NOTES ON MALAY METAL-WORK.

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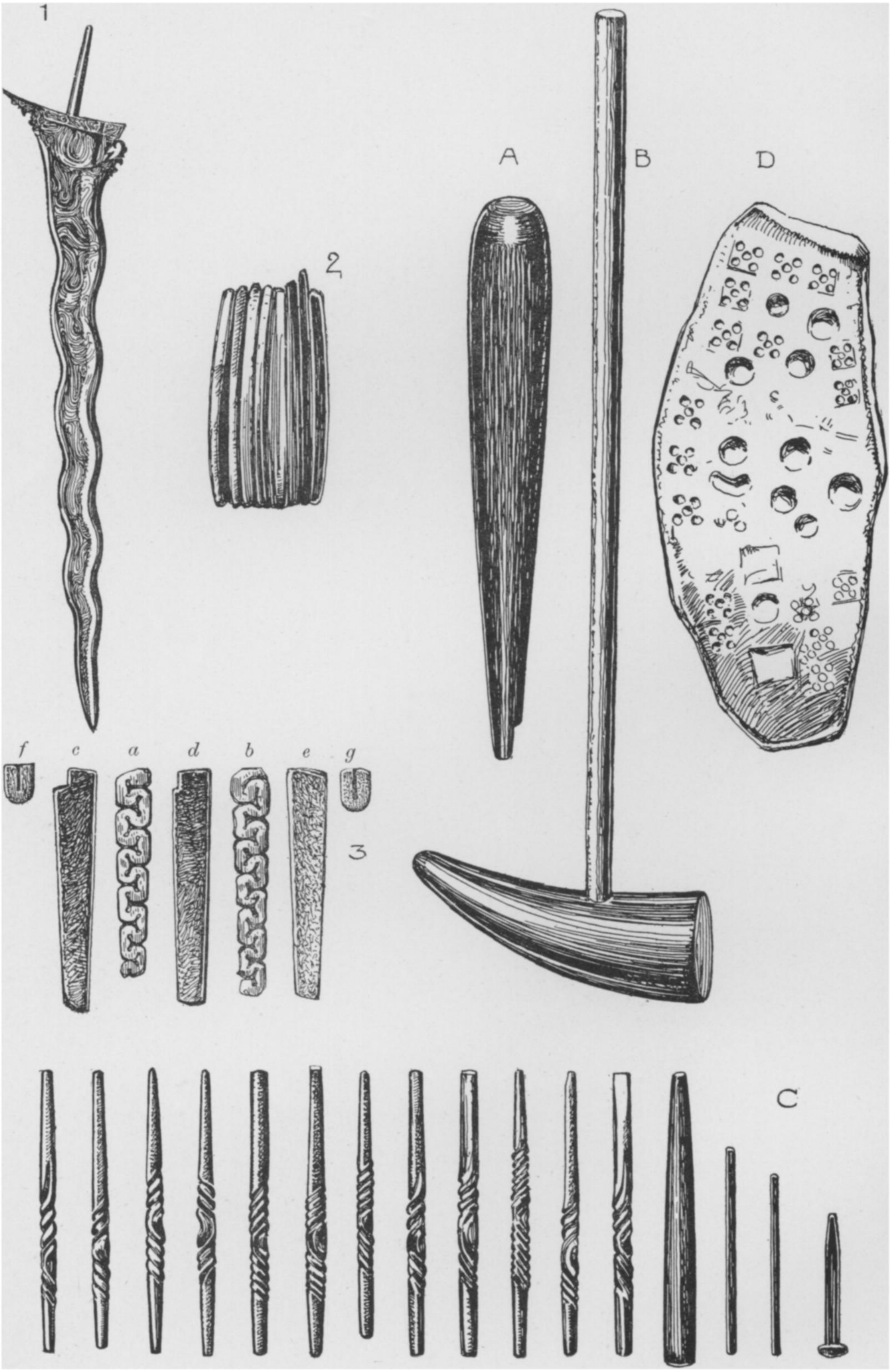
[Presented February 12th, 1901. With Plates X, XI.]

Mr. W. W. Skeat recently asked me to examine a number of specimens of Malay metal-work, in the hope that the use of the microscope would enable me to settle all doubts as to the nature of some of the metals used by the Malays. The present notes embody the results of the microscopic examination but in all other respects are based on Mr. Skeat's account of processes which he has himself witnessed. The experimental work described below was carried out in the Engineering Laboratory at Cambridge by the kind permission of Professor J. A. Ewing, F.R.S.

