to be incrusted in places: the thin lamellæ are cementite interspersed with ferrite. The ferrite itself appears quite dark (800 diams.).

The metal immediately adjacent to the incrusted skin is more or less regularly hardened. Upon the face of a crystal of iron thus incrusted, etching with picric acid so as to eliminate the rouge reveals a highly coloured, granular, and irregular surface, whereas this surface would be clear, shining,

Fig. 82.—Case hardened steel, hand-polished on dry sulphate rouge, showing independent cementite and ferrite. ×800.

and almost specular but for the previous incrustation. Sometimes the incrusting material is furnished by the abrasion of one of the structural components. An example occurred when a gold-aluminium alloy, containing the purple constituent $AuAl_2$ (Roberts-Austen), was polished on dry rouge. This constituent yields a dust which adheres to the soft constituent (richer in aluminium), and forms almost gilded outlines resembling somewhat the appearance of eutectics.

Fig. 83 (100 diams.) shows a soft steel polished on new and unwashed commercial felt. New felt is

rather greasy, and more or less dusty: the pearlite is fairly well polished in bulk without showing up distinctly, and appears in the form of jagged white patches; the ferrite is generally scratched and slightly incrusted, with the exception of three bands which remain brighter; these are bands due to the rolling, and their crystalline orientation is nearly constant.

This observation shows us that the method by

Fig. 83.—Pearlite and ferrite in dead soft steel. ×100.

incrustation might serve to differentiate not only two constituents of very different hardness, such as ferrite and cementite, but also different grains of the same phase according to their orientation. We have succeeded, in iron and steel, with dry sulphate rouge on washed cotton-velvet by suitably regulating the speed and pressure. If the preparation has received a preliminary polishing in light bas-relief, the reliefs naturally become incrusted before the cavities. Fig. 84 (400 diams.) shows two neighbouring grains of iron, very coarsely crystalline. One of the grains which is in *intaglio* remains white, the other has become

incrusted, with the exception of a Neumann line which was below the surface. The specimen has been

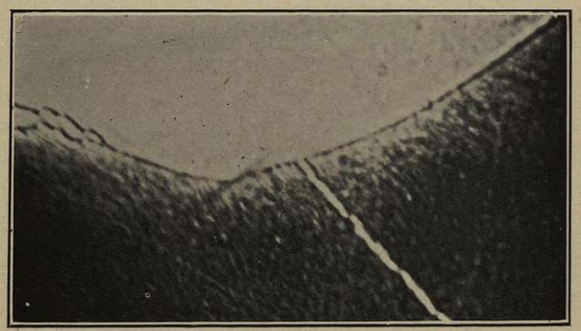

Fig. 84.—Two neighbouring grains of Crystallised Iron, subsequently etched, showing result of incrustation by polishing medium. ×400.

slightly etched with picric acid in alcohol after the incrustation, which serves to intensify the contrasts.

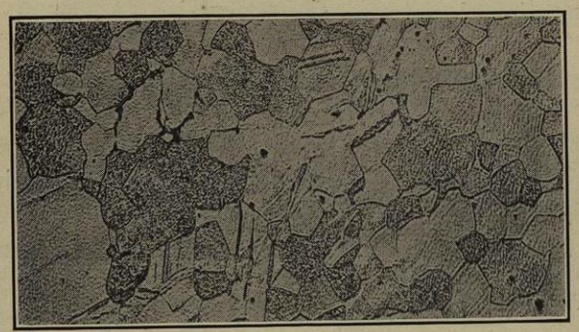

Fig. 85.—Crystallised Iron (Stead), showing differential incrustation revealed by cuprous ammonium chloride etching. ×150.

Dry polishing with rouge produces bas-relief even when no previous polishing has been purposely employed. The chief factor which permits of differentiating the grains is their crystalline orientation with respect to the section.

Each grain wears more or less according to its orientation. As soon as a difference in level occurs, the pressure varies between one grain and another; the incrustation, which is influenced by the pressure and probably also directly by the crystalline orientation, varies at the same time. Finally, a preparation can

Fig. 86.—Pearlite grains in a eutectoid Steel, revealed by dry polishing on rouge. ×400.

be obtained, similar to fig. 85 (150 diams.). This is a photograph of a crystalline iron prepared by Dr Stead, in the middle of a section, where the grain is not so coarse as at the edges. Each grain is differentiated by incrustation just as it would be by etching with the double chloride of copper and ammonium. Neumann lines may also be perceived.

