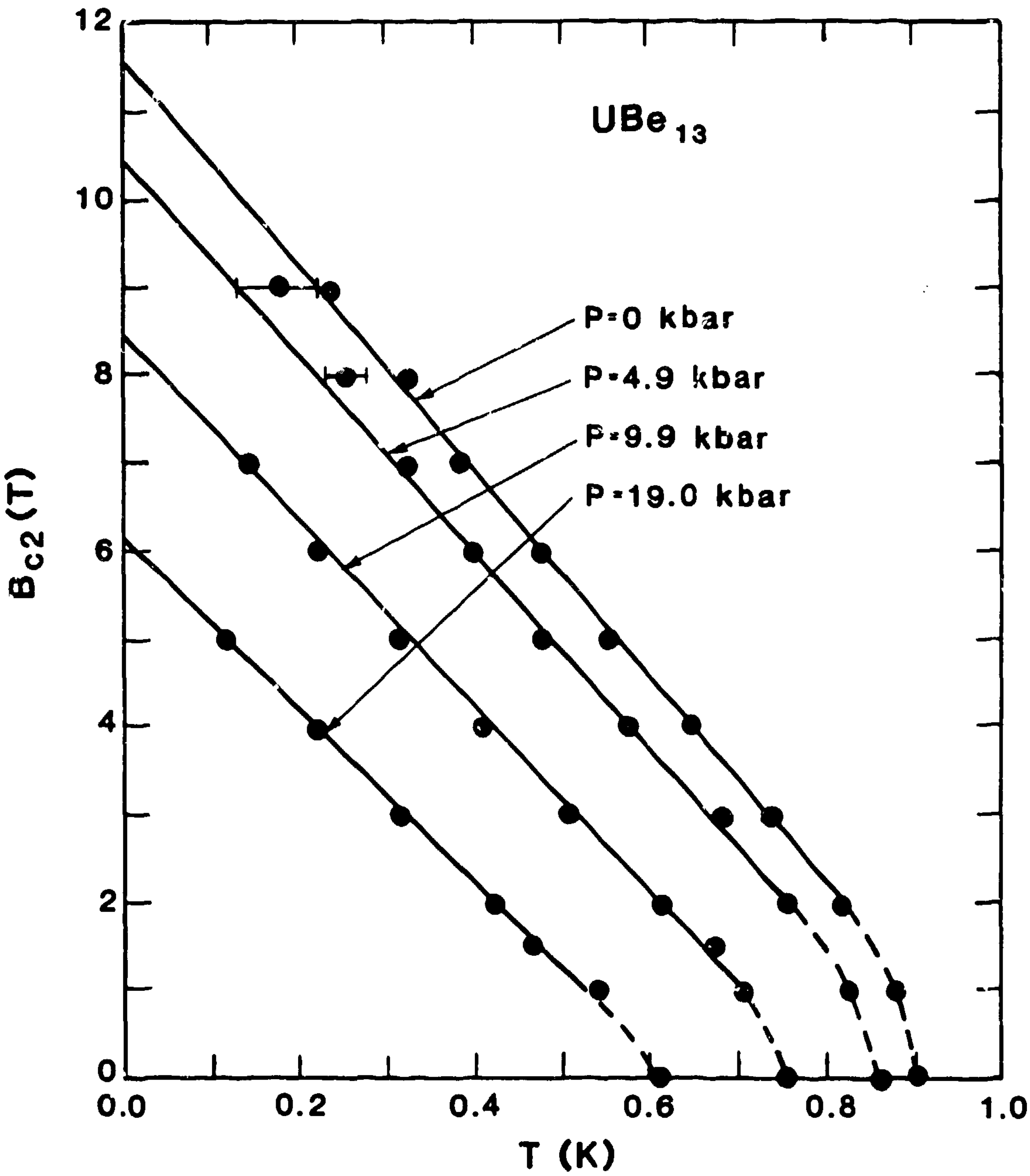

Figure 4

Willis et al.