I. The Making of a Malay Kris.

The most interesting specimen is a damascened Malay *kris*-blade, illustrated in Pl. X, 1, XI, 3. It was made for Mr. Skeat near Trenggānu by a Malay smith who spent four days on the work. The tools of the Malay smith are simple and of somewhat primitive construction, but do not differ very much from those to be found in a European smithy; forge, anvils, hammers, tongs, chisels and files are all in use, but the European "cold and hot setts" used for cutting off pieces of iron are replaced in the Malay smithy by a tool called *lépa*. This is simply a small "cold chisel," but it is fixed in a long wooden handle from which the chisel projects at right-angles, and in use the head of the chisel is struck with a hammer while the handle merely serves to hold it in place. Another peculiar feature of the Malay smithy are the bellows, which are made on the cylinder-and-piston principle.

The Malay smith begins the manufacture of a *kris* by making a pile of short bars, as shown in Pl. X, 2. In this pile it will be seen that the bars are alternately thick and thin, and according to the Malay smith, the thick bars are made of a different metal from that of the thin bars. In fact, one set of bars had been made by cutting up and forging down a rod of wrought-iron obtained, presumably, from Singapore, while the others were made by straightening and drawing down the blade of a weeding-instrument called *krî*. The smith called the wrought-iron *bēsi swē*, while he called the metal of the hoe-blade *bĕsi pāmor*, so that he seems to have regarded them as two different kinds of iron; on the other hand the Malay name for the steel of their tools is *bĕsi bāja*—so that the smith must have known that the hoe-blade he used was not made of the same steel as his tools. The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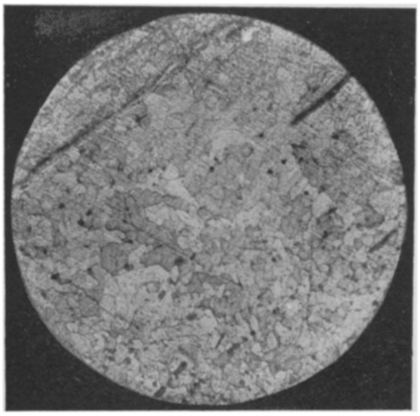

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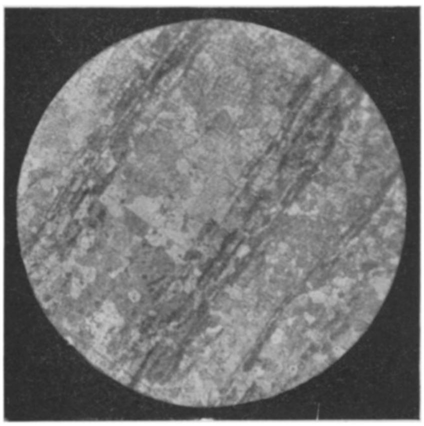

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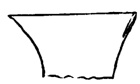

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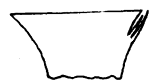

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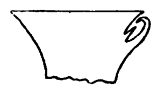

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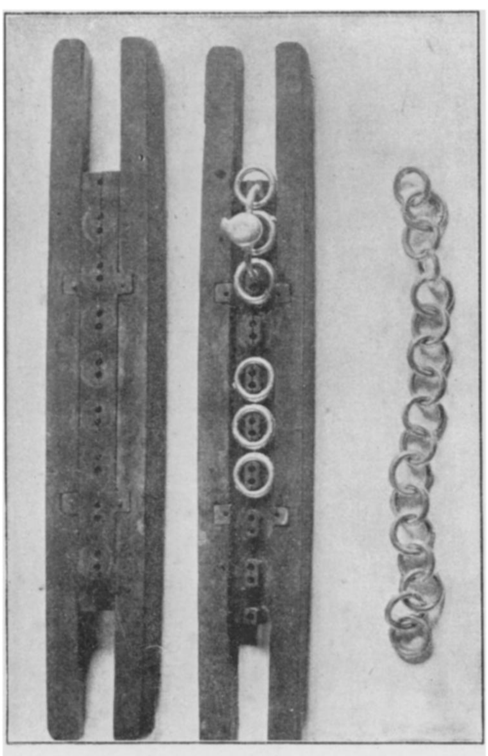

