Description of an apparatus for preparing thin-sections of rocks.[1]

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[Read November 12, 1912.]

EARLY in the year 1912 extensive modifications were introduced in the apparatus for slitting rocks, and for grinding and polishing thin-sections in the Mineral Department of the British Museum, the whole of the alterations and additions being carried out to my designs by Messrs. Plume[2] and Parry, 47 Old Compton Street, London, W. The changes made were chiefly in the means for holding the specimen or section during the operations; much of the actual machinery remained unaltered, and some of it dates back to the initial installation, upwards of forty years ago. It may not, therefore, be without interest if a brief description of the history of the installation be included with the description of the present apparatus.

That the study of thin-sections was essential for a satisfactory investigation of the structure of substances was recognized almost as soon as microscopes suitable for the purpose were available, but for want of a proper adhesive medium really transparent sections were at first not practicable. It was William Nicol, to whom science owes an immense debt of gratitude for his invention of the prism that bears his name, who devised the process which is in all essentials the same as that practised to-day. He probably made the discovery in 1828, in connexion with his prism, of the valuable properties of Canada balsam, and shortly afterwards applied this resin to the preparation of thin-sections, and found it to give excellent results. Among the earliest sections made by him were a series which were utilized by Henry Thornton Marie Witham[3] in

[1] Communicated by permission of the Trustees of the British Museum.

[2] I much regret to state that Mr. J. A. Plume, the head of the firm, under whose personal supervision the apparatus was constructed, died suddenly on February 15, 1913.

[3] H. T. M. Witham, 'Observations on fossil vegetables,' 1831, Edinburgh, William Blackwood; London, T. Cadell. He acknowledges on p. 4 his indebtedness to Nicol, and on pp. 45–47 gives verbatim the latter's description of the method used. The description is quoted in full in a notice of the book appearing in the Edinburgh Journal of Science, 1831, vol. v, pp. 183–189.

an investigation of the minute internal structure of fossil wood. Henry Clifton Sorby was the first to make use of thin-sections for the study of rocks, in 1849, in the course of an investigation of the microscopical structure of calcareous grit,[1] but the new means of research thus opened out met with little appreciation and much ridicule among geologists, even after the publication, in 1858, of his important paper on the microscopical structure of crystals,[2] and it did not come into general use until about 1870, from which year may be said to date the renaissance of petrology. In his book on 'The Founders of Geology',[3] Sir Archibald Geikie pictures Sorby as realizing the importance of a study of thin-sections after seeing (in 1856) the cabinet of sections belonging to Alexander Bryson, which included all those left by Nicol. As Professor J. W. Judd points out in an obituary notice[4] of Sorby, the latter had, as a matter of fact, commenced making sections several years before. Professor Judd goes on to remark, 'I am not aware, however, that Nicol anywhere claims to have invented the method.' The lapidary's art, of course, goes back far beyond Nicol, and Brewster[5] was studying sections of minerals in 1816; but without the use of Canada balsam as the mounting medium, for which we have to thank Nicol, thin-sections, particularly of rocks in which the component substances vary so much in character, would not have been feasible.

The earliest sections made in the British Museum were those prepared about the year 1860 by M. H. N. Story-Maskelyne, the Keeper of Minerals at that time, in the course of his investigations of the composition and constitution of certain meteorites.[6] These sections, which are still preserved in the Mineral Department, would be accounted somewhat thick if judged by modern standards. They were made without any elaborate apparatus or machinery; fragments or pieces resulting when the specimens were sawn in order to expose a plane surface, which was afterwards polished and etched so as to reveal the character of the structure, were polished and fixed to a piece of thick glass, and rubbed down by hand on a plate until sufficient transparency was obtained. Many of the sections were considerably larger in area than is customary now, and the glass to which they were fixed was much thicker than the slips used to-day. This process was, of course, tedious and laborious,

[1] H. C. Sorby, Quart. Journ. Geol. Soc., 1851, vol. vii, pp. 1–6.
[2] H. C. Sorby, Quart. Journ. Geol. Soc., 1858, vol. xiv, pp. 453–500.
[3] 1st edition, 1897, p. 278; 2nd edition, 1905.
[4] J. W. Judd, Geol. Mag., 1908, vol. v, p. 197.
[5] Sir D. Brewster, Trans. R. Soc. Edinburgh, 1817, vol. viii, p. 371.
[6] M. H. N. Story-Maskelyne, Phil. Trans., 1870, vol. clx, p. 189.

