This was found to make less difference to the final result than that caused by observing the different oppositions.

The results obtained for the position of the pole of Mars are as follows:—

	R.A.	Dec.
Position upon the earth's equator...	315° 32′	54° 51′
Intersection of the Martian equator and Martian ecliptic	85° 56′	24° 32′
Inclination of Martian equator to Martian ecliptic	—	22° 55′

THE STRUCTURE OF METALS.[1]

THE subject of the lecture was the structure of metals, mainly as revealed by the microscope. The first serious application of the microscope to the study of metallic structure was made in 1864 by Dr. H. Sorby, of Sheffield, but the lead then given was not followed for nearly a quarter of a century. In the last fifteen years or so, however, it had been taken up with the greatest zeal and success, nowhere more than in Dr. Sorby's own town. There and elsewhere, in France, Germany, and America, as well as at home, a band of enthusiastic workers had been engaged in creating what might be described as a novel branch of physical science, as interesting on the physical side as it was important in its practical aspect. In this work Cambridge had done its share. The lecturer referred especially to work done in the engineering laboratory by Rosenhain, Humfrey, and other of his own former research students, and to the admirable investigation of alloys carried out by Neville and Heycock in the laboratory of Sidney Sussex College.

It was only possible to give in a single lecture a very brief account of part of this work. Photography had lent its powerful aid in recording what the microscope made visible. By means of lantern slides showing microphotographs of polished and etched metallic surfaces, the lecturer proceeded to exhibit the characteristic structure of a pure or nearly pure metal, where the whole mass is made up of irregular grains with well marked boundaries more or less polygonal in form. The grains could be distinguished from one another not only by the presence of the boundaries, but by differences of texture which were especially conspicuous under oblique lighting. Each grain was a true crystal made up of similarly oriented particles in a perfectly regular tactical arrangement, such as might be exemplified by imagining it to be built up of minute brickbats all of the same form and size. When a polished surface was etched the facets of the elementary brickbats were exposed, and the manner in which these reflected the light into or away from the microscope determined the appearance which the grain presented under oblique illumination. A slight change in the direction of the incident light would greatly affect the brightness of the grain, making it shine out or grow dull, but over each grain there was a uniform degree of brightness due to the uniformity of its tactical formation. Each grain had grown as a crystal, starting from a chance nucleus, and the boundaries were determined by the casual interference of grain with grain in the process of growth. In general, the growth was at first dendritic, skeleton forms shooting out until they met similar growths in neighbouring grains, and the interstices of the skeleton were filled in later. In some metals the grains were products of crystallisation from the liquid state; in others, notably in iron, a re-crystallisation took place long after the metal had solidified, and in such cases the grains, as we knew them under ordinary conditions of temperature, were the result of an internal re-arrangement which took place while the metal was solid. In such cases they were characterised by less regular boundaries, and there was evidence of more intimate interlocking between grain and grain. The structure might be fine or gross; in specially pure metals, and under specially slow conditions of cooling, it was apt to become specially gross. An instance was exhibited of a piece of lead of exceptional purity allowed to solidify by very slow cooling, in which the grains were so large as to be visible to the audience without magnification. Their appearance under oblique lighting was projected on the screen, and by tilting the block of lead the striking changes of brightness due to change in the incidence of the light were exhibited. Other evidences of the crystalline character of the grains were referred to, namely, the pits and geometrical forms developed on the surface by etching, and the geometrical forms assumed by very minute bubbles of gas or air imprisoned in the process of solidification.

Coming next to the consideration of effects of stress, the lecturer described the experiments by which, in conjunction with Mr. Rosenhain, he had demonstrated that the plastic yielding of metals when severely strained is due to a multitude of slips occurring along cleavage planes in the several grains of which the metal is a conglomerate. The appearance of "slip-lines" in various metals was shown, and the character of the lines was discussed. As Rosenhain had recently pointed out, the slip-lines were comparatively straight in grains formed by solidification from the solid (as, for example, in cast lead, silver, and gold), but were broken up into steps which gave them the appearance of being curved in metal which had undergone re-crystallisation while in the solid state. This was ascribed to the more intimate interlocking of the grains in the latter case. That the slips showed themselves by steps or sudden slight changes in the level of the surface was clearly demonstrated when the slip-lines were examined under oblique light. All the parallel slips on a given grain would then flash out simultaneously when the direction of the incident light suited the particular slope of the planes in which the slips had taken place. The form of slips in twin structures was exhibited, and also in an example (due to Humfrey) of lead with a structure so gross that the relation of the slips to the geometry of the grain could be readily traced.