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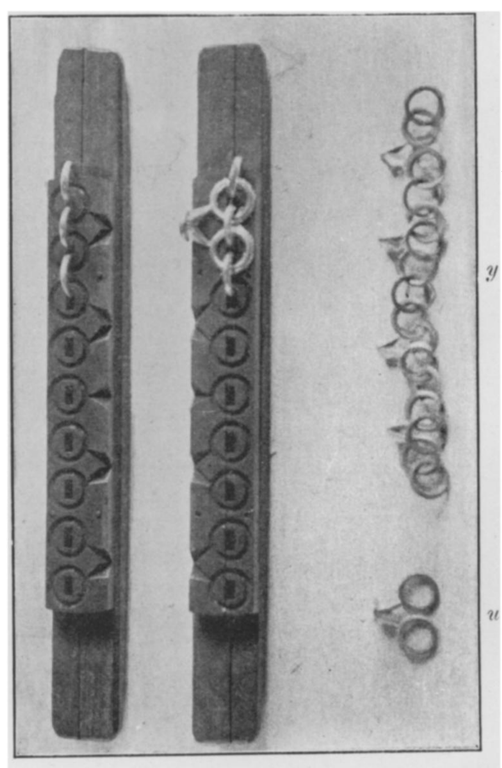

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microscopic examination of specimens of these metals has, I think, settled the question of the nature of the *bĕsi swē* and *bĕsi pāmor* used in Mr. Skeat's specimen.

The pile of nine bars as seen in Pl. X, 2, is then heated, welded together and drawn down to a considerable length; but the welding process is very primitive:—the pile is heated, dipped in water mixed with clay, re-heated, and then hammered together. The long bar so formed is heated again, and is then bent into the form of the scroll seen at (*a*) and (*b*) in Pl. X, 3. It should be remembered, however, that in making this scroll, the long bar is so held that the bending takes place in the plane of the welds, so that, in the scrolls as we see them in Fig. 3, we have nine laminæ standing on edge next to one another, but of course welded together. Two such scrolls are used for each *kris*.

In the next step of the process, *bĕsi bāja*—*i.e.*, steel derived from old tools—is forged into three pieces, shown at (*c*), (*d*) and (*e*) in Fig. 3, corresponding in shape to the two scrolls (*a*) and (*b*). The central layer (*d*) is much thicker than the others and ultimately forms the body of the blade. Finally two small pieces are cut from the laminated bar of which the scrolls have been made, and are bent to form the pieces shown at (*f*) and (*g*) in Fig. 3. The seven pieces shown in Fig. 3 are then welded together, being placed in the order in which they are shown in the figure, the result being a bar having a central layer of tool-steel, with a layer of laminated scroll on either side of it, and that again covered by a thin layer of steel. When this pile has been welded it is forged down to the length and thickness required to give a blade of the desired size. This is done with some care, as the Malays believe that the dimensions of the finished *kris* are of great importance in bringing good luck or misfortune to the wearer.

The "haft" of the *kris* is then formed by notching the edge of the blade close to its base and gradually drawing the portion between the notches down to the form of a thin spike which is intended to enter the hilt. The next step in the making of the *kris* is the production of the waves or sinuosities of the edge. Where these are small and numerous, they are produced by grinding and filing, but where they are fairly long they are made by forging. In this operation the entire blade is bent alternately to one side and then to the other; this is done by supporting its ends upon two anvils and holding it edge up while it is struck with a hammer. But the bending is localised at each successive spot required, by first heating the blade and then cooling it with water, leaving only that part red-hot where the bending is to occur. Each wave thus represents a separate operation of heating and bending.

When the waves are finished, the *kris* is driven into the ground for about two-thirds of its length and thus held firmly while the *dagu* or "chin" of the blade is formed. Two notches are cut in one edge of the blade, the notches are filed out and the small tongues of metal left are then bent as indicated in Pl. XI, where (4), (5) and (6) represent three successive stages of the process.

The blade is then withdrawn from the ground and its cutting edges are roughed out with a file, the blade being held in V-blocks. In this operation the thick central portion of the blade is carefully left untouched. The next step is to heat the haft and twist it in a way which is believed by the Malays to give it a better hold on the hilt. Then the collar or guard is welded on the blade at the haft end. This collar is made of a piece cut off from the end of the blade in the rough state and therefore consists of alternate layers of steel and "laminated scroll The piece is forged to the proper shape, punched to receive the haft, and notched on the under side so as to form a sort of "mortice and tenon" joint with the blade when pushed down upon it. Some indentations are also punched on the sides of this collar and it is claimed that they cause the pattern to appear more clearly at a later stage.

The blade being now completed, is hardened by first heating in the forge and then quenching in water, the temper attained being a mere matter of accident or guess-work. The blade is then ground to its final shape on a grindstone hung in a frame; the stone is driven by a string which is pulled and released in such a way as to alternately wind and unwind itself on the spindle of the stone. When such a grindstone becomes eccentric through wear, the Malay smith "trues" it by turning, much as an English smith would do.

