MAGNETIC BEHAVIOUR OF BASALTS CONTAINING VERY FINE SINGLE DOMAIN GRAINS

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INTRODUCTION

FROM several different types of studies[1-3] carried out in the past few years, it has been established that many basalts contain magnetite or titanomagnetite in the form of single domain grains. Some basalts show low field hysteresis loops, also called Rayleigh loops[4] and this has been attributed[5,6] to the presence of fine single domain grains which have relaxation times of the order of experimental durations or in other words blocking temperatures just above that of room temperature. The possibility that a few rocks may contain still finer grains which are superparamagnetic at or even below room temperature is there but no attempt to detect these has been made till recently. Since the grain size of the magnetic mineral in basalts can cover a wide range (from the smallest upto a hundred microns) the technique should be able to detect the superparamagnetic particles in the presence of other single and/or multi domain grains. It is well known that big single domain grains can be made to show superparamagnetism at an appropriate elevated temperature or the very fine ones to behave like big ones by cooling. Following the experiments described in the next section, a simplified procedure to detect the presence of superparamagnetic particles in rocks is given.

EXPERIMENTS AND RESULTS

By studying the low field hysteresis, basalts showing wide Rayleigh loops have been separated. These specimens were heated to 100° C. either in an oven or by immersing in boiling water and their Rayleigh loops have been observed at this temperature. Typical examples of the low field hysteresis behaviour of two specimens are given in Fig. 1. It is interesting to note that the specimen K 3 shows much reduced intensity of magnetization and negligible amount of hysteresis (Fig. 1 a II) at 100° C. whereas 708 shows more intensity at the same temperature.

The low field susceptibility *versus* temperature curves, referred to as $k(T)$ curves, in the range 4-175° C. for K 3 and 708 are shown in Fig. 1 a III and b III respectively. These are the single domain (SD) type curves proposed earlier,[3] with k-peaks as 20° C. for K 3 and 135° C. for 708. It can be inferred from the $k(T)$ curves that specimen K 3 contains many grains that are superparamagnetic at room temperature whereas such a state can be obtained for 708 at 135° C.

The values of susceptibility at 25° C. and 100° C. for K 3 are 0·26 and 0·06; the same for 708 are 0·43 and 0·81 (all in units of $\times 10^{-3}$ CGS) respectively. Thus measurement of susceptibility at two different temperatures itself provides a method for isolating basalts that have superparamagnetic particles at about the room temperature.

The hysteresis loops of the specimens in a field of 200 Oe at different temperatures have been studied. The method consisted of cooling the specimen to the desired temperature in a Dewar flask and then quickly transferring it into the specimen holder of the hysteresis loop tracer. The hysteresis loop of the specimen can be photographed within ten seconds from the time it was taken out of the Dewar flask and hence it could be considered that the temperature of the specimen to be almost the same as that when it was in the flask.

A set of hysteresis loops obtained for the specimen K 3 are given in Fig. 2.

DISCUSSION

It is interesting to note that the specimen nearly gets saturated (Fig. 2 a) even in a field of 200 Oe at 25° C. which means that most of the grains have coercive force much less than the applied field. Also the remanence ratio R (ratio of remanent intensity to the saturation value) is considerably less than 0·5 expected for a specimen containing randomly distributed single domain grains.[7] In this case the main obvious reason is the presence of superparamagnetic particles. At − 70° C. the hysteresis loop (Fig. 2 b) quite resembles that of the single domain grains with R value very close to 0·5. As the temperature is lowered to − 150° C. it shows more coercive force which is expected,[8] being 100 Oe (Fig. 2 c) and a