A question of immense practical interest was the "fatigue" which metals underwent when exposed to many repetitions of a straining action. The microscope threw valuable light on this by showing how, under repetition of pulls or pushes or bendings, a piece began to give way, first by slips appearing on isolated grains, and then by some of these slips gradually developing into cracks. Instances were cited from a joint research by the lecturer and Mr. Humfrey. Mr. Rogers, who had pursued this subject with much zeal, had recently found that breakdown by fatigue was much more liable to occur in steel which had been thermally treated in such a manner as to develop a comparatively large structure than in the same steel when the treatment was such as to make the structure normally small.

Going on to speak of alloys, the lecturer described shortly the various ways in which two constituents might combine, or rather act together, in the composition of a binary alloy. In the liquid state each dissolved in the other, in the solid state one might remain wholly or in part dissolved in the other, forming what was called a solid solution. Thus with two constituents A and B, if A were present in small quantity only it might be found wholly contained as a solid solution in B. More generally, however, a solid solution would crystallise out first, leaving a mother liquor richer in A, which, by throwing down more and more solid solution, finally reached the proportion of the "eutectic" alloy, and then solidified as a eutectic mixture, showing under the microscope the zebra-like marking which characterised eutectic alloys. This process was explained by means of freezing-point curves, and was exemplified by a beautiful series of photographs taken by Mr. Stead, showing alloys of various proportional composition in which iron and phosphide of iron were the two constituents. When very little phosphorus was present, the whole solidified as a solid solution showing grains undistinguishable in general appearance from those of a pure metal. With a little more phosphorus the solid still consisted mainly of large grains, but the interstices (or in one case the inner parts of a dendritic skeleton) showed traces of the eutectic, which was the last part to solidify. With more phosphorus still the solid solution showed itself as incomplete skeleton grains interspersed with large quantities of eutectic. With more still the eutectic proportion was reached, and the whole solidified as a eutectic mixture, showing zebra markings all over the surface. With more still—that is to say, with an excess of phosphide—crystals of phosphide were first

[1] Abstract of the Rede lecture delivered before the University of Cambridge, June 11. By J. A. Ewing, LL.D., F.R.S., Hon. Fellow of King's College, Director of Naval Education.

deposited, and the remainder froze as a eutectic in which these crystals were encased. The phosphide crystals showed sharp geometrical outlines, in marked contrast to the outlines of the crystals of solution, because the phosphide was deposited as a definite constituent in which the other constituent (iron) was not soluble.

To explain the zebra markings characteristic of eutectics, Dr. Ewing briefly referred to the phenomenon of surfusion, and gave it as his opinion that the formation of a eutectic occurred by alternate surfusion or supersaturation of each constituent in the other. A eutectic in the fluid state and about to freeze might be defined as a saturated solution of A in B which was at the same time a saturated solution of B in A. On the temperature falling, an alternating condition of instability results. By surfusion, A is at first supersaturated with B, until some of B is thrown down, leaving, in the liquid that remains, B supersaturated with A. Consequently, some of A is in turn thrown down, and so on alternately. In the appearance of a eutectic alloy there was much that was suggestive of alternate deposit of the two constituents, and it was in some such way as this that Dr. Ewing conceived the alternation to take place.

Eutectics in which the constituents were not of the same crystalline system appeared to be mechanically weak. A very small quantity of bismuth added to copper or silver or lead was shown by Arnold to produce great brittleness, owing to the weakness of the cement which the eutectic formed in the joints between the grains, although the individual grains themselves preserved their original malleability. In other eutectics no such weakness, as a rule, was found, and the intergranular cement was as strong as the grains themselves—often, indeed, it was distinctly stronger.

From the engineering point of view, by far the most important alloys were those in which the chief constituents were iron and carbon, or rather iron and carbide of iron. By help of Roozeboom's diagram, the lecturer explained briefly the characteristics of high and low carbon steels, and the transformations which occur in the process of cooling at temperatures far below that at which the metal becomes wholly solid, which had formed the subject of much study by Osmond, Roberts-Austen, and others. By the process of quenching these changes might be to some extent arrested, and the mechanical properties secured which characterise hardened steels. The evolution of heat in the transformation was illustrated by means of cooling curves, and by experiments in which steel wire was allowed to cool after being electrically heated above the transformation points. While passing through the region in which transformation occurs, the steel is specially plastic; this was illustrated in the cooling from bright redness of a steel wire coiled into the form of a spring and carrying a light weight. The spring extended in a conspicuous way while the process of re-crystallisation associated with "recalescence" was going on. The phenomenon of recalescence was further illustrated in an automatic record obtained during the lecture with a Callendar recorder which was exhibited by the Cambridge Instrument Company. The recent results of Carpenter and Keeling, in their research at the National Physical Laboratory, were referred to as giving in most particulars a general confirmation of Roozeboom's views. Other examples of transformation occurring in the solid state were illustrated by photographs selected from Neville and Heycock's series for the copper-tin alloys.

