from the thirty-seven years' observations now available.

The principal results for the magnetic elements in 1910 were:—

Mean declination	15° 41·2″ West.
Mean horizontal force	0·18532 (C.G.S. units.)
Mean dip (with 3-inch needles)	66° 52′ 37″.

There were no days of "great," and only six of "lesser," magnetic disturbances.

The mean temperature for 1910, 49·7°, was 0·1° above the 1841–95 average, but the sunshine recorder showed a deficiency; July provided only about half the average number of hours of bright sunshine, and May was the only month when the amount was appreciably above the average. The rainfall, 25·93 inches, was 1·81 inches in excess of the 1841–95 average, and the number of "rainy days" was 175.

In the time department, the performance of chronometers is reported as satisfactory, and that of chronometer watches as exceptionally good. The increase of electrical devices on board ships having made the question of the magnetic disturbance of chronometers an urgent one, special experiments are being carried out with strong magnetic fields at the observatory.

THE HARD AND SOFT STATE OF METALS.

Dr. G. T. Beilby, F.R.S., delivered the second annual May lecture of the Institute of Metals on Friday, May 12, taking for his subject "The Hard and Soft States in Metals."

In the course of his lecture Dr. Beilby said that the hardening effect of cold working on ductile metals, and the softening effect of reheating, must have been known to the earliest workers in metals. To the general mind, the phenomena were sufficiently explained as being due to the "compacting" effect of hammering and the "opening up" effect of heat. The advent of scientific methods of inquiry led to the exposure of this fallacy, and to the discovery of new points of difference in a metal in the two states. The discovery that the polishing of all substances, even of those so hard or brittle as antimony or calcspar, involves the transient liquefaction of a thin layer on the surface, led to the study of this subject from an entirely new point of view. In a pure ductile metal which has been slowly cooled from the molten state, the structure of the solid is completely crystalline, and the metal is in its softest condition. Any permanent deformation of the mass, whether by hammering, by rolling, or by wire drawing, hardens and stiffens it. The microscopic examination of the hardened metal shows that its original crystalline structure has been broken up and replaced by a new type of structure. If the hardened metal is raised to a sufficient temperature, the softness is completely restored *and the crystalline structure is also restored.* In the ductile metals the greatest degree of softness is always associated with well-developed crystallisation.

The composite character of the hardened structure, which in some cases resembles a bed of broken and distorted strata concreted or cemented together by a matrix, can only be explained by the presence of two constituents, namely, the broken-down remains of crystals and an amorphous or glass-like form of the metal by which the mass is so firmly cemented together that it has become vastly more rigid and mechanically stable than the crystalline structure. This amorphous or vitreous form of the metal stands in the same relation to the crystalline form as glass does to the crystalline silicates of which it is composed, or as the clear, vitreous "barley sugar" does to the ordinary crystals of the breakfast table.

The pure ductile metals cannot be obtained in the vitreous state by cooling, because their molecules retain sufficient mobility to enable them to marshal themselves in crystalline formation for a range of about 800° below the solidifying point. All the facts show, however, that when liquefaction is produced by mechanically induced flow the solidification is so rapid that the solid which results is in the vitreous condition.

Microscopic analysis of the surface skin produced by polishing a plate of calcite shows that the disturbance due to polishing has penetrated to a depth of one thousandth of a millimetre, and that the subsequent healing over of the disturbance has been so perfect that it can only be explained by the assumption that the transient liquefaction of a layer some thousands of molecules in thickness has occurred. It is evident that the conditions necessary to bring about liquefaction and solidification at the outer surface must equally exist within the substance at all surfaces of slip or shear, and the microstructure of the hardened metal confirms this view.

The direct bearing of these researches on the obscure subject of molecular structure in solids was pointed out, and a "pulsation cell" hypothesis of the three states of matter was outlined.

Prof. Quincke's "foam-cell" theory of solidification was referred to, and was applied to the explanation of certain observations made by Prof. Carpenter some years ago. In view of the possible bearing of this theory on questions of foundry practice, it was suggested that the Institute of Metals might offer a prize for the best research on the subject.

HYDRO-ELECTRIC PLANTS IN NORWAY AND THEIR APPLICATION TO ELECTRO-CHEMICAL INDUSTRY.[1]

The physical configuration of Norway is remarkably favourable for the utilisation of the large number of waterfalls to be found on the seaboard of the mountain chains which almost cover the country, and through the valleys of which the enormous quantity of water precipitated from the western and south-eastern sea breezes finds its way as rivers flowing down to the sea. In the winter the rainfall takes the form of snow, so that the volume of water brought down by the rivers is at its greatest from May to July, when the snows melt on the mountains. To make use of the water-power, storage is therefore necessary, and for this the nature of the country is peculiarly adapted, being covered with lakes that have very contracted outlets, and which can be easily converted by damming into storage reservoirs. Thus in the watershed of Skien the natural water-power of 50,000 horse-power has been increased to an available horse-power of 375,000, while the Mösvand reservoir has increased the water-power of the Rjukan factories from 30,000 to 250,000 horse-power, with a capital outlay of only some 85,000*l.*

The total water-power in Norway has been estimated at from five to seven million horse-power, but as much of the country has not been hydrographically surveyed, this is probably too low an estimate. The power stations can supply power at from 22*s.* to 44*s.* per e.h.p.-year, and in some cases even for less; and as the quantities available are as high as from 50,000 to 100,000 horse-power for a single fall, the conditions are ideal for the development of electrochemical and electrometallurgical industries. Many such industries have already reached an advanced stage of development. Thus nearly 180,000 horse-power will be utilised this year in the manufacture of nitrates of lime, soda, and ammonia from the air by the Birkeland-Eyde process and the Badische Analin und Sodafabrik Company's process; about 60,000 horse-power are employed in the manufacture of calcium carbide, and other electrochemical and electrometallurgical industries absorb at present some 20,000 horse-power. Now that a suitable electric furnace—the Grönwall—has been designed for the smelting of iron ore, a furnace that has yielded excellent results on a practical scale, electric iron and steel smelting is likely to develop largely in the near future, for Norway possesses extensive deposits of iron ore. Three plants, aggregating 16,000 horse-power, with provision for increasing to nearly 60,000, are now being erected at Hardanger, Arendal, and Tinfoss. Other ores, notably copper, nickel, zinc, will also possibly be electrically smelted at no distant date.

The second portion of the paper describes in some detail the various hydro-electric schemes now being developed in

---

[1] Summary of a paper read before the Faraday Society on May 2, by Mr. A. Scott-Hansen, of Christiania.