The central portion of the blade has been ground down a little in the last operation, but now the whole blade is filed down and is then ready for "pickling" or etching. The blade is laid in a wooden trough containing a mixture of sulphur, salt and boiling rice-water, some of this mixture being rubbed all over the *kris* with a spatula. The blade is left in this liquid for two or three days, when the damascened pattern appears on the surface, and it only remains to clean the blade with limes.

Two questions arise in connection with this process of *kris*-making:—

What are the metals used, and what is the nature of the action that produces the damask pattern? I hoped that the microscope would enable me to throw some light on these questions, and I accordingly examined sections of metal cut from the layers of the final pile shown at (*d*), (*c*), and (*a*) in Fig. 3. The specimens were cut from the ends of the pieces (*d*), (*c*) and (*a*) respectively, and a surface of each was polished and etched with dilute nitric acid in the manner customary for microscopic examination. As was to be expected, the specimens (*c*) and (*d*) were both found to consist of the same metal, a "high carbon steel" such as is commonly used for tools and cutlery; in the specimen it was in the soft or "annealed" state. In this case the evidence of the microscope bears out exactly the statements of the Malay workman as to the nature of the material.

With specimen (*a*) the result was rather different. From Mr. Skeat's account of its manufacture, from alternate layers of *pāmor* and *swē* iron, I expected a transverse section of the scroll to show alternating bands of two different metals such as wrought-iron and mild steel. The actual section simply shows a series of layers of common wrought-iron, differentiated by no peculiarities of structure or composition, and only marked out by the lines of the very imperfect welds between the layers. The imperfection of these welds is very marked, and is due to the Malay's neglect

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to clean the welding surfaces adequately, and the imperfection of the welds plays a most important part in the formation of the damask pattern. Pl. XI, 1 and 2 are photographs of sections of the laminated scroll, seen under normally reflected light, with a magnification of 80 diameters. The micro-structure is typical of common wrought-iron; some of the black bands seen in the photographs are traces of slag-bands which have been eroded by the acid used in etching; the most marked bands, however, are due to the imperfection of the welds between the laminæ, where oxide and other impurities have been imprisoned.

The microscope then first of all shows that the laminated scroll is made up of layers of one kind of metal only; in this specimen, at any rate, the *bĕsi swē* and the *bĕsi pāmor* of the Malay smith differ only in name. It is of course quite possible that Malay tradition requires the smith to use iron from two different sources although it seems probable that the smith believed he was dealing with two different kinds of metal. It is also just possible that in the specimen I have examined, the scroll was accidentally made of one metal only; but this is unlikely, particularly as I believe the damask pattern can be produced with a scroll made of iron only. According to this view the whole process depends upon the imperfection of the welds between the laminæ of the scroll—an imperfection which is very clearly shown by the microscope. This scroll is placed between two layers of steel and subjected to prolonged hammering at a high temperature, the blows falling edgewise on the welded laminæ. No better treatment could be designed for the purpose of opening the welds and spreading the individual layers, and at the same time driving the steel into the interstices from above and below. At the temperature of working, the steel is softer and more nearly fluid than the iron, and will therefore force its way into any opening that may occur. For the later stages of the process the outer layer of steel is entirely ground away, and the pickling or etching process brings out the pattern by attacking and corroding the steel while leaving the iron untouched. It is a well-known fact that steel can be stained and corroded by many organic substances—such, for instance, as the juice of the liquorice-root—which do not attack iron, and the active element of the Malay's pickling-bath is probably a substance of this kind.

Final confirmation of the correctness of this view could only have been obtained by cutting a section through the finished *kris*, but as this would have destroyed the specimen, I was not able to do it. Careful examination of the pattern on the surface, however, strongly confirms the view stated above; the pattern is seen to consist of bright uncorroded veins of iron, embedded in, and slightly projecting from a matrix of blackened and corroded steel. Taken with the microscopic evidence showing that the scroll consists of one metal only, I think these facts justify the conclusion that this theory of the production of the pattern is correct.

