such a publication is produced. The publishers, in a special note, direct attention to these difficulties, and say that the Astronomical Society of France, confident in the triumph of right and of civilisation, pursues, by the publication of this monthly Bulletin, its work of instruction and scientific propagation with untiring energy, and counts on its adherents to forward at once their subscriptions for the current year. The two issues mentioned above contain numerous communications of interest, among which may be mentioned the first observations of the transit of Mercury, an episode in the life of François Arago, an address by Monsieur C. Flammarion, delivered at the annual general meeting of the Society on April 11 of the present year, and a summary by Comte de la Baume Pluvinel, at the same meeting, of recent discoveries in astronomy. The application of selected filters to the study of Comet Delavan is described by Mentore Maggini, being a summary of a research he undertook in the year 1913.

IRON, CARBON, AND PHOSPHORUS.

DR. J. E. STEAD'S knowledge of iron-carbon-phosphorus compounds is so remarkable, and indeed so unique, that the recent meeting of the Iron and Steel Institute in London was rendered memorable by his presentation of a most illuminating paper on this subject. As a matter of fact, the word "paper" is an inadequate description of the publication, which is very composite in character and deals with some ten aspects of the iron-carbon-phosphorus equilibrium; most of them practical, some of them purely scientific.

The constitutional diagram of the iron-carbon-phosphorus alloys is not yet completely known. The studies of Stead, Wüst, and Goerens have established with sufficient accuracy the liquidus fields of that part of the triangular diagram the corners of which are represented by iron, iron phosphide, Fe_3P, and iron carbide, Fe_3C. The compositions of the three "binary eutectics" are known, as is also that of the ternary eutectic, which contains 91·19 per cent. of iron, 1·92 per cent. of carbon, and 6·89 per cent. of phosphorus, and freezes at about 950° C. But, in spite of the fact that the paper under notice contains much new and interesting information about some of the solid phases and their relations between the solidus and the ordinary temperature, we are still without accurate knowledge of the composition of most of them and their variation with varying temperature. The constitutional diagram below the solidus has still, for the most part, to be determined, and until this has been done the interpretation of a good many of Dr. Stead's results can only be provisional.

In some earlier experiments Dr. Stead squeezed a portion of the ternary eutectic out of grey Cleveland iron by pressure. The amount extruded, however, was only a small fraction of the total quantity present, for the mould was not maintained, as it would have had to have been, at a temperature just above the freezing-point of the eutectic. It appears, however, that the requisite temperature and pressure conditions are realised in the formation and very slow cooling of the so-called "blast furnace bears." These are accumulations of grey iron which gradually form underground below the well or crucible of the furnace, and sometimes attain an enormous size. One of these dug out from beneath one of the Skinningrove furnaces weighed between 500 and 600 tons. The circumferential contraction of this large mass on cooling compressed the central portion, which was the last to freeze. According to Dr. Stead, "the effect of this enormous pressure caused the central plastic mass to assume a vertical column, an arrangement closely resembling on a small scale the basalt of Giants' Causeway." These columns could be separated from one another. Chemical analyses indicate that about 90 per cent. of the phosphorus originally present had been extruded vertically between the columns during the period of intense compression. A "bear" with a similar columnar structure has also been found in the hearth of a Cleveland furnace of Messrs. Bolckow, Vaughan and Co. at Eston. Here, too, the columns were all vertical, and varied from $\frac{1}{8}$ to $\frac{1}{4}$ in. in diameter, and in some places were so loosely attached to each other that they could be separated by hand. These also were found to be low in phosphorus. In the case of a bear under an Ormesby furnace which had been in blast some thirty-eight years, about two-thirds of the original phosphorus had been removed, but there were no indications of columnar structure. On the other hand, the metal found in the hearth of one of the furnaces at Ferryhill consisted of columnar crystals of iron saturated with iron phosphide, with walls of iron phosphide, but entirely free from carbon and silicon. Here, therefore, the conditions must have been much more oxidising, and no ternary eutectic was present. It is, however, abundantly clear that by far the greater part of the phosphorus in highly carbonised iron is concentrated in the last portions which freeze.

