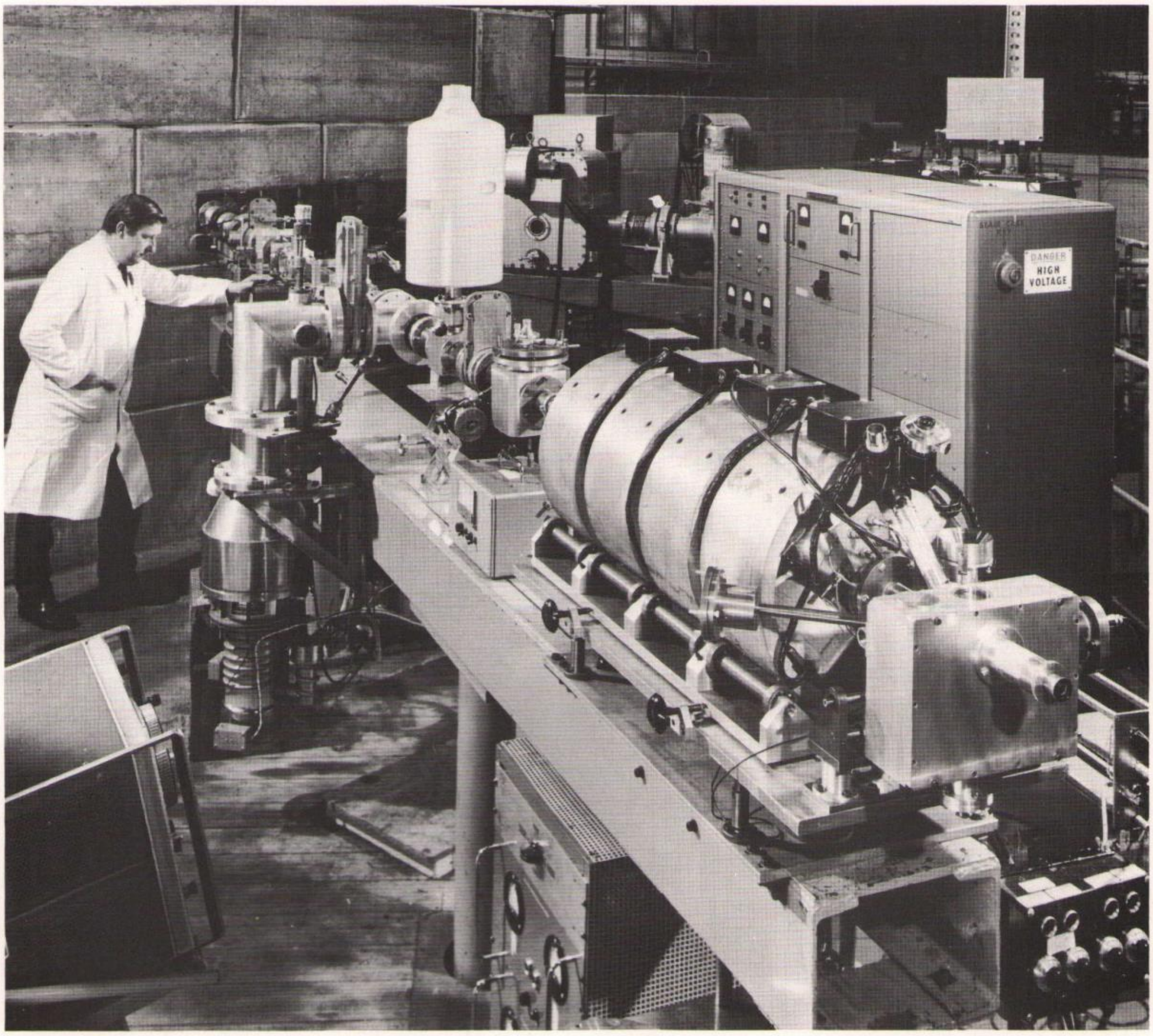
Proton microbeam facility

This is a system which focuses a beam of protons or other ions from the 3 MV IBIS accelerator down to a 4 μm spot size for use in analysis.

The beam of ions travels down the vacuum pipe from the 3 MV accelerator behind the wall. It is collimated by the slit system which the operator is adjusting, and then focused by the four quadrupole lenses to give a 4 μm diameter spot in the target chamber in the foreground.



The proton microbeam facility

The Harwell IBIS 3 MV Van de Graaff accelerator is equipped with this unique facility which gives a **focused** beam of protons, deuterons or alpha particles down to less than 4 μm diameter. The beam from IBIS is collimated by a special slit assembly which provides a rectangular aperture of adjustable size. A set of four high quality magnetic quadrupole lenses arranged as a 'Russian Quadruplet' focuses the beam down to a spot which is an image of the collimator aperture and can be as small as 4 μm square.

The system has a target chamber with a very wide range of facilities which include:

1. Accommodation for two specimens 28·3 mm diameter by 5·8 mm thick as well as a thin quartz for observing the beam spot.
2. Stepping motor movement in three directions.
3. Electrical deflection of up to 800 μm in two directions or TV type scanning over an area 800 μm square.
4. 100X optical microscope to view the bombarded surface.
5. Cold trap to suppress carbon build-up.
6. Surface barrier detector for nuclear particles.
7. A high resolution lithium drifted silicon X-ray detector for multi-element analysis down to ppm sensitivity.
8. Crystal diffraction spectrometer for even better X-ray energy resolution and sensitivity.
9. Sodium Iodide detector for nuclear gamma rays.
10. Lithium-drifted Germanium detector for better resolution with nuclear gamma rays.

