

seems now to be a fair amount of agreement about many features of this process. For example, it is generally assumed that slip has its origin in Frank-Read sources; it is not now believed that the speed of moving dislocations is great enough for important dynamic effects to occur involving the kinetic energy of a dislocation, and Dr. J. D. Eshelby (Birmingham) presented a new paper on this point. Everyone was agreed on the importance of the fine slip lines (about 10μ long and around 100 A. high) first observed on many metals by Wilsdorf (Pretoria), and that one of the main mechanisms of work-hardening is the elastic interaction between the dislocations which produce this fine slip; this is very much as envisaged in the paper which G. I. Taylor published in 1934. There was much less agreement on the cause of the slip bands which can be seen under the optical microscope and which are much longer. The case of alpha-brass, however, is particularly instructive, and was discussed by Dr. J. C. Fisher (General Electric, Schenectady). Here no fine slip was observed by Wilsdorf, and single crystals of this alloy show very little hardening, at least so long as slip is confined to one set of planes. This shows that the dislocations on neighbouring coarse slip lines are too far away from each other to interact strongly. Fisher's explanation of the absence of fine slip and the conspicuous coarse slip in this alloy is that there is a certain amount of short-range order, which has to be destroyed over a plane when a dislocation moves across it and which therefore hinders its motion. Once a dislocation has moved along a plane, however, others from the same source can follow it under the influence of a much lower stress.

Another mechanism of hardening and also of resistance to flow in annealed metals is the work which must be done to push dislocations past screw dislocations which cut the slip plane. When this occurs, a 'jog' is produced in a dislocation line, and this needs a certain energy. This mechanism of resistance to flow is expected, like the resistance due to locking by impurities, to show a strong dependence on temperature; that due to the elastic interaction of dislocations (G. I. Taylor's mechanism) is not. Cottrell showed some curves giving as a function of temperature σ/G for copper work-hardened at the temperature of liquid air; σ is here the flow stress and G is Young's modulus. This quotient except between 200° and 270° K., is quite independent of the temperature. In this narrow range, however, there is a rapid slope, and Cottrell assumes that here only is this cutting mechanism, which he calls the effect of the 'forest', the one that determines the strength. He also determines from the behaviour in this range the energy of a jog; for copper it is about 4 eV.

It was particularly emphasized by Seeger (Stuttgart) that the jog energy in aluminium is much lower, perhaps 0.5 volt. This is because in face-centred cubic lattices the dislocations split into two half dislocations separated by a stacking fault. At a jog the two halves must be brought together again, and the energy required to do this is the greatest part of the energy of a jog. Now it is characteristic of monovalent metals that the energy of a stacking fault, as of a twin boundary, is very low; there is no contribution from interaction between nearest neighbours, and little from the electrons at the surface of the Fermi distribution due to the fault in the reflecting planes. Therefore the separation between the halves of the dislocation is large, and

the work required to bring them together is large, too. For zinc and aluminium it is much less, thus providing rather convincing evidence that the behaviour of electrons near the boundary of a Brillouin zone does provide a sort of long-range force between atoms that are not nearest neighbours.

According to Seeger, many of the differences between aluminium and copper are to be associated with this large difference in the energy of a jog. Mechanical recovery and polygonization are believed to be dependent on the process known as 'climb', when a dislocation gives off or absorbs vacancies. But it can only do this at jogs, and so, if the jog energy is low, climb and recovery without recrystallization can take place at low temperatures, as is the case for aluminium.