reduced intensity of magnetization which could be due to less number of grains contributing. At − 190° C. the specimen does not show any hysteresis (Fig. 2 d) which can be explained by the fact that almost all the grains would in the apparatus itself. The loops given in Fig. 2 are a few stages chosen to illustrate the hysteresis shown by a specimen containing a mixture of superparamagnetic and single domain particles.
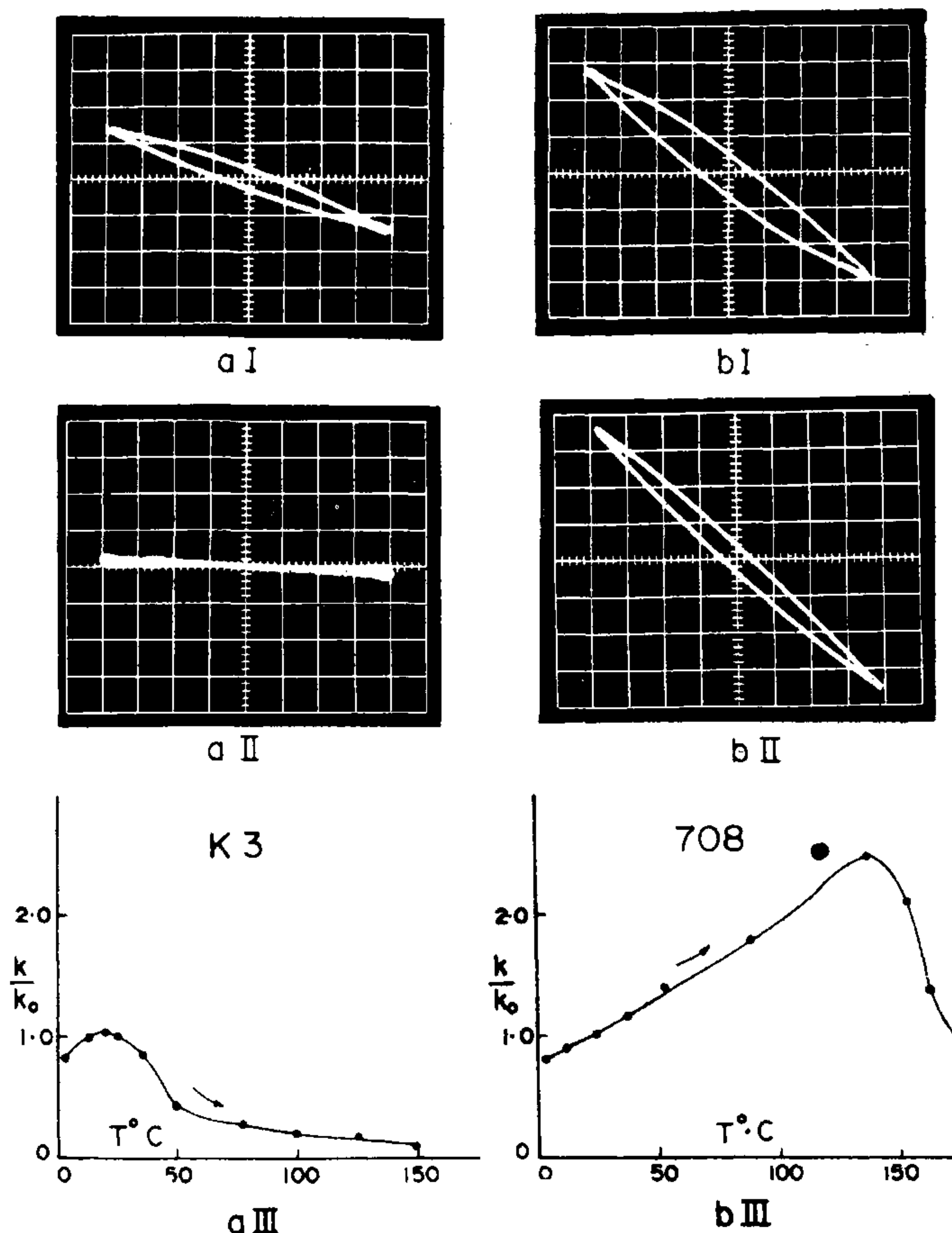

FIG. 1. Rayleigh loops and k (T) curves for two specimens K3 and 708. Scale for a I, b I, a II and b II, X-axis (magnetic field) 1 small division = 0·5 Oe, Y-axis (magnetic moment) 1 S.D. = 0·06 emu.

have coercive force much greater than the applied field of 200 Oe.

