THE ORIGIN OF THE PLANETESIMAL THEORY*

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Abstract. T. C. Chamberlin suggested in 1897, on the basis of geological and climatological arguments, that the planets were formed by accretion of cold solid particles. With F. R. Moulton he developed convincing arguments against the Laplace nebular hypothesis and published a comprehensive 'planetesimal theory' of the origin of the solar system in 1905. The Chamberlin-Moulton theory has current as well as historical interest.

Several contemporary accounts of the formation of planets are based on the 'planetesimal theory' proposed at the beginning of the 20th century by Thomas Chrowder Chamberlin (1843-1928) and Forest Ray Moulton (1872-1952). They argued that gases extracted from the Sun by the action of a passing star first cooled and condensed to solid particles and then slowly accreted to form planets. Gravitational contraction would supply heat at a later epoch appropriate to the development of life, but not rapidly enough to produce significant large-scale melting of the Earth at any time.

Historically the Chamberlin-Moulton theory was introduced as a replacement of the Laplace 'nebular hypothesis' which was generally accepted throughout most of the 19th century. Laplace had suggested that a rotating Sun with a greatly extended atmosphere would spin off rings of hot gas as it shrinks, and these rings would condense to molten balls which eventually cool to planets having solid crusts. This theory seemed to fit well with geological evidence; some rocks had apparently been formed at high temperature, and mountain ranges could be attributed to the crumpling of a solid crust settling into a liquid interior that contracted as it cooled. Volcanic eruptions, and the steady increase of underground temperature with depth, suggested that the interior is still hot enough to be mostly liquid.

The nebular hypothesis was the foundation of a grand scheme of cosmic evolution, from the primordial gas to the development of organic species on earth. Such schemes were being discussed even before the publication of Darwin's *Origin of Species* in 1859, and provoked the same religious objections that were later raised against Darwin's theory. From the scientific viewpoint the main difficulty with the scheme was that the only phase that could be worked out quantitatively, the cooling of the Earth from its initial molten state, gave results that seemed to contradict geological evidence. Lord Kelvin, assuming uniform cooling of a solid sphere with no internal heat sources, estimated that the age of the Earth since its solidification was no more than 10 or 20 million years. Geologists on the other hand thought that hundreds of millions of years had been occupied by the slow

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processes they studied, and Darwinian evolution was also believed to require a similar time scale. Kelvin was not flatly opposed to evolution (as is sometimes stated) but he did object to the random character of natural selection. (See Brush, 1977, for a discussion of this debate.)

T. C. Chamberlin was already in his fifties when he began to develop his planetesimal hypothesis, and published his complete theory at age 62. He was a geologist whose interest in glacial rock formations had led him to consider theories of the cause of the ice ages based on hypotheses about changes in the carbon dioxide content of the Earth's early atmosphere. It had been suggested that the Earth started with a dense hot atmosphere rich in carbon dioxide, but Chamberlin concluded from G. J. Stoney's application of the kinetic theory of gases that such a state is unlikely. At the high temperatures required by the nebular hypothesis for the primeval Earth, the atmospheric gases would have been dissipated into space. A cold origin of the Earth was needed to account for retention of the gas up to the present time.

In looking through the literature on the nebular hypothesis, Chamberlin found that the planets had sometimes been supposed to have formed by accretion of solid particles – the so-called 'meteoritic theory' – rather than by condensation of hot fluid balls. But the meteoritic theory suffered from one fundamental defect: solid