Dr. P. L. Pratt (Birmingham) and Dr. J. C. Fisher (General Electric Company, U.S.A.) emphasized that the dislocation forest is responsible for one kind of 'river line' marking observed on cleaved crystal faces. New river lines begin at places where the advancing crack crosses a region of localized plastic deformation or a low-angle boundary. A crack must develop a step whenever it cuts through a screw dislocation, and elementary river lines thus produced run together to form large steps. The cleavage stress is increased due to the extra surface exposed on these steps. Dr. Fisher mentioned an interesting consequence of this effect. The surface area associated with the river lines increases as r^3 , where r is the radius of a radially expanding crack, and not as r^2 . This upsets the Griffith criterion for a critical crack size. Previous treatments have deduced a critical size by balancing an r^3 elastic energy term against an r^2 surface energy term; but in circumstances where the above r^3 surface term predominates over the r^2 one, there will not be a critical crack size, and cracks of all sizes will grow at the same critical stress.

N. F. MOTT

INTERNATIONAL UNION OF CRYSTALLOGRAPHY THIRD CONGRESS

THE Third Congress of the International Union of Crystallography was held in Paris, at the Sorbonne, during July 21-30 and was attended by more than seven hundred members, representing some twenty different countries, including, it is gratifying to report, the U.S.S.R. This large membership raised several problems, particularly concerning the number of papers offered; these numbered about six hundred and were divided into groups of about ten, which were presented in seven parallel sessions. Since this system would normally give opportunity to members to attend only those sessions in which they were particularly interested, several survey papers were offered in addition. In this way, members were able to keep in touch with progress outside their own particular specialities. Aid in the choice of sessions was given by an 84-page booklet containing résumés of all the papers to be read.

It is naturally impossible, in this account, to deal with the whole of the Congress. Even had it been physically possible for a single person to be present at all the sessions, he could not have been expected to cope adequately with all the mathematics, physics, chemistry, mineralogy, metallurgy, biology and

crystallography that would have been presented to him. The study of crystals is affecting intimately developments in many subjects; but in this article the writer will attempt only to direct attention to what seem to him to be the main lines of advance in the study of the solid state. A large number of papers were concerned with the details of crystal structures; these obviously will have to be ignored.

Crystal-structure Determination

The theory of methods of crystal-structure determination is at an interesting stage. At one time it was thought that, since the relative phases of the scattered beams could not be determined experimentally, it was impossible to devise a direct method of producing an image of a crystal structure. About six years ago, it was shown by D. Harker and J. S. Kasper, of General Electric, U.S.A., that the absence of negative electron density imposes certain conditions which, in some problems, enables the phases to be determined directly. This approach has led to many new ideas, and there is some possibility, according to J. Karle and H. Hauptmann, of the Naval Research Department, Washington, D.C., that a direct solution of *all* centrosymmetrical problems is possible. This view has been challenged by V. Vand and R. Pepinsky, of the Pennsylvania State University, and by M. M. Woolfson and W. Cochran, of Cambridge. It will be interesting to look back in a few years time to see how the subject has developed.

Meanwhile, although direct methods have produced several new structures, the main advances have been made rather by standard methods—Patterson synthesis, isomorphous replacement and 'heavy' atoms. Mrs. D. Hodgkin, of Oxford, described a partial solution of the structure of vitamin B₁₂; the molecule contains about a hundred atoms, almost three times as many as the most complicated molecule that has yet been dealt with successfully. Similar methods combined with the Fourier-transform concept have also enabled Sir Lawrence Bragg and M. F. Perutz, of Cambridge, to report some success with haemoglobin, the molecule of which contains about ten thousand atoms. Unfortunately, the Fourier projection obtained, having a resolution of only 4 Å., is not particularly clear, and some intense study will be required before any reliable deductions can be made from it.

This work illustrates the difficulty of studying such compounds by X-ray diffraction. There is still much rather subjective argument, and more evidence of the Bragg-Perutz type is needed to decide between the individual opinions concerning the nature of the protein structure.

Fine Detail of Structures

As experimental methods have improved, it has been found possible to distinguish more detail in the images of crystal structures. J. M. Robertson, of Glasgow, first showed that hydrogen atoms in organic crystals could be detected, and the difference synthesis of W. Cochran put this work on a sounder footing. Anisotropy of heat motion can also be measured, and further progress should enable electron distribution in bonds to be detected.