A dramatic development of the hysteresis phenomena shown by the specimen can be seen on the oscilloscope screen when it is cooled to − 190° C. and allowed to warm up

The following procedure emerges from the experiments described above :

1. Select rocks showing wide Rayleigh loops (like those in Fig. 1 a I and b I).
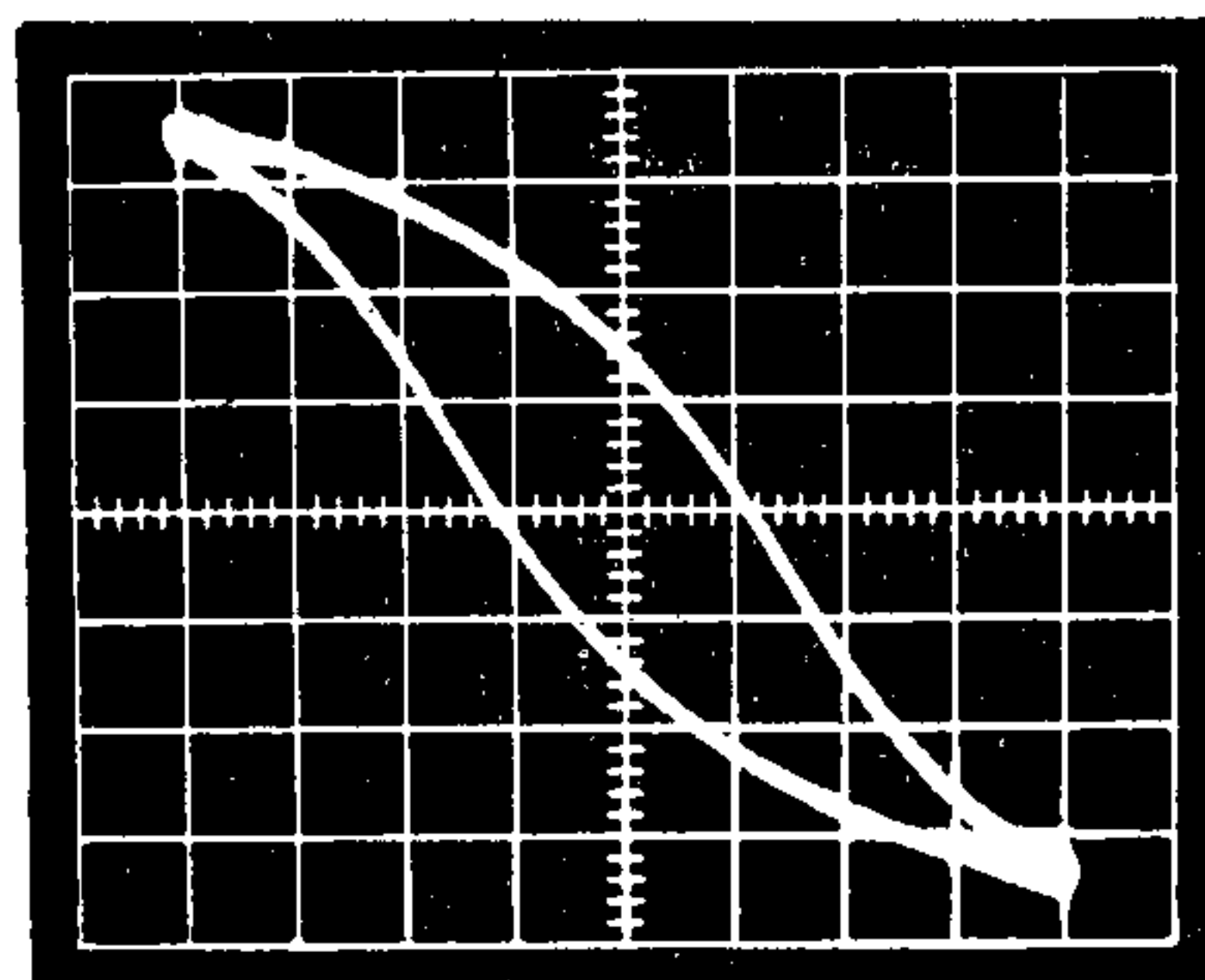2. Study the Rayleigh loops of the specimens at 100° C.

