An improved technique for producing thin rock-sections.

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Summary. The preparation of thin rock-sections using a modified high-speed surface grinding machine is described. The machine is fitted with a new type of jig designed to hold $\frac{1}{4}$ in. thick glass slides to which the rock slices are mounted for grinding. The machine operates automatically once a cut is set and the large size of the jig enables fifteen 3 in. × 1 in. sections to be produced at one grinding operation without the constant attention of an operator.

SINCE the war the development of high-speed diamond-impregnated cutting wheels and grinding laps has done much to speed up the erstwhile laborious and slow task of preparing thin rock-sections. One of the most important refinements in technique was the introduction of the G.F. 3, a high-speed grinding machine described by Rowland[1] in 1953. With this machine it was possible to grind three sections simultaneously, and more recently jigs holding 6 or 7 specimens have been described (Owen, 1957).[2]

The aim of this paper is to record an improved technique developed at Queen Mary College arising out of the need to use the working time of laboratory technicians to the best advantage by attempting to grind a larger number of sections, automatically, and with greater accuracy than had been achieved hitherto.

The machine chosen for the task was a horizontal-spindle surface grinder of the type used by engineers for grinding flat surfaces on metals to tolerances of the order of ±5 microns (0·0002 in.). Such machines are ideally suited to grinding thin sections and, although relatively expensive when new, can be bought secondhand and in good condition at reasonable cost. The grinder in use at Queen Mary College (fig. 1) was bought secondhand and adapted for 'wet' grinding by fitting a coolant system and pump. The grinding wheel is a 6 in. × $\frac{2}{3}$ in. diamond-impregnated wheel of 120 grade, which revolves at 2500 r.p.m. giving a grinding rate of 4000 surface feet per minute. The amount of cut on these machines is controlled by a wheel that raises and lowers the grinding wheel. The

[1] E. O. Rowland, Min. Mag., 1953, vol. 30, p. 254.
[2] H. G. Owen, Min. Mag., 1957, vol. 31, p. 437.

table to which the jig holding the thin sections is clamped moves always in the same plane, traversing the work beneath the wheel. This movement is automatic; the table reverses at the end of each traverse and a predetermined amount of crossfeed is applied at each point of reversal so that a rectangular area can be ground without attention from an operator. Stops are set so that the machine switches off after completing the grinding operation. The effective working area of the machine is 18 in. $\times$ 6 in., allowing more sections to be ground simultaneously than by previous methods.

The next and in many ways the crucial step was the design of a jig capable of meeting the double demand of increased capacity and increased accuracy. Hitherto, most jigs have relied on the principle of pushing upwards a normal 3 in. $\times$ 1 in. glass micro-slide with a rock slice attached, against metal retaining bars at either end. The problem of making an upward-acting jig over a foot in length and to a tolerance of about 5 microns was clearly insurmountable without extreme practical difficulty, and after some experiments with smaller models, a jig of the type shown in fig. 1 was constructed.

It consists of a cast-iron baseplate to which detachable retaining bars are screwed, the longer of which is bevelled at 45° to take the special glass slides described later. The glass slides are clamped securely in position by movable bars with bevelled edges, sliding on rectangular dowels. Any 'end float' in the row of slides is taken up by the sliding bar working in the slot and operated by a screw and nut (fig. 1). All these parts can be very quickly removed, allowing the upper surface of the baseplate to be ground.

The jig operates by pushing down $\frac{1}{4}$ in. thick glass slides with their shorter edges bevelled at 45° on to the dead flat upper surface of the baseplate, previously ground on the machine itself. It is essential that the upper surface of the jig should be ground in this way. One of the sources of error in a grinding operation lies in the slight, but significant, unevenness of the height of the moving table during a traverse and this is cancelled by grinding the jig top surface on the machine itself. Once fixed in position on the machine and ground, the jig is never moved—to do so would disturb the dead-flat upper surface specific to the unique position of the jig on the machine. It is immediately obvious that, if the required accuracy is to be approached, the thick glass slides must also be of constant thickness and have accurately ground, flat upper surfaces. They were ground with the diamond wheel and are parallel and flat to within 5 microns across both length and width. The fixed and sliding retaining