Methods other than X-ray diffraction can be used for detecting hydrogen atoms. Electron diffraction has provided some promising results, particularly in the hands of Z. G. Pinsker, of the U.S.S.R.

Low-temperature Studies

Room temperature is rather an arbitrary level at which to take X-ray photographs, and several different laboratories are working intensively on apparatus for cooling crystals to low temperatures. There are several reasons for this work: first, one can investigate compounds which are liquid at room temperature; secondly, there are many phase transitions below room temperature; thirdly, greater accuracy of co-ordinates can be obtained when heat motion is reduced; and finally, more detail for determining crystal structures can be obtained (although this may be regarded as a mixed blessing!). I. Fankuchen, of Brooklyn, gave a summary of methods that have been devised for taking photographs of crystals at liquid-nitrogen temperature. So far, most work has been concerned with the first two headings, but there is promise that the other two will also be developed.

Methods of Computation

Much of the work so far dealt with requires extensive calculations. Punched-card machines have been greatly used; but the greatest development since the last Congress has been in the use of electronic digital computers. In Britain, the most important machines are at Manchester and Cambridge, and work on these machines was reported by D. W. J. Cruickshank, of Leeds, and A. S. Douglas, of Cambridge. The former was chiefly concerned with the determination of fine structural detail, and the latter with direct methods of structure determination.

Diffraction

As more complicated crystals are tackled, the mere process of amassing the diffraction data becomes formidable, particularly now that three-dimensional methods are so much used. Photographic methods can barely cope with the problem, and Geiger counters, coupled to recording apparatus, are becoming increasingly popular. Much ingenuity has been applied to this work, and it is to be hoped that soon some standard form of apparatus will be produced; at present there seems to be a gap between the people devising such apparatus and those who are working out complicated structures.

Neutron Diffraction

Despite the smallness of the number of atomic piles, the results of neutron diffraction are increasing rapidly. Having the experience of X-ray diffraction as a background, the workers in this field have made great progress, both in supplementing X-ray work in, for example, the investigation of superlattices and the detection of hydrogen atoms, and in discovering new phenomena such as antiferromagnetic structures, which cannot be found by X-rays. Most work has been done on powders, but a promising start has been made on single crystals; such crystals have still to be rather large, but it seems likely that rapid progress in the use of much smaller crystals will be made in the future. An instructive account of recent work was given by H. A. Levy, of Oak Ridge.

Crystal Growth

Emphasis on the crystalline state has stimulated work on the way in which crystals grow. F. C. Frank, of Bristol, presented an entertaining film showing the development of spiral growths in

crystals. Many such examples are known, and in some quarters the process is believed to be a general one; there are, however, still some people who believe that it occurs for a few crystals only.

Crystal Imperfections

The existence of growth spirals implies that crystals containing them are imperfect, and indeed it has been known for a long time that perfect crystals would not diffract X-rays in the ways observed. The study of imperfections by means of X-ray diffraction is, however, difficult; it depends upon secondary effects not easy to interpret. B. E. Warren, of Massachusetts Institute of Technology, gave a general account of the investigation of one type of imperfection—order-disorder changes in alloys. These changes may be regarded as producing an imperfection based upon a perfect lattice and so should be easier to consider than imperfections of the lattice itself; much theoretical and experimental work has been done, but Warren maintained that the physical interpretation of the results is still obscure.

The conference gave a general picture of the consolidation of existing methods and rapid development of new ones. There seems to be a thriving future for the subject of crystallography, applied to many different branches of science. Much ingenious apparatus was shown in the accompanying exhibition.

In some ways, however, regret must be felt for the departure of the days when an individual worker could make an X-ray tube, construct a simple diffractometer, buy a set of Fourier strips, and produce contributions of real value to the subject. Nowadays, he appears to need an electronic computer, or at least a punched-card machine, some complicated diffractometers and a Geiger-counter outfit. The only steps in the opposite direction seem to be those which make use of optical analogies, introduced by G. von Eller in Paris and by the writer in Manchester. Crystallography will take its own course; but it will be a pity if it follows nuclear physics as a subject which can be studied only at centres large enough for complicated and expensive apparatus to be available.