Rocks which show reduced Rayleigh loops (like Fig. *a* II) at 100° C. contain predominently superparamagnetic particles. It may be mentioned here that all the samples showing wide
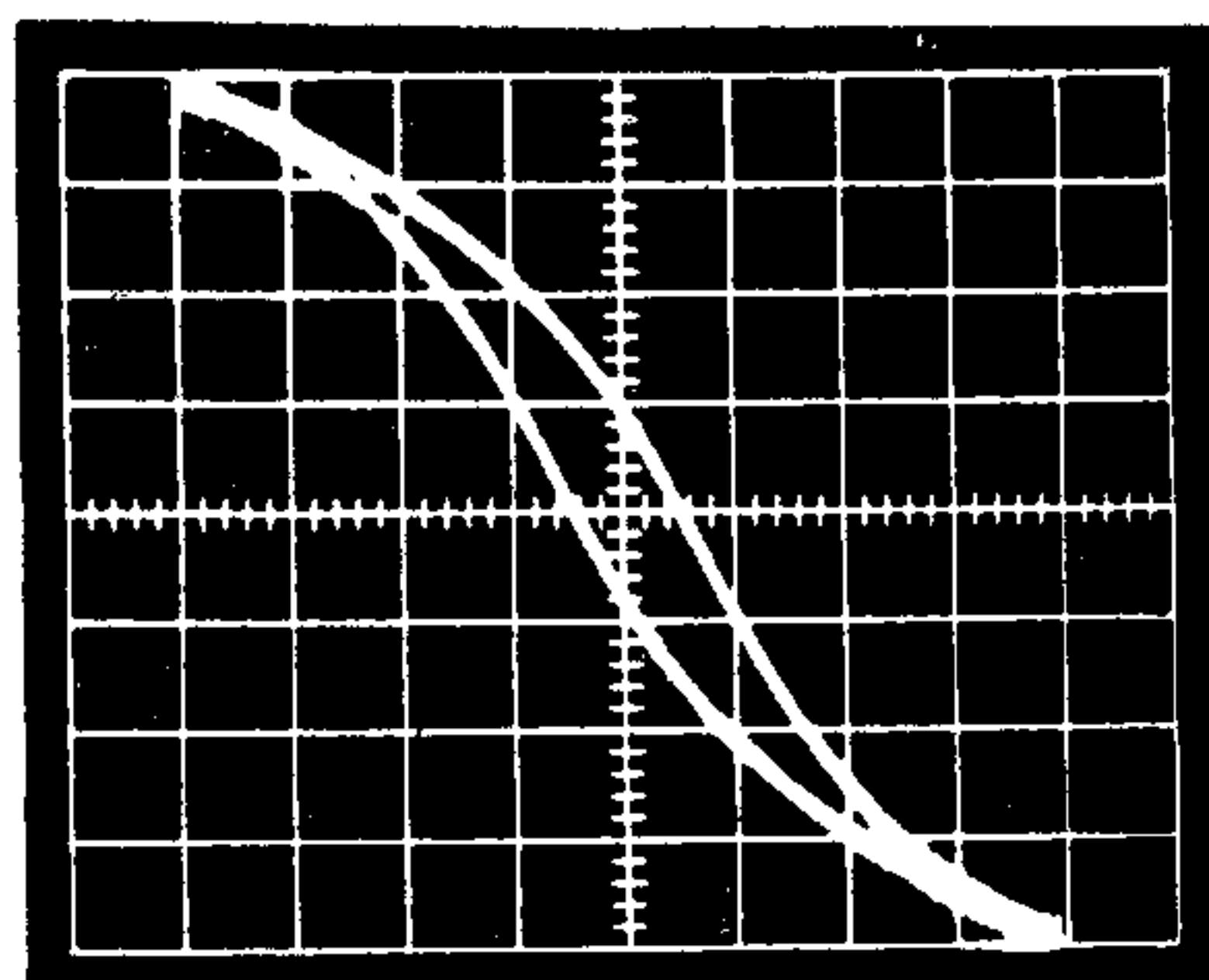
a (25° C)