Uses of the microbeam

For many specimens the distribution of materials across the surface may be obtained by recording the spectrum of X-rays or nuclear particles and then using either the stepping motor system or a voltage applied to deflector plates to step-on to the next area. However, for heat sensitive materials it is more appropriate to use the deflector plates and power supplies which are available to scan the beam along a line or over a TV-type raster. Appropriate data handling techniques are available for both point by point and continuous scanning.

Because proton bombardment produces characteristic X-rays with very little background it is possible to achieve much greater sensitivity than with conventional electron microprobes. The attainable sensitivity depends strongly on the element being measured, the matrix material, and the positional resolution, but for favourable combinations such as iron in graphite a sensitivity of 1 ppm can readily be achieved.

For light elements ($Z<12$) quantitative analysis using X-ray emission becomes difficult and it is often preferable to detect nuclear reaction products. The wide range of instrumentation in the microbeam system makes it possible to find a reaction which will give good sensitivity for most combinations of light element and matrix material. Fig. 1 shows microbeam measurements of the carbon distribution through a steel specimen. A beam of 1·3 MeV deuterons was scanned point by point across an edge section of the specimen with the yield of protons from the $^{12}C(d,p)$ reaction measured at each point. The positional resolution was about 10 μm and carbon concentration down to 100 ppm could be readily measured. The figure also shows the good agreement between the microbeam results and the technique of machining away successive layers for chemical analysis.

For some specimens, e.g. where there is a low concentration of a heavy component in a lighter matrix, back-scattering of protons or alpha-particles can give a direct depth profile. The microbeam makes it possible to perform this type of analysis at specific locations on the specimen and has obvious applica-

Fig. 1
Measurement of the variation of carbon content across a section of a steel specimen. Results from the proton yield produced by the $^{12}C(d,p)^{13}C$ reaction with a microbeam of 1·3 MeV deuterons are seen to agree very well with chemical analysis.

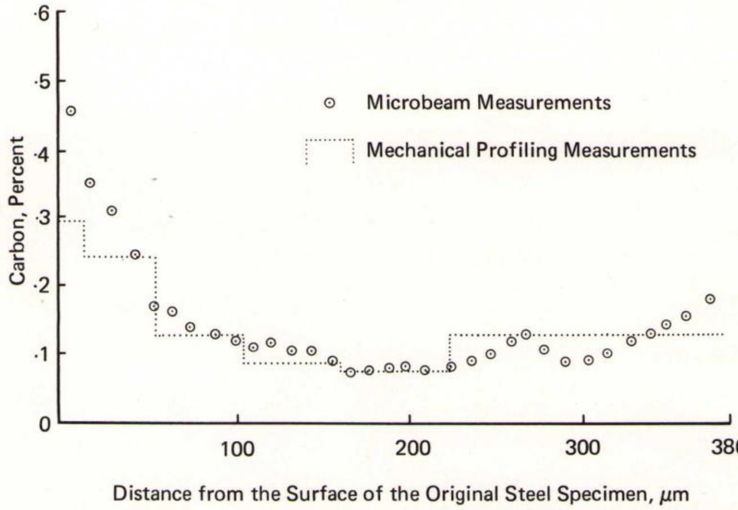
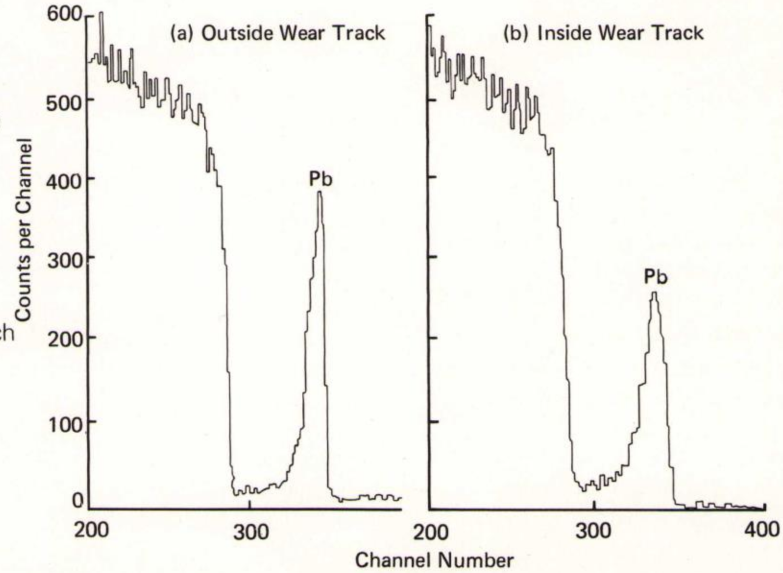


Fig. 2
Back-scattering of 2 MeV alpha-particles from 2 areas of a steel specimen in which lead had been implanted:

(a) region outside a wear track

(b) region of the steel which had been subjected to wear testing.



(uses of the microbeam continued)

tions in the study of semi-conductor devices. A somewhat different application is shown in fig. 2 where lead had been ion implanted into steel and the frictional properties of the resulting surface had been measured. Back-scattering of 2 MeV alpha-particles with a beam spot about 15 μm square was used to compare the lead distribution in an undamaged part of the specimen with that inside the ~ 100 μm wide track left by wear testing.

Specification

Spot size:	From 4 μm square up to 220 μm square (or a rectangle with sides between 4 and 220 μm).
Beam Energy:	1·0 to 3·0 MeV for protons, deuterons and alpha particles.
Beam Current:	26 μa per mm^2 for protons 13 μa per mm^2 for deuterons 10 μa per mm^2 for alphas
Other facilities:	Fully instrumented target chamber. Mechanical and electrical scanning Cold trap.

Enquiries regarding the use of this facility should be made to:

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