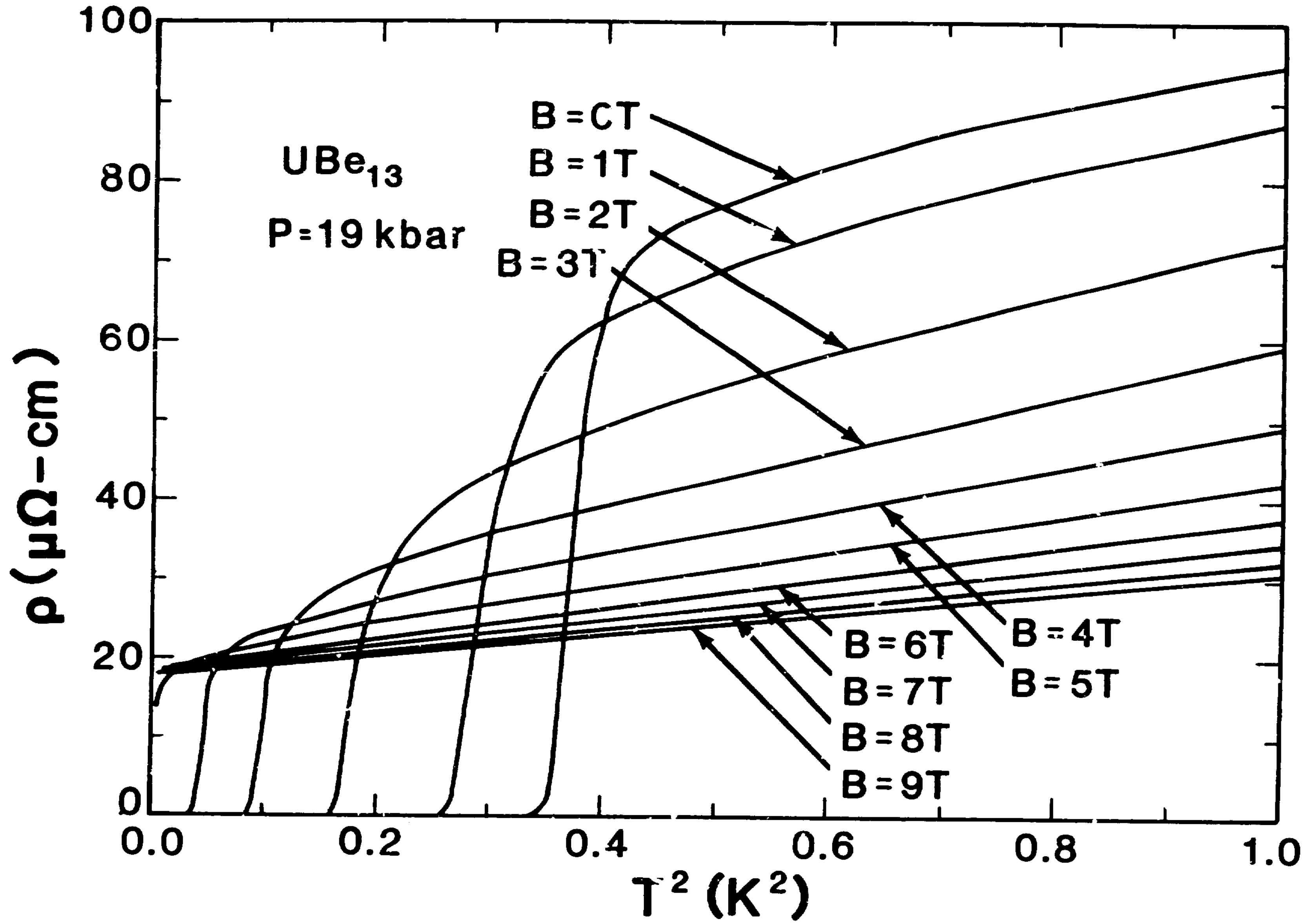

Figure 5
Willis et al.