In a eutectoid steel, that is to say, a steel containing about 0·9 per cent. of carbon, made up entirely of pearlite, the grains of pearlite may also be dis-

tinguished from one another by polishing on dry rouge (fig. 86, 400 diams.). As a matter of fact, this method of incrustation is neither the most practical nor accurate means of attaining that end. It is not, however, the less interesting, because it shows a mechanical process competing with a chemical process, and throws some light upon the affinities of two sciences long regarded as radically distinct.

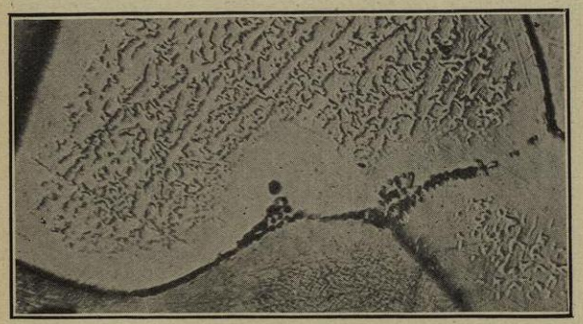

Fig. 87.—Structure revealed by dry-polishing with calcium sulphate. ×400.

In the polishing of iron and steel in bas-relief on parchment moistened with water and sprinkled with white powder — calcium or barium sulphate,— the parchment and powder are coloured, not iron grey, but yellow ochre. The iron removed by polishing is therefore immediately oxidised, possibly by carbonic acid dissolved in the water which is used, and possibly the iron detaches itself in the form of isolated and easily oxidisible particles (fig. 87). In this instance, what parts can be assigned, respectively, to mechanical and to chemical action?

SCALING.

The presence of a hardened layer does not generally give much trouble in the micrographic analysis of alloys. The etching reagent used to bring out the structure dissolves the epidermis and part, at least, of the dermis, if the latter has been reduced to a minimum thickness by careful progressive polishing. The remains of coarse accidental scratches which have left deeper hardened traces do not give much trouble, and it is an easy matter to remove them. It is no longer the same when it is desired to study the internal traces of systematic distortion. Evidently these traces are of the same nature as those which accrue from grinding, grinding being in itself a mode of distortion. The part played by the latter must therefore be entirely eliminated. Hence arises the necessity of a third operation, which we shall call "scaling," and which removes the skin from polished metals.

The operation is very easy, and requires nothing more than a sufficiently strong etching to dissolve the whole thickness of the dermis. Etching of this kind, however, usually causes crystalline corrosion figures following the joints and the contact lines between the various constituents. Finally, a very uneven surface is obtained, full of detail, in which the distortion cracks sought are masked by those of the inherent structure unsought for. It is necessary to dissolve the dermis, and also to preserve the epidermis without creating a fresh dermis by finishing. Success is often difficult in practice, because in reality the grinding and finishing are not so distinct as on paper, and the finishing slightly hardens the sample on its own account. The difficulty increases rapidly, as may

be well understood, in proportion as softer bodies are employed. It is not, however, insurmountable. The superficial dissolution and the reconstruction of an epidermis are two distinct things. They can be effected separately by repeating them as many times as may be necessary, or combined in the joint operation known as polish attack.

In point of sequence polish attack is anterior to alternate polishing and etching in the technique of metallography; but to proceed from the simple to the complex, as clearness of exposition requires, it is logical first to describe the latter and its application.

For iron and steel, Igewsky's reagent, a solution of 5 per cent. of picric acid in absolute alcohol, is more suitable to our ultimate object, because with ferrite it gives more even etching than any other reagent, while it has only a slight tendency to spread to the adjoining crystallographic structure.

There is but little, therefore, to be done in order to remove the small inequalities produced even after protracted and relatively strong etching. This is done by passing the preparation over a cloth surface sprinkled with alumina moistened with water. This treatment does not renew the dermis on iron when the substances to be polished are of good quality and the operation well carried out. By repeating the two processes as often as necessary, the dermis created by grinding can be completely removed. It was by this method that the results published in conjunction with Frémont[1] on the study of internal distortion in iron were obtained. There is greater difficulty with bronzes and, *a fortiori*, with copper.

As stated above, the two operations, polishing and

[1] *Revue de Metallurgie*, January 1905.

etching, may be conducted simultaneously by moistening the cloth with a suitable reagent. It would seem that some advantage would accrue, but the method is exceedingly delicate. According to the concentration of the reagent, the speed, pressure, etc., the etching is either too far in advance of the polishing or *vice versa*. In the first case, the surface is too uneven, and in the second, the dermis renews itself on the soft metals. We therefore incline towards superseding polish-attack by alternate polishing and etching. It is not so elegant a method, but it is safer, and it may be applied, with some modifications, to soft metals such as zinc, tin, and lead.

Finally, the systematic application of scaling has led to a more effectual microscopic study of the distortion of metals.