and it had the further disadvantage of entailing great waste of material. It was therefore ultimately decided to acquire suitable lapidary's machinery, and in March, 1870, an installation both for slitting and for grinding was supplied by Messrs. C. & F. Darker, a firm of optical lapidaries and scientific instrument makers, of 9 Paradise Street, Lambeth, London, S.E., now no longer existing. For a few years William Lunan, a lapidary, who had a small shop in Museum Street, Bloomsbury, London, W.C., near the British Museum, and who was not on the Museum staff, was employed to do whatever work was required, but he gave it up in 1874, as he found it to interfere adversely with his own business. By that date it had become evident that the quantity of section work was such that it was desirable the lapidary should be on the permanent staff of the Museum, and accordingly Thomas John William Ryley, who had entered the service of the Trustees in 1872, was appointed lapidary. The work was done at that time under what would seem to us, accustomed to the conveniences of the present day, intolerable difficulties. The workshop was a room in the basement of the old building at Bloomsbury, and was illuminated by such light as was not cut off by a brick wall which was within a few yards of the window, and the top of which was beyond the line of vision from within the room. The precautions against fire would not allow of the use of a flame or artificial light, and every section had to be mounted in a distant room where a spirit lamp was permitted on a slate slab. Upon the transference in 1881 of the Natural History Departments to the building in the Cromwell Road, South Kensington, which had been erected to receive them, the plant was at first placed in a room in the north-east corner of the basement, but the position was not found suitable, mainly owing to the want of proper heating arrangements at that time, and it was shortly afterwards removed to the present lapidary's shop, which was formed by screening off a portion of a corridor near the studies of the Mineral Department in the south-east corner of the basement. Beyond the replacement from time to time of discs, laps, and worn-out parts no change was made in the plant till 1904, when electromotors replaced the machinery for hand-driving in the case of both the slitting and the grinding machines. It was found more convenient to install two separate motors, rather than to attempt to rearrange the apparatus and benches within the narrow space of the shop. Ryley retired in 1911, and was succeeded as lapidary by Thomas Vincent, an attendant in the Mineral Department.

I will first describe the apparatus as it was previous to the recent changes. The slitting machinery itself has not been altered. It consists of a disc, 10 inches (25 cm.) in diameter, mounted on a vertical spindle and driven by a motor under the bench. The disc is held between collars, $3\frac{1}{2}$ inches (9 cm.) in diameter, of which the upper is visible in fig. 1, and the lower is hidden by the disc. They are tightened by the nut *a*. The specimen-holder originally rotated round a vertical spindle, fixed firmly to the bench in about the same position as the present spindle (*b*, fig. 1), by means of a loosely fitting collar, and was maintained at the proper height to suit the work in hand by means of a smaller collar clamped to the spindle. To the short stout arm forming part of the collar of the specimen-holder a long wooden jaw was screwed, the total length from the axis of rotation being about $15\frac{1}{2}$ inches (39·5 cm.). Two screw bolts, square-shaped towards the head, passed through holes in the jaw, which were similarly shaped so as to fit the bolts tightly, and passed also loosely through round holes in the shorter piece of wood forming the other jaw; two wing-nuts riding on the screws tightened the jaws. The specimen-holder was therefore movable round the fixed spindle by means of the loose collar referred to. A weight connected to the end of the arm by means of a piece of string passing over a small pulley-wheel, fitted on the edge of the bench, drew the specimen on to the slitting disc.

The flat face of the small piece cut off from the rock in the manner described was ground smooth on the grinding-lap, the piece being held in the hand, and finished on a brass plate. This face was fixed by means of Canada balsam in the usual way to a microscope glass-slip, 3 by 1 inches and $\frac{1}{16}$ inch thick (76 by 25 by 1·5 mm.), of the kind customary in this country. If the piece were thick, the glass-slip was set in the jaws, and as thin a section as practicable cut from the piece by the slitting disc. Further reduction in the thickness was effected by holding the glass-slip in the fingers and applying the section to the surface of the rotating lap. The surface of the lap was made slightly convex, because it was found by experience that otherwise the edges of the section were ground thinner than the centre, or even possibly worn away altogether. When the section was thin enough the second face was finished off as before on the brass plate, and a small cover-glass was attached with Canada balsam.