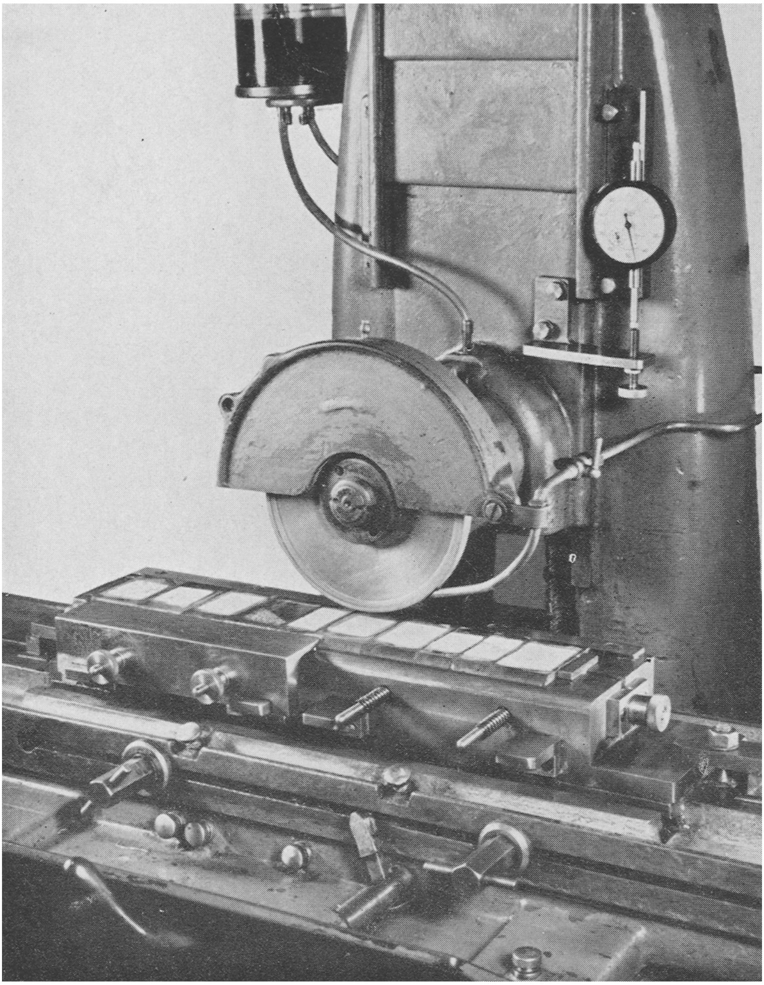

FIG. 1. The jig in position on the grinding machine at the completion of a grinding operation, with one movable clamping bar removed for clarity. Both 3 in. × 1½ in. and 3 in. × 1 in. glass slides are shown, their bevelled edges being clearly visible.

bars are less than ¼ in. thick, allowing the glass slides to project above them so that the entire surface of the glass slides may be ground. This is a marked advantage; with previous jigs the grinding wheel moved between raised retaining clamps at either side, restricting the area that could be ground and making it essential for the grinder to be operated manually so as to avoid the grinding wheel being damaged by accidental contact with the retaining bars.

Early experiments with the new jig made it clear that an accurate method of measuring the distance between the grinding wheel and the upper surface of the glass slides was required and for this purpose a dial gauge graduated in units of 10 microns was fitted to the grinder as shown in fig. 1. This instrument made it apparent that false impressions of thicknesses of rock slices are obtained if the graduations marked on the setting wheel are taken as indicating the amount by which the grinding wheel is raised or lowered. The setting wheel operates a screw thread and, even when new, there is sufficient play in the threads to affect the reading significantly.