The gradual changes of structure which go on even at atmospheric temperatures in lead and other metals after the structure has been broken up by severe straining were next described, photographs by Rosenhain and the lecturer being exhibited to demonstrate the progressive character of these changes, and the manner in which they would be accelerated by elevating the temperature.

In conclusion, the lecturer referred to the analogous case of glacier ice. It had for long been known to possess a granular structure, and each grain was a crystal just as in the case of metals. Photographs by Principal Skinner, illustrating this granular structure, were shown. In the upper névé the grains were vague and comparatively small; as the glacier slowly travelled down the grains became consolidated and large, and their outlines became well defined. It was clear that a slow process of crystal growth was going on, and in the lecturer's opinion it was to this very process of growth that the plasticity of the glacier as a whole was to be ascribed. How ice came to be plastic in large masses was a question to which physicists had suggested more than one answer. But the plasticity was intelligible enough when one realised that the whole mass was in the act of structural change. Just as the spiral spring in the experiment with steel showed during its transformation a special plasticity, so the glacier showed a general plasticity throughout its course, inasmuch as it was undergoing a slow and probably continuous structural change in the crystallisation of its individual grains. Alike in the metal and the ice, nature was apparently following one structural process, and the consequences as to plasticity were alike in both. In neither case was any constancy to be found save the constancy of change. Nothing was more striking to a worker in this field than the evidence he found that those substances on which we were most accustomed to rely as constant were undergoing, sometimes comparatively fast and sometimes very slowly, a process of internal flux. A monument more enduring than brass might be a lofty ideal, but it was seen at least to be an ideal easy of conception when one realised how far from constant the inner structure of brass and other metals was apt to be.

THE GAS SUPPLY OF THE METROPOLIS.

A committee was appointed by the Board of Trade in January last to inquire and report as to the statutory requirements relating to the illuminating power and purity of the gas supplied by the metropolitan gas companies, and as to the methods now adopted for testing. The report of this committee has now been presented, after hearing evidence from the metropolitan gas referees, from representatives of the London County Council, the Corporation of the City of London, and each of the three gas companies concerned.

The supply of gas in the metropolis being a monopoly, provision is made in the private Acts of the various companies for securing the maintenance of certain standards of purity and illuminating power. Three gas referees are appointed by the Board of Trade, with power to prescribe and certify the situation and number of testing places to be provided, and to lay down the conditions under which the testings are to be made. By the insertion of clauses in recent Acts obtained by the gas companies bearing on the mode of testing, these powers have been somewhat curtailed. The testing places are usually fitted up in houses owned or leased by the gas companies, the tests being made by officials appointed by the controlling authority, either the London County Council or the Corporation of the City of London. A comparison of the tests made at the official stations with tests made with a portable photometer in the neighbourhood of those stations having shown considerable discrepancies, attempts have been made by the controlling authority to legalise the portable photometer, but these attempts have been successfully resisted by the gas companies before Parliament, and the present committee in the report is not prepared to recommend the adoption of such tests. As, however, these results have given rise to doubt as to whether the gas supplied to the testing stations really represents the gas supplied to the public, the gas referees have laid down a requirement that the gas to be tested is to be brought direct from the main to the testing place by a single service pipe, without tap or branch or provision for connection of any kind outside the testing place. This has been strenuously resisted by one of the companies, and has led to the curious result that, although the referees have powers to prescribe testing places, they have no powers to enforce their prescription, and owing to the deadlock thus created two testing places have remained closed for some years.

The committee is of opinion that this requirement is a reasonable one, and that it might with advantage be made a statutory requirement not dependent on the prescription of the gas referees.

In the case of any deficiencies being found by the official examiners, action is taken by the controlling authority before a magistrate, with a view to the recovery of the forfeitures specified in the Acts. If any technical objection is raised by the gas companies, the question is referred to