when blocks hurled from an explosive volcanic eruption dig into the surface materials.

A whole plethora of steep-sided irregularities are, however, found on the centimetre scale. At this scale (*H* in Fig. 1) the lunar surface bears a remarkable similarity to the scoriaceous surface of an aa (Hawaii) type of lava flow, but we recognize that the irregularities might equally well have been sculptured by meteoritic churning. In any event, solar sputtering must have played a part in shaping the sub-centimetric irregularities and the short-wave and corpuscular radiation from the Sun must, in addition, have darkened the rocks from their original lighter tone.

It is well known that the lunar surface has reflexion properties unlike those of any terrestrial materials. These unusual properties are well illustrated by the graph in Fig. 2. The figure shows the brightness of marial material as a function of angle of observation for a given constant angle of incidence (in this case 30°), and is constructed by reducing the lunation brightness curves of many points to the curve of mean albedo; data have been derived from measurements by Fedoretz[9] and Bennett[10]. It seems that the observation that the Moon's surface (in both maria and highland areas) scatters a large fraction of the incident light back in the direction of incidence can only be explained satisfactorily by assuming that the surface is very rough and, in particular, that individual holes or pores are interconnected.

We have attempted to explain these features on the assumption that at least some parts of the lunar surface consist of lava flows. If this is so it will be appreciated that the lava reaching the surface encounters not an atmosphere as in the case of the Earth, but a high vacuum, and as a result any release of entrapped gas is likely to cause a higher degree of vesicularity than in the corresponding terrestrial case. Following Dobar *et al.*[11], we have, therefore, rapidly evacuated the atmosphere from vessels containing molten igneous rocks and examined the resulting solids after cooling to room temperature. In all cases a highly vesicular material is found consisting of interconnected vesicles from 0·1 to 2 or 3 cm in diameter. Such material, when darkened by solar radiation, is consistent in appearance with the terrain so far resolved in the Russian photographs, and our material also reproduces the observed lunar photometric properties. It is not yet possible to decide to what extent the surface has been broken up by meteoritic impacts and re-sintered by the solar bombardment; photographs taken with a resolution of less than 1 mm will be needed to resolve such questions. There is, however, strong evidence based on polarimetric observations[12] that the irregularities photographed by *Luna* 9 will be found to be peppered with darkened but individual grains that are certainly produced by micrometeorites.

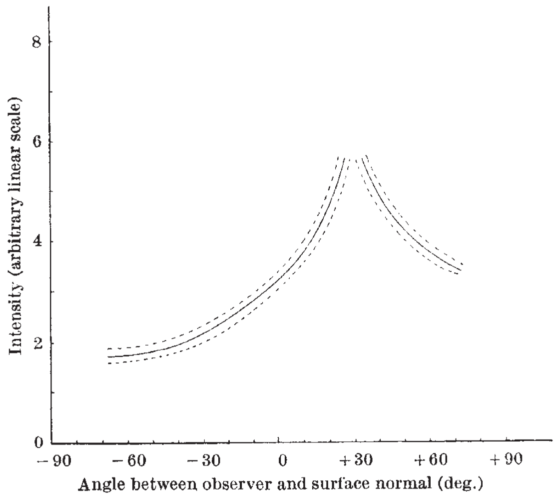

Fig. 2. Scattering diagram for maria with angle of incidence of sunlight = 30 degrees. The dashed lines indicate the limits of probable error

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OBITUARIES

Sir Gordon Morgan Holmes, C.M.G., C.B.E., F.R.S.

Sir Gordon Morgan Holmes died at his home in Farnham, Surrey, on December 29, 1965. He was in his ninetieth year.

Holmes was born in Castlebellingham, Co. Louth, Ireland, in 1876. After gaining his M.D. with the gold medal of the year from Trinity College, Dublin, he was for a short period a resident medical officer at the Richmond Hospital in Dublin, but then turned to the study of the comparative anatomy of the nervous system and proceeded to the Anatomical Institute at Frankfurt, then directed by the famous neuro-anatomist, Ludwig Edinger, where Holmes also encountered another pioneer in the field, Carl Weigert.

During the two years that he remained at Frankfurt he produced work on the nervus acusticus, on the forebrain of the bird, and was given by Edinger the task of working out the residual anatomy of one of Goltz's 'dogs without forebrain'. So impressed was Edinger by his young student that he offered Holmes a position as his assistant, and this might well have determined Holmes's future place and order of study. However, he came to England and turned to neurological medicine, filling successively the roles of resident medical officer, pathologist, director of research and finally physician to the National Hospital, Queen Square, London, until his retirement during the Second World War.

From his first arrival at this well-known neurological hospital, which enjoyed an international reputation for research many years before it finally achieved university recognition after Holmes's retirement, his output of original work was continuous. It covered the anatomical and morbid anatomical investigation of the human nervous system and the manifestations of diseases of the nervous system over a wide range.

The study and analysis of cerebellar defect, due to disease or injury, began in 1904 when, with Grainger Stewart, he published the first adequate study of cerebellar tumours. Later, during the First World War, which he spent in France as neurological consultant to the British Forces, he amplified his analysis of cerebellar function by investigations on acute injuries from gunshot wounds. The final results of all his investigations on this subject were published in 1917 and 1922.

During the opening decade of the century he worked in collaboration with Henry Head on disturbances of sensation associated with cerebral lesions, drawing from them inferences as to the role of the cerebral cortex in sensory function.

This was a remarkable collaboration, for Holmes, his training soundly anchored in anatomy, not only devised quantitative methods of sensory assessment, but also was a brake on Head's eager fancy. It will be remembered that Head's early studies with Rivers on the afferent sensory system, though brilliant, had a fatal defect, in that Nature had not provided the structural facilities for the theories which they had put forward. Holmes, therefore, was an essential complement to his partner in this work, and between them they produced a more delicate and precise concept of the role of the cortex in sensation than any earlier one.