When I came to examine the plant in 1911 several obvious defects called for remedy. In the case of the slitting machine, the collar of the specimen-holder had become so worn that it no longer fitted the upright spindle, about which it turned, with even approximate tightness, and at the point of the arm where the specimen was clamped there was over $\frac{1}{2}$ inch (1 cm.) play. The cut was therefore never flat, and it was impossible to maintain uniformity of thickness when slitting the second face of the section; instead, a wedge of irregularly increasing thickness was cut, and a considerable amount of unnecessary grinding entailed. A further difficulty was presented by the way the jaws were tightened. The screw-bolts were not rigidly attached to the longer jaw, and the round holes in the other were more than a little larger than the diameter of the bolts. Consequently, in the final tightening there was a tendency for one jaw to shear with respect to the other, and the glass-slip, if that were being held, became distorted and the Canada balsam loosened, with the result that the piece of rock was flicked off and had to be refixed. The method of using the grinding-lap was very unsatisfactory, the want of a mechanical section-holder being severely felt. The glass-slips used were only $\frac{1}{16}$ inch (1·5 mm.) in thickness, and it was quite impossible in grinding the second face of the section for the lapidary to prevent the tips of his fingers coming into contact with the lap; they were, in consequence, often torn, and the work was at times at a standstill until the lapidary's fingers were healed. Moreover, full use could not be made of the electric power, because at any point beyond moderate speeds the section was inevitably wrenched out of the fingers.

An entirely new specimen-holder was designed for the slitting machine. The apparatus is illustrated in fig. 1, as arranged for cutting the second face of a section. The holder is similar to the old one, but differs from it in several important details. The spindle (b), which is of steel, is no longer rigidly fixed to the bench, but may turn between fixed centres. The bearing surfaces are conically shaped, and to facilitate lubrication at each end the upper cone is pointed, and the lower one recessed. The screw (c) at the top allows of the fit being made as tight as may be desired, while the locking-nut (d) prevents any accidental loosening; should any of the bearing surfaces wear in the course of time it is only necessary to tighten the screw up slightly. The holder consists of two parts—the jaws and a rectangular frame. The latter is attached to the spindle by two collars (e_1, e_2), which are clamped by screws working into a U-shaped groove running the length of the spindle. The frame (f) has two sets of vertical slots, into either of which the tongue of the iron arm carrying the jaws may be fixed by the nut at the back; it is usually placed in the lower set as in fig. 1. A piece of hard wood, which forms one jaw, is screwed to the bar. A pair of screws (g_1, g_2) are tapped and riveted to the arm, at a distance of $5\frac{1}{2}$

inches (14 cm.) apart and at right angles to it. On each rides a nut, $2\frac{1}{2}$ inches (6·5 cm.) in length. Little more than half is visible in fig. 1. One half, in shape a smooth cylinder of $\frac{1}{2}$ inch (13 mm.) diameter, passes into the second jaw, which is drilled with slightly larger holes for the purpose. To prevent distortion the second jaw has an iron frame at the back—not a bar, to save weight. By this arrangement of carrying the second jaw, there is no tendency for it to shear at the moment of tightening. The spindle has been made of ample length, so as to admit

