A RAPID PARALLEL GRINDING MACHINE FOR SERIAL SECTIONING OF FOSSILS

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FOR many years the internal structures of fossils have been investigated by means of orientated serial sections. There are two essential requirements of any machine used for this purpose: the successive surfaces must be parallel and the interval between them must be known and preferably capable of being controlled. Croft (1950) gave a brief historical account of the development of equipment designed for this purpose. In the same paper he gave details of an instrument that he had designed capable of producing ground surfaces at an interval of 10 μ, a considerable improvement in precision over previous machines. Perhaps the most notable advance in equipment for serial sectioning since 1950 is that described by Jefferies, Adams, and Miller (1962), who have successfully designed and produced a machine capable of automatically grinding and producing a photograph of the surface of the specimen every 100 μ.

Problems currently being investigated in the Department of Geology, University of Nottingham, include studies of the variation of internal structures in species of brachiopods and ontogenetic studies of these forms. With the material used, both these projects require a serial sectioning instrument with an accuracy comparable to that of the Croft grinder. A second requisite is that, as in the Croft grinder, the specimen should be readily removable from the instrument to enable an acetate peel to be made of the ground surface. For our purpose the acetate peels have an advantage over other methods of recording the ground surface of the fossil, since in material that has not recrystallized they record the micro-structure of the shell, which itself may provide some information on the ontogenetic history of the various structures, particularly those associated with the cardinalia. Either 'wet' or 'dry' peel techniques can be used. We employ the former as we find it gives better resolution and freedom from bubbles and with the materials used has a speed comparable with that of the 'dry' method.

The projects were initiated using a hand-operated Croft grinder. Manual methods are, however, extremely time-consuming and laborious if much sectioning has to be done. The machine described below was devised in an endeavour to improve the efficiency and speed with which successive peels could be produced and has proved very successful.

Basically the machine consists of a small lathe unit with several attachments. Grinding of the surface of the specimen is accomplished by passing it across the face of a diamond-impregnated cup wheel. The movement and cutting action are similar to that of the larger machine used by Olsen and Whitmore (1944) in their studies of fossil mammals. Their machine, however, was designed for handling relatively large specimens and its standards of accuracy would be unacceptable when dealing with invertebrates, particularly if they were small.

Among the existing relatively low-priced lathes that are available, the small models initially designed for watch-making are well suited for adaption to a serial sectioning

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machine for use with small- and medium-sized invertebrate fossils. They are compact and designed to work to close limits. The machine used was constructed from basic units of the Pultra lathe, obtainable from Smart and Brown (Machine Tools) Ltd., Biggleswade, Beds. The units employed were a lathe bed, chip tray base plate, high-speed head-stock, compound slide rest, and an arbor for holding the cup wheel. The compound slide rest is screw operated, with precision ground threads of 1 mm. pitch. Micrometer collars, adjacent to the handles, are graduated in $\frac{1}{100}$ths of a revolution, each graduation representing a movement of 10 μ.

The 3-inch diameter electrometallic diamond cup wheel, with 240-grade diamond, is mounted on the arbor held in the headstock spindle of the lathe. The machine is Vee-belt driven by a $\frac{1}{2}$ h.p. electric motor mounted beneath the bench, producing a wheel speed of approximately 5,200 r.p.m. Coolant in the form of a soluble cutting fluid (Sternopal) is supplied by drip feed from a can mounted at the rear of the machine, the waste suds running through the lathe bed, down a plastic tube to a large bottle also beneath the working bench. A 'Perspex' guard was formed and mounted round the wheel to reduce spray from the coolant.

The specimen holder consists of a permanent magnet chuck, in this case an 'Eclipse' magnetic positioner from which the 'V' shape on the face away from the wheel was removed. The positioner is screwed on to the tool post block of the lathe. It has a working face of 63·5 × 51 mm.

The specimens are embedded in polyester resin. 'Ceemar' cold-setting resin has been used and found very satisfactory, but extensive tests on other brands have not been carried out and many others may be equally suitable. Small polythene moulds, sold for making ice cubes, make good containers in which to carry out the embedding process, because the resin is adhesive to most common materials except polythene and expands slightly during setting. The embedded specimens are attached by tough wax (obtainable from Cutrock Engineering Co. Ltd.) to mild steel mounting blocks. A number of mounting blocks were made of 6·25 mm. mild steel, both sides being ground to obtain accuracy and maximum holding power. The blocks are all 50 mm. long and of various widths, the actual width of mount used depending on the size of the specimen. The mounting block with specimen fixed can then be readily attached to the magnetic chuck and this switched on. No trouble has been experienced with movement of the specimen on the mounting block or with movement of the block on the magnetic chuck. Care has to be used to keep the working face of the chuck and the back of the mounting block clean if the high precision of the machine is to be utilized.

With the present arrangement of the machine the maximum area it can grind is 50 × 40 mm. and the specimen can be of any length up to 25 mm. It is capable of grinding successive surfaces at a minimum spacing of 10 μ; the grinding time for removal of this increment varies slightly with the size of the specimen and the nature of its matrix, but is in the order of 10–15 seconds. If, as often is the case, larger spacings are required between successive sections, these may be removed in increments of up to 50 μ by successive passes across the diamond wheel.

The cycle for a specimen is as follows. The embedded specimen, attached to its steel block, is fitted to the magnetic chuck while clear of the diamond wheel. Longitudinal and cross feeds are adjusted to bring the specimen block just into contact with the grinding surface of the wheel. The cross feed is wound back and the longitudinal feed advanced not more than 50 μ. Advancing the cross feed now causes the removal of 50 μ from the block surface, this process is repeated until the specimen is exposed. At this stage the block is removed from the chuck and details recorded in the desired manner, the longitudinal feed reading having been noted in readiness for the next grinding operation. After recording the details of the surface of the specimen, it is returned to the chuck, the longitudinal feed then advanced the desired increment between 10 μ and 50 μ over the previous setting and the surface ground as before.

With the 'wet' acetate peel technique used, the longest stage in the preparation is the drying of the acetate solution on the block surface. A solution of 50 per cent. by volume of liquid 'Cerric' DL4013 cellulose acetate and acetone produces a quick-drying film, which with care is free from bubbles. It is necessary to dilute the solution occasionally during use to compensate for the loss of acetone by evaporation. A thin syrupy consistency should be maintained to enable a smooth coat to be brushed on quickly. The drying time can be reduced by using only a very thin layer of acetate solution. The resulting film has little strength, but after its margins have been freed, it may be readily peeled from the block using cellulose adhesive tape ('Scotch' tape or 'Sellotape'). It has been found convenient to process a number of blocks in such a way that the acetate on the earlier ones dries while the following blocks are in turn ground, etched, and coated with acetate solution. Using ten blocks, the acetate on the first may be peeled after the etching and painting of the last is finished, thus a continuous cycle may be maintained by a single operator without having to wait for material to dry. Using the above solution and ten blocks it is possible to produce at least twenty-five peels per hour, which is a very great improvement over any of the hand-operated methods that have been tried. A further advantage is the high degree of cleanliness of the method; it is not necessary after grinding to use more than a paper tissue to dry the block prior to etching.

The total cost of the machine as illustrated (Pl. 20) and described is in the order of £135.

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