II. MALAY GOLDSMITH'S TOOLS.

The next specimens with which I had to deal were a set of tools and implements used by Malay gold and silversmiths. These, it should be remembered, are used for working purer, and therefore softer, metal than is used in Europe. The Malays melt their gold in very small clay crucibles, on a charcoal fire, in a portable hearth, with bellows attached; but much of their work is wrought—*i.e.*, done by hammering, filing, chiselling and embossing. Some of the more interesting tools are shown in Plate X, A–D. A is a conical piece of hardwood used for forming rings by bending and hammering gold and silver wire. The hammer is shown at B; its head is made of the tip of a bullock's horn. This very light hammer is also used with the set of punches and chisels seen at C. These chisels have a great variety of points and edges, and they are made from a metal which is almost white, with a slight yellow tinge; this metal is also used for making gongs. An analysis shows it to consist of 70·8 per cent. copper and 29·2 per cent. tin; it is thus a hard bronze not very different from speculum-metal. Its microstructure which I have examined, is fairly characteristic of bronzes containing about 30 per cent. of tin; the microstructure further shows that the metal has not been wrought, but cast in its present shape and finished by cutting and filing. The metal has in fact been cast in a chill mould, and is consequently hard but brittle.

Plate X, D, illustrates the slab moulds used by Malay goldsmiths; these moulds bear ornamental impressions into which gold sheet or wire can be hammered or punched. The impressions in the mould itself are produced while the material of the mould is still soft and plastic. According to the Malay account these slabs are made of a substance called *pandang* which is made by boiling a stiff mixture of finely powdered laterite or limonite, "rock rosin," and cocoanut oil. Mr. Skeat's specimen, however, proved on examination to be a slab of practically pure tin. Mr. Skeat supposes that this is an exceptional example and that the Malays as a rule do use *pandang*.

III. VESSELS OF COPPER AND WHITE METAL: *Cera perduta* PROCESS: MALAY LATHE.

Mr. Skeat's specimens further include a number of hollow vessels of copper and white metal. The white metal is called by the Malays "white copper," but it consists of 95 per cent. tin and 5 per cent. copper. These hollow vessels are produced by casting, and the method used by the Malays is similar to the ancient European *cera perduta* process. First, a wax model of the object to be cast is made. The model is then bedded in clay, put on in successive layers alternately with layers of sand. The entire mould when small enough is attached to a stick which serves as a handle; as soon as it is dry the mould is heated and the melted wax is allowed to flow out by a small hole pierced through the clay for that purpose. The mould then contains a cavity of the precise shape of the original wax model, and an article of that shape can be cast by pouring the molten metal in through the hole through which the melted wax had run out. The articles cast in this way have a rough surface which the Malays remove by turning the article in a lathe. The Malay lathe is always a simple affair, and in one form of it the work is made to rotate in alternating directions by means of a cord which is attached to a flexible rod and passes round part of the work on the lathe to a treadle. When the treadle is pressed the string is pulled and the work rotates in one sense while the flexible rod becomes bent; the treadle and cord are then released and the bent rod straightens itself, driving the work in the opposite sense. This appliance has also been in use in Europe.

IV. Chains made by Casting.

Another striking feat in metal-work is the production of chains by casting which is practised by the Malays. These chains are used to weight and strengthen their casting-nets, and they consist of jointless rings about $\frac{3}{4}$ inch in diameter as at *u* in Fig. 8; the material is a fusible alloy of lead and tin. Jointless chains, produced by casting, are made by European and other goldsmiths, but their production by the Malays is evidence of very high development of metallurgical arts, particularly if the ingenious and well-made moulds are of Malay design and workmanship; and this, I have reason to believe, is the case. The mould itself consists of four separate pieces of brass which fit well together; each piece is attached to a wooden handle by means of which it can be attached to its fellows or removed from them. Pl. XI, 7 and 8 show the mould in two positions, with portions of a chain in place. Each length of chain is produced in two stages. First, a set of rings are cast, attached to one another in pairs (*u*), by using the mould as shown at *x*, only without the three loose rings. These pairs of rings are then cut off from the "tags" which hold them together; then the mould is opened as seen in Fig. 7, and the separate rings are inserted into the recesses provided for them, as at *w* (lower part). Their position now, relatively to the other portion of the mould, is shown at *v* in Fig. 8. From this figure it will be seen that if, when with these rings in position, the mould is closed and another cast is made, the new set of attached rings will be linked through those placed in the mould, as at *w* (upper part) in Fig. 7, and at *x* in Fig. 8; the result, when released from the mould, being shown at *y* in Fig. 8. It now only remains to detach the "tags" resulting from the second casting, and the finished chain is obtained as at *z* in Fig. 7. It is obvious that by placing the last ring of one chain in the first recess of the mould when the next chain is being made, successive lengths of chain may be joined up; so that endless chains can readily be made. This process is very simple in practice, so that it is commonly carried out by the Malay women; but the design and workmanship of the mould are proofs of great mechanical skill and ingenuity.