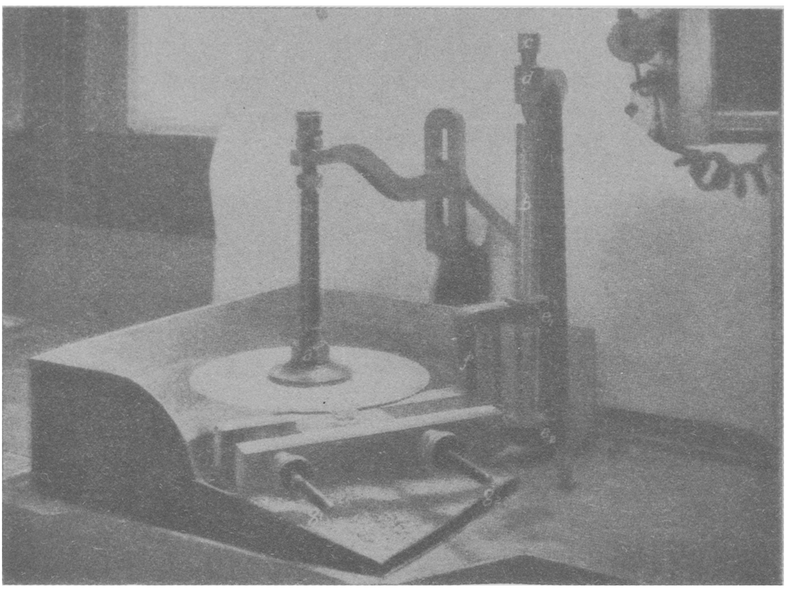

Fig. 1.—Slitting machine in the lapidary's shop in the Mineral Department of the British Museum (Natural History).

of large or awkwardly-shaped rocks being cut, the specimen-holder in such a case being placed above the slitting disc. If so desired, the spindle and the collars of the frame might be threaded so as to permit of successive sections being cut from a specimen at determined intervals. The standard supporting the spindle has underneath a pin which passes through the bench and is held by a nut. At the shoulder above the bench a metal plate is attached. A similar, but loose plate is underneath the bench. In addition to the pin mentioned three bolts connect the two plates so that they grip the bench firmly. The standard is of iron except for the bearing centres and the pin underneath, which are of steel. By packing the upper plate the spindle may be adjusted towards the axis about which the slitting disc turns.

The slitting discs previously used, which were of the slightly conical kind common among lapidaries, were discarded, and plain ones, of sufficient thickness not to bend in the cut, substituted; some difficulty was, however, experienced in obtaining truly plane ones. Soft iron discs which had been tinned held the diamond dust well, and gave

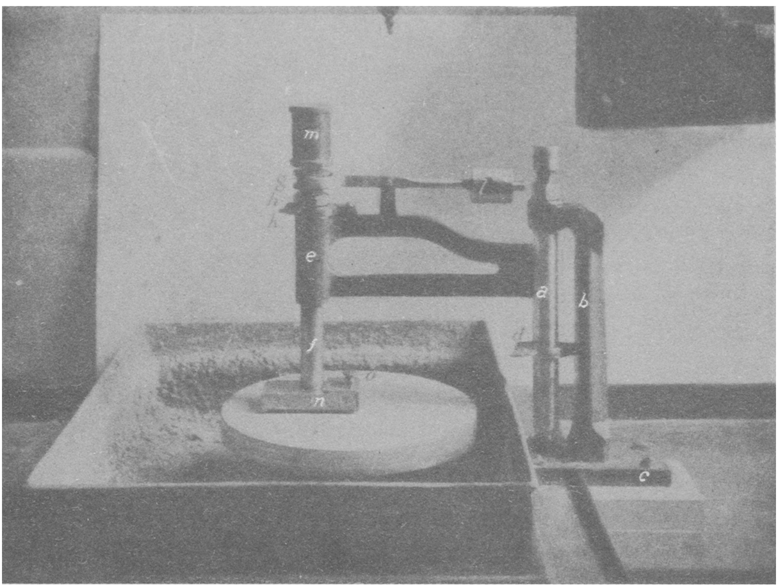

FIG. 2.—Grinding and polishing machine in the lapidary's shop in the Mineral Department of the British Museum (Natural History).

excellent results as long as they did not become distorted. Mild steel discs were tried; they were very flat, but failed to retain the diamond dust. A sufficient number of resistances have been provided in the electric circuit to give a wide range of speeds in the motor to suit the varying kinds of rocks dealt with.