A Congress of these dimensions could not have been easy to organize. It would have been better if there had been fewer papers; but granted the necessity for accepting all the papers offered, the organizers are to be congratulated on a most successful outcome of their efforts. H. LIPSON

OBITUARIES

Sir Lewis Fermor, O.B.E., F.R.S.

THE death of Sir Lewis Leigh Fermor on May 24 removes one of the most distinguished geologists who have worked in India during the present century, and his passing at a time when there was still much for him to do is a severe loss to Indian geology.

Fermor was born in London on September 18, 1880. He was educated at Wilson's Grammar School, Camberwell, and was awarded a National Scholarship to the Royal College of Science in 1898. Hoping to secure a post at the Royal Mint, he took his A.R.S.M. in metallurgy. However, at the invitation of Prof. J. W. Judd, he became a student assistant in geology while working for his B.Sc., and it was Judd who

persuaded him to apply for one of three vacancies in the Geological Survey of India before he had completed his B.Sc. course. He was duly appointed in 1902, along with G. E. Pilgrim and J. M. Maclaren, and thus went to India primarily as a trained metallurgist, a fact that undoubtedly influenced the course of his geological work in India.

Soon after his appointment to the Survey, Fermor was deputed by Sir Thomas Holland to report on the manganese ore deposits of the country. Holland never anticipated that the investigation would be so detailed or so prolonged. But the resulting memoir was not published until 1909, and it extended to 1,294 pages. It was by this monumental work that Fermor became best known outside India. It included not only a detailed account of all the deposits, with a discussion on their mode of origin, but also important observations on the methods of mining, in which the pitch of the folded rocks was shown to be an important controlling factor. The field-work had also brought to light six new manganese minerals: hollandite, blanfordite, winchite, vredenbergitte, sitaprite and juddite, while a seventh mineral, fermorite, was afterwards named after him.

On the completion of this work, Fermor was placed in charge of a party deputed to carry out a systematic survey of the Archæan rocks of the Central Provinces, and he himself surveyed a tract of country between Nagpur and Chhindwara, mapping the rocks in a more detailed manner than had ever before been attempted. The work was interrupted by the First World War, when his services were first lent to the Railway Board in connexion with the exploration of the Bokaro-Ramgarh coalfields, and later placed at the disposal of the Indian Munitions Board. In recognition of this work he was made an O.B.E. in 1919. After the War, work in the Central Provinces was resumed, and Fermor's own portion was completed in 1926. Unfortunately, administrative and other duties prevented the publication of this fine piece of work, though a summary of it was given in his later memoir on the correlation of the Archæan rocks of India.

Work of economic importance that Fermor accomplished during the same period included examination of the Singhbhum and Sikkim copper deposits, the iron ores of Ratnagiri and Goa, the Korea coalfield, the chromite deposits of Baluchistan and Singhbhum, and mica in Ajmer and Orissa.

In 1913 he had published a paper on "Garnet as a Geological Barometer". This was the starting point of a theme that was to recur more than once in his writings; for it led him to the conception of an infra-plutonic zone in the earth's crust composed of eclogite, which he considered to be responsible for the explosive nature of deep-focus earthquakes by the exothermic change of garnet to less dense minerals, for isostatic adjustments in the earth's crust, and for the high fluidity of the lavas of fissure eruptions. He also believed that the chondrules of stony meteorites had once been garnets. His views on these matters were elaborated in a series of lectures that he delivered to the Indian Association for the Cultivation of Science as Ripon professor for 1937, entitled "The Role of Garnet in Nature".

Before he retired from India, Fermor began the writing of a memoir that was to be an attempt at correlating the ancient schistose formations of India. After giving a general discussion on the factors to be considered in effecting a correlation, he had planned to give a summarized account of the geology of the