Two photographs reproduced in Dr. Stead's paper illustrate the structure and mode of occurrence of the ternary eutectic extremely well. Both were developed by heat-tinting, iron phosphide appearing blue or purple, iron carbide red, and iron saturated with phosphide white. No. 1 is termed by Dr. Stead the "normal" structure, and is clearly lamellar, recalling the well-known pearlite in its form; No. 2 is evidently that of a very slowly cooled specimen, the lamellæ having coalesced to an appreciable extent.

The equilibrium relations between iron, iron carbide, and iron phosphide in the range of temperature 1000° C. to 700° C. are of the utmost importance in the light they shed on the so-called "ghosts" or "phantoms," which are very liable to occur in large forgings of mild or medium steel. These are lines or streaks which can only be detected after rough turning. As the names indicate, they are not deep-seated. They are completely removed by turning off a thin layer of the steel, but are liable to reappear in other places. It is clear, therefore, that they are very attenuated and irregularly distributed. The usual view held is that they are harmful, and forgings are sometimes rejected on account of their presence, in spite of the undoubted fact that some of them have proved satisfactory in service even though such ghost lines were present. Their occurrence, in Dr. Stead's view, is due to the fact that "in steels containing 0·45 per cent. and less carbon, although the carbon may be equally distributed when the steel is at 1000° C., on very slow cooling the ferrite first appears in the parts richest in phosphorus. The portions which are partially saturated with phosphorus cannot so readily hold in solid solution at certain temperatures as much carbon as the surrounding portions which contain little or no phosphorus; consequently, when in cooling it reaches these temperatures, the carbon diffuses out of the phosphorised parts into the surrounding pure metal." These areas of phosphide concentration constitute the ghosts, and, as sulphides and phosphides segregate together, sulphides are generally present in them as well.

Dr. Stead has succeeded in producing typical ghost lines synthetically by heating to 1000° C. strips of soft

iron sandwiched with ternary eutectic and then forging down to a ¼-in. sheet. This treatment squeezed out the excess of eutectic and left the juxtaposed faces perfectly united with a thin layer rich in phosphorus. After very slow cooling, sections were cut, polished, and etched. The structure was found to consist of "strings of disconnected patches of pearlite and straight lines of ferrite," very similar to those found in ship and boiler plates. All the carbon originally present in the eutectic was found to have diffused into the iron beyond the phosphoretic junctions Heating to 1350° C., however, followed by a three days' cooling period to 700° C., caused a uniform distribution of the carbon and phosphorus in the steel.

Dr. Stead's general conclusion is: "After careful study I am inclined to believe that if they"—*i.e.* ghost lines—"are not associated with a material amount of slag inclusions, they are not dangerous or liable to lead to the failure of engineering structures. I am led to that conclusion by submitting cross-sections to violent shock test, so that the stress applied is greater across the lines; for when this is done fracture does not start where they are located unless there are sulphide or slag inclusions in material quantity. The subject should have more consideration, and be thoroughly investigated by making suitable mechanical tests."

Only two aspects of Dr. Stead's publication have been touched upon in this article. The complete paper, however, should be studied by those who are interested in the presentation of the subject in a series of masterly and informing sub-papers which no one but he could have written.

H. C. H. CARPENTER.

THE SEISMOLOGICAL SOCIETY OF AMERICA.

FOUR volumes of the Bulletin of this society were completed with the last year. They contain many papers of interest and value, most of which have been noticed in these columns, and several —evidently the work of novices—which the Publication Committee might with advantage have suppressed.