Also during the period spent in France, Holmes made a number of valuable studies on disturbances of visual function from brain lesions. These included a somatopic cortical representation of the afferent visual pathway, and the bases of visual orientation and attention. These considerable cerebellar and visual studies were collected and published as a supplement to *Brain* (of which journal Holmes was editor during 1922–37) in 1956 on his eightieth birthday. Appended to that supplement is a bibliography of his published work which reveals his immense productivity and the wide range of his thought over the fields of neurological anatomy, physiology, morbid anatomy and nosography.

During the years between 1919 and 1939 Holmes also gained an international reputation as an incomparable teacher of postgraduate students in neurological medicine. These young men flocked to the National Hospital from the British Commonwealth and from the United States to join Holmes's staff as clinical clerks. These clerks and his own house physicians formed a generation of neurologists still to be found in all parts of the English-speaking world, holding senior positions in neurological departments. Holmes was an exacting taskmaster to these men, but he had the gift of lucid and logical exposition so that the 'how' and 'why' of his conclusions and of his diagnoses were apparent. He was not a showman anxious to impress, but a born teacher.

Personally, Holmes was a man of great strength and inexhaustible energy and of a forceful temperament, sometimes frightening but never malicious, always gaining the respect and later the affection of those he taught. To be trained by him was a salutary discipline. Committees he loathed, and was an impatient and sometimes intolerant member of them. But for younger men in whom he saw a keenness and a capacity for original work he had infinite patience and sympathy.

Finally, it is worthy of note that Holmes was one of the last representatives of those physicians of an earlier generation who depended entirely on the private practice of consulting medicine, whose research was carried out in their hard-won spare time, and who wholly lacked academic or other support. With the death of the voluntary hospitals this way of life ceased to be.

Holmes was appointed C.M.G. and C.B.E. during the First World War and was knighted in 1951. He was elected a Fellow of the Royal Society in 1935; he was an honorary member of numerous foreign medical societies, and received honorary degrees from the Universities of Dublin, Durham and Edinburgh and from the National University of Ireland. He married, in 1918, Rosalie, daughter of Brigade-Surgeon Jobson, and had three daughters. F. M. R. WALSHE

Prof. William Wilson, F.R.S.

WILLIAM WILSON died on October 14, 1965, at the age of 90. He retired in 1944 from the Hildred Carlile chair of physics at Bedford College, University of London, which he held from the time of its creation in 1921. He came from a farming family and spent his boyhood at Goody Hills in Cumberland. From the village school at Holme St. Cuthbert he obtained scholarships to the Aspatria Agricultural College and to the Royal College of Science. At this stage, he found difficulty in changing his course of study from one in biological subjects and temporarily abandoned his scientific career for school teaching. He taught English in the Berlitz School of Languages in Dortmund for a time, but was able to return to scientific work by studying physics and mathematics in German universities. Later in life he often praised the freedom of choice which was given to students in Germany and held that the British system of examinations imposed an undesirable and discouraging rigidity.

His first published work, in the *Annalen der Physik* for 1907, is an extract from his Dr. Phil., Leipzig, inaugural dissertation. It is an account of experiments on photoelectric emission and on the photoconductivity of such materials as silver iodide. He long retained an interest in the photoelectric effect and published a quantal theory of thermionic emission based on the idea that the electrons were ejected photoelectrically by quanta of radiation in thermal equilibrium. He showed that the temperature dependence would be similar to that deduced by O. W. Richardson, who used non-quantal arguments. It later became clear that these photoelectrons could account for only a small fraction of the thermionic current.

After becoming an assistant lecturer at King's College, London, in 1906, his interest was aroused by the atomic speculations on nebulium of Prof. J. W. Nicholson, professor of mathematics at the College, which antedated Bohr's theory of the hydrogen spectrum. In 1915 Wilson's famous paper "The Quantum Theory of Radiation and Line Spectra" appeared in the *Philosophical Magazine*. In this he first proposed the Wilson–Sommerfeld quantization rules in the form:

$$\int p_1\, dq_1 = \rho h$$
$$\int p_2\, dq_2 = \sigma h$$
$$\int p_3\, dq_3 = \tau h$$

where $\rho, \sigma, \tau, \ldots$ are positive integers (including zero) and the integrations are extended over the values p_s and q_s corresponding to the period $1/\nu_s$. The q are Hamiltonian generalized co-ordinates of position and the p are their conjugate components of generalized momentum. The paper applied the rules to the simple harmonic oscillator, to find $E_\rho = \rho h\nu$. An application of statistical mechanics to an assembly of oscillators gave Planck's radiation formula but failed to give the Bohr frequency relation:

$$h\nu = E_1 - E_2$$

In 1916 appeared "The Quantum of Action", which preceded Sommerfeld's first paper on the subject. In this Wilson deduced that if elliptic orbits existed in the atom they could only have a few discrete values of the eccentricity ε given by

$$\sqrt{1-\varepsilon^2} = \sigma/(\rho+\sigma)$$

where σ and ρ are positive integers as before.

Wilson did not follow this up, but in the quite independent work of Sommerfeld on the other side of the firing lines in Germany it led to the idea of space quantization and to a theory of the fine structure of the lines of hydrogen. In this theory the energies of the levels agreed with the values given later by the relativistic wave mechanics of Dirac.

The sharply defined elliptic orbits used in the theory are incompatible with the indeterminacy relations of Heisenberg, so that their success in explaining the fine structure must be regarded as an accidental coincidence. In this, the theory resembles many other steps forward in