For use with the grinding-lap (fig. 2) a mechanical section-holder has been designed. The spindle (*a*) and the standard (*b*) supporting it are of the same type as those just described, but smaller in dimensions. The latter has no pin underneath it, but is held by four bolts passing through its shoulder-plate (*c*). As before, the spindle may be adjusted towards the axis about which the lap rotates by packing the plate. The heads of the bolts underneath the bench are provided with washers to prevent their being pulled into the wood. A split-ring clamp (*d*) is fitted to the spindle to prevent the arm being carried round by the friction of the lap on the section. An arm (*e*), of gun-metal and about 9 inches (23 cm.) in length, is rigidly attached to the spindle. Its free end is cylindrical in shape, and is drilled with a smooth bore to take a steel tube (*f*), $\frac{7}{8}$ inch (22 mm.) in diameter. The upper part of the tube is threaded, and carries two nuts. The upper one (*g*) has a double flange wide enough to take the rollers fitted on pins on the inner sides of the forked end of the counterpoising lever. The second and lower nut (*h*) may be placed at any desired position to stop further grinding; as soon as it falls on to the top of the arm grinding automatically ceases. A precaution of this kind is desirable, because if the lap were left unattended for a while, the section might be ground away altogether. The clamp (*k*) is used to prevent any undesired rotation of the tube and the section; it is not necessary to tighten it so much as to interfere with its freedom to move up and down within its sleeve. The counterpoising weight (*l*) may be fixed by the screw to be seen in the figure at any point on the thin rod carrying it. The cylindrical box (*m*) at the top is partially filled with lead shot in order to secure sufficient pressure of the section of the grinding-lap. It has a short pin underneath which fits into a cylindrical hole in the tube. The section-holder (*n*) is constructed to take pieces of plate-glass, $3\frac{1}{2}$ by $1\frac{1}{2}$ inches and $\frac{1}{4}$ inch thick (89 by 38 by 6 mm.). It is provided with flanges on the longer, and lips on the shorter sides. At one end the piece carrying the lip may be pulled out far enough to allow the glass plate to be slipped under the other lip. The screw (*o*) holds the movable lip firmly in position. It will be noticed that the plate which the screw grips is slotted, but not cut through to the edge, so that the piece cannot be removed altogether without first removing the screw, and the risk of its accidental loss is minimized. At the back of the section-holder (above in the position of fig. 2) is a pin which fits into the tube, and is held by a screw-clamp (behind the tube and invisible in fig. 2); the pin is flattened where the screw impinges in order to give a better grip. The section-holder is of gun-metal, except for the flanges and lips, which are of brass.

The distance between the axes of the tube and the spindle is 9 inches (23 cm.), and between the axes of the spindles of the lap and the holder $7\frac{1}{4}$ inches (18·5 cm.), so that on turning the arm of the section-holder, the section moves across the lap from one extremity of a diameter to another. It is not desirable to bring the section too near the centre of the lap, because the rate of grinding would vary appreciably over the section. The standard supporting the arm is of such a height that the hand may conveniently rest on the screw on the top of it while regulating by means of the counterpoise the pressure on the lap. By the feel of the counterpoise it is possible to judge if the work is progressing satisfactorily on the face of the section. By depressing the counterpoise the section is immediately brought clear.

The surface of the lap is now plane, and not convex as before. It has a conical pin underneath, which fits into a similar but hollow cone in the spindle, and is pressed tightly home by a wedge-shaped key pushed in transversely. The lap and its fittings have been very accurately constructed, but the surface of the lap is not quite exactly at right angles to the axis about which it rotates. The tube carrying the section-holder may, however, move sufficiently freely within its sleeve to maintain uniformity of grinding during the complete revolution of the lap.

The pieces of plate-glass are used to simplify the manipulation of the sections, because, being thick, they are far more easily dealt with than the ordinary slips. The latter are stuck to the plate-glass with bees-wax or other adhesive material, which melts at a lower temperature than Canada balsam; they are therefore fixed or removed without, if proper precautions are taken not to heat them too much, in any way interfering with the section or softening the Canada balsam.

The slitter cuts so truly flat that the surface of the piece of rock used requires no grinding and only a little rubbing down to finish it, and with ordinary care the section may be cut under $\frac{1}{20}$ inch (1 mm.) thick before grinding. Since high speeds of rotation of the grinding-lap are available a fine grade of carborundum or emery powder may be used, and little rubbing down is afterwards needed.

I was greatly assisted in designing the apparatus by many helpful suggestions made by my colleague, Mr. W. Campbell Smith, M.A., F.G.S., and I desire also to record my indebtedness to Mr. J. A. Plume for the zeal and interest which he displayed in carrying out my ideas.