The first part of the fifth volume, which has been issued recently, contains six papers, three of which are of general interest. Of the others, one on the seasonal periodicity of earthquakes is inconclusive. Mr. Carl H. Beal describes an earthquake which originated near the town of Los Alamos, in south-western California, on January 11 last. This is probably the first earthquake in which the long-distance telephone has been used in the collection of records. Prof. J. C. Branner insists on the untrustworthiness of personal impressions on the direction of an earthquake-shock, and he urges that, in investigations of an earthquake, the question dealing with such impressions should be omitted. It has long been known that single observations on the apparent direction of the shock or on the fall of a column, etc., are valueless, the apparent direction being almost invariably perpendicular to the principal walls of the house in which it is observed. But the average of a large number of personal observations within a limited area has been found in several cases to coincide with the direction of the area from the epicentre. Moreover, after the Tokyo earthquake of June 20, 1894, Prof. Omori measured the direction of fall of 140 stone lanterns with circular bases in Tokyo, and the average of these measurements coincides exactly with the direction of the single great oscillation registered in that city.

The first place in the number is given to Mr. Carl H. Beal's account of the Avezzano earthquake of January 13. The material of this paper is derived chiefly from newspaper reports and from a short article which appeared in NATURE (vol. xciv., p. 565), but the author adds an interesting note with regard to the origin of the earthquake. "The higher mountain ranges near Avezzano," he says, "rise to an altitude of from 6000 to 7000 ft. and trend generally north-west and south-east, the direction apparently being determined by a series of nearly parallel fractures which extends from a region south-east of Avezzano north-west to the vicinity of Cittaducale. . . A fault is known to pass through Luco, Cappelle, Sourcola, and very close to Avezzano, and as these cities were completely demolished, it is quite probable that movement along this fracture caused the shock."

On November 8, 1914, a fairly strong earthquake was felt in central California. From the duration of the preliminary tremors at Berkeley, and from the initial times at Santa Clara and the Lick Observatory, and taking the velocity for the tremors at Zeissig's value of 6·3 km. per sec., Mr. E. F. Davis finds that the epicentre was situated on the San Andreas Rift close to the town of Laurel. From a study of the distribution of intensity, Mr. Carl H. Beal had previously assigned approximately the same position for the epicentre. The San Andreas Rift is the great fault along which for 270 miles the movements took place which gave rise to the Californian earthquake of 1906.

Since 1832, there have, according to Mr. H. O. Wood, been twenty-five eruptions of Mauna Loa, in the south of Hawaii. With the majority of these no earthquakes are recorded, and this might also have been said of the last eruption which began on November 25, 1914, had it not been for the instrumental record of a large number of feeble shocks. Mr. Wood concludes that "nothing appears in the sequence of events which would have justified confident, or definite, *prediction* of outbreak," though the numbers of shocks recorded during the five preceding weeks were one, five, sixteen, thirteen, and thirty-eight.

C. DAVISON

INDIAN GEODESY.[1]

THE two volumes referred to below supplement one another, for while the general report gives an abbreviated account of the year's work, more detailed descriptions and the discussions of the results obtained find their place in the Records.

Pendulum observations were made at fourteen stations between lat. 20° N. and lat. 30° N., all in the immediate neighbourhood of the 78th meridian, thus filling in the gap which existed between Lieut.-Colonel Lenox-Conyngham's work from Mussoorie to Meerut, and that of Captain Cowie in the Central Provinces. The stations include that of Kalianpur, the station of origin of the Indian triangulation, and here the pendulums were swung in the same room where Captain Basevi swung his pendulums in 1867. At Dehra Dun the new pendulum room was used. Some changes have been introduced in presentation of the results; Helmert's formula of 1901 is employed instead of that of 1884, which had been used previously; also the formula for the mass correction has been modified by taking somewhat smaller values for the mean surface density of the

[1] "General Report on the Operations of the Survey of India during the Year 1912–13." By Colonel S. G. Burrard, C.S.I., R.E., F.R.S. (Calcutta, 1914.)
"Records of the Survey of India." Vol. v., Reports of Survey Parties, 1912–13. (Calcutta, 1914.)