The relatively coarse grade of diamond wheel used precluded taking the rock sections down to a thickness approaching 30 microns for the same reason as it is inadvisable to attempt to make a section by hand using coarse carborundum powder throughout. It was found, experimentally, that it was best to grind to a thickness of about 100 microns and then to remove the sections and complete the grinding by hand. In early experiments, this finishing, like the initial polishing of the rock slice, was done on glass plates with most discouraging results: in every case the edges of the section were worn away, leaving a circular fragment of rock which thickened towards its centre. This trouble was soon traced to the fact that when a rock slice is ground on a glass plate, the carborundum powder wears away both the slice and the glass plate, making the latter distinctly concave; the wear takes place very quickly and frequent renewal of the plates did little to remedy the fault. In effect the rock slices were being ground as biconvex disks. In normal slide-making this fault is not apparent because the resilience of the thin 3 in. × 1 in. slide allows it to bend to the contour of the plate and a skilled operator can control very closely the amount of rock removed by the amount of finger pressure applied. A $\frac{1}{4}$ in. glass slide, being rigid, does not bend to the contour of the grinding plate but rests on its outer edges, leaving the centre clear of the concave worn surface of the plate. The result is that when rock sections are ground in this way they are always thicker at the centre than at the edges. This problem has been successfully solved by using rotating cast-iron laps for both the polishing and finishing processes. The laps are checked regularly for flatness and trued up by grinding if any noticeable wear is detected; they have been found to last for months without attention and the $\frac{1}{4}$ in. slides afford an excellent grip in the finishing process. This method is entirely successful.

Where, for teaching purposes, several sections of the same rock are required, it has been found of great advantage to use glass slides measuring 3 in. × $1\frac{1}{2}$ in.; the more usual 3 in. × 1 in. size being kept for single sections such as are required for research purposes. The jig illustrated will hold nine 3 in. × $1\frac{1}{2}$ in. slides and fifteen of the 3 in. × 1 in. variety. An additional advantage of the jig is that it will hold both sizes of slide in any order and is capable of holding slides larger in size than 3 in. × $1\frac{1}{2}$ in. if desired.

Procedure. The following procedure is followed in making teaching sets of thin sections; it applies also to single research sections except for the final mounting stage.

The rock is first sliced and ground to a rectangular shape, so as to cover the upper surface of a 3 in. × $1\frac{1}{2}$ in. × $\frac{1}{4}$ in. slide, leaving a small margin of cement around the slice. One surface is polished on the rotating cast-iron lap and it is then cemented by Lakeside 70 to the glass slide. The technique of grinding a shallow channel in the glass slides was found to be unsatisfactory in practice owing to the fact that the additional thickness of cement in the channelled portion is resilient and results in that part of the section over the channel being ground away in the final stages faster than that on the rigid glass. It has been found that if the flat surface of the slice is pressed firmly against the flat surface of the glass slide with a sliding action and at a hot-plate temperature of 115° C, the layer of cement is thin (30 microns) and of uniform thickness. This is essentially the technique described by Owen (1957).

The undersides of the glass slides are now carefully cleaned with xylene and clamped to the clean upper surface of the jig. The cut is set and the machine started, leaving the technician free to continue with other work whilst the grinding is done automatically. The jig is unloaded when the slices are about 120 microns thick, about three or four grinding cuts being required to reduce slices initially $\frac{1}{8}$ in. to $\frac{3}{16}$ in. thick to this thickness. One such complete traverse across the loaded jig takes about 10 minutes. The slides are next finished by hand on the rotating lap using 3F and 700 grade carborundum powders, this taking an average of 5 to 7 minutes per slide. The accuracy of the surface grinder means that the finished section is the size of the slice, provided the polishing and finishing processes are in the hands of a skilled operator.

Finally, the finished section is painted with a solution of *Durofix* in amyl acetate, cut into four and each part transferred and mounted to a 3 in. × 1 in. slide in the normal way. Thus a jig-load of nine 3 in. × $1\frac{1}{2}$ in.

slides makes 36 normal thin sections. The thick glass slides are cleaned and used again; they last indefinitely.

Using this technique, two technicians can produce 40 finished sections in a day. The slowest processes are cutting, mounting, and remounting the sections. Both technicians using all their time on these tasks cannot keep the grinder fully occupied, it grinds sections faster than it can be fed and much faster than sections can be remounted.

Work is now in hand to speed up the slicing process and to develop a second grinder with a fine-grade wheel. It is hoped to be able to produce finished sections automatically, thus relieving the technicians of the hand finishing process.

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