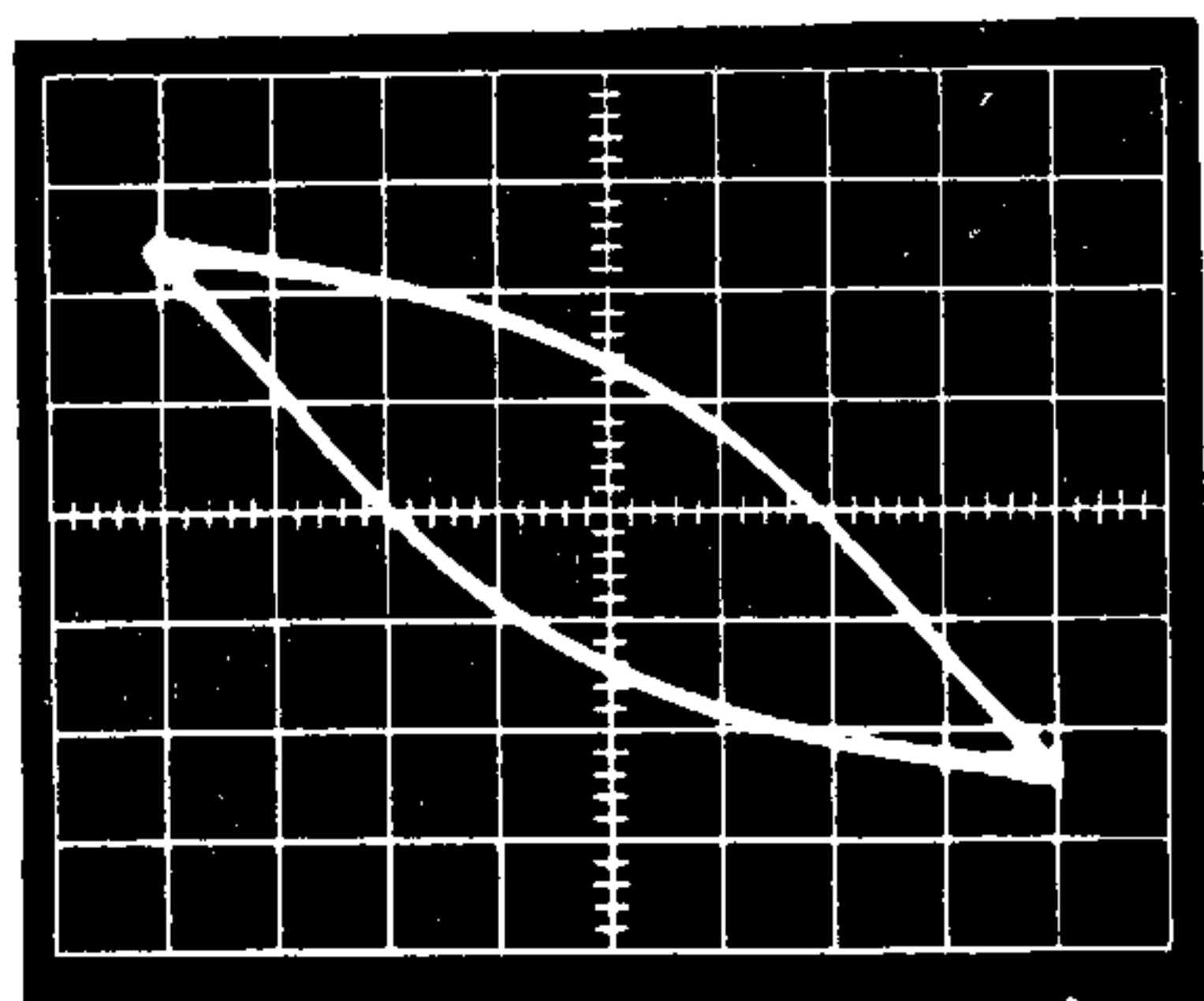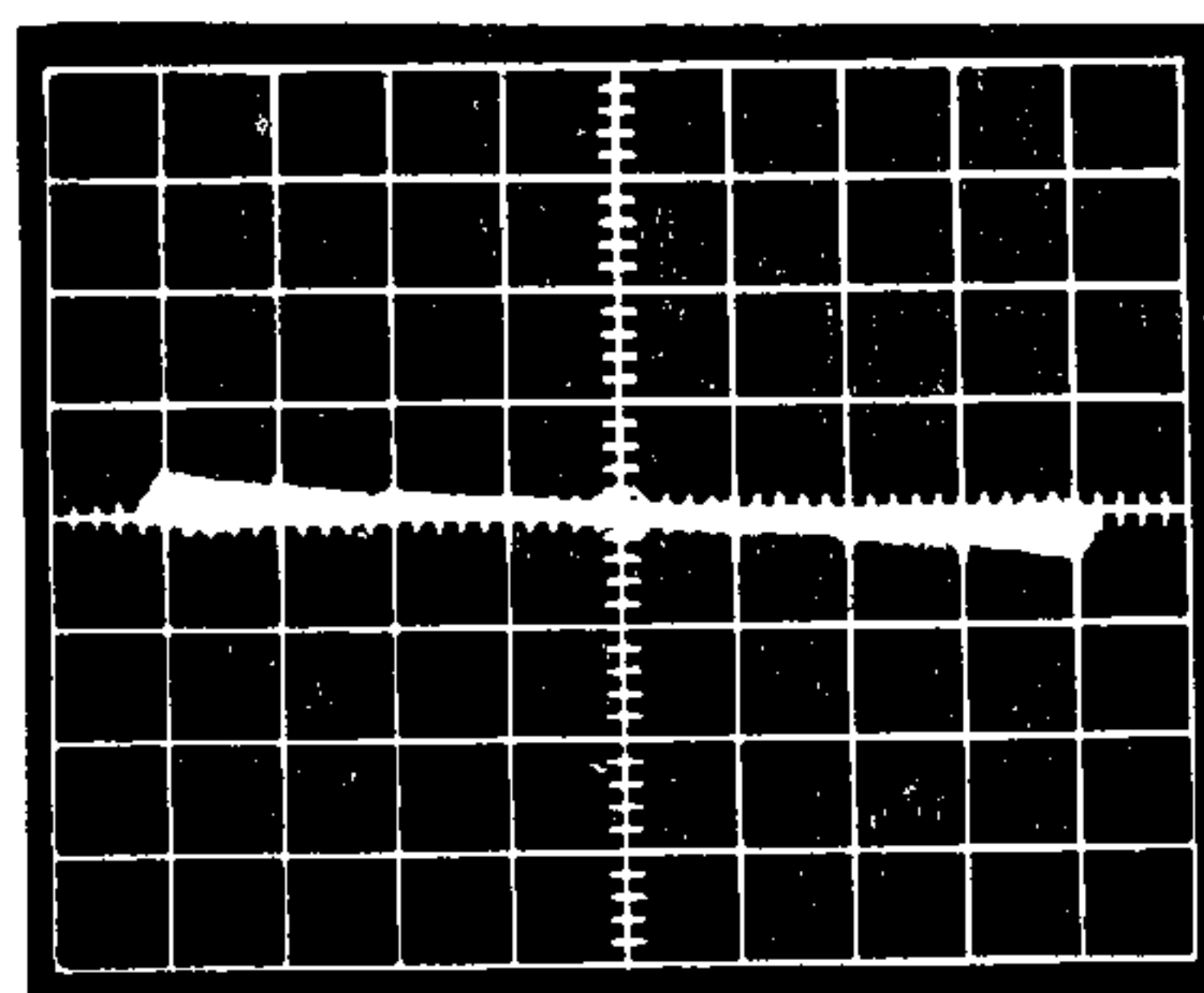b (-70°C)

C (-150° C)

d (-190°C)

FIG. 2. Hysteresis loops of K3 at different temperatures in a field of 200 Oe. Scale X-axis 1 S.D. = 10 Oe, Y-axis 1 S.D. = 0.25 emu.

Rayleigh loops do have some superparamagnetic grains.

CONCLUSIONS

It has been shown that some basaltic rocks c o n t a i n predominently superparamagnetic particles even at room temperature and these can be separated by a few simple experiments.

The hysteresis phenomena shown by a random distribution of single domain grains are dramatically revealed by basalts containing superparamagnetic particles when cooled to different temperatures.

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