ART. XLIII — *On Croll's Hypothesis of the Origin of Solar and Sidereal Heat*; by Professor DANIEL KIRKWOOD.

THE Quarterly Journal of Science for July, 1877, contains an able and interesting article by James Croll, LL.D., F.R.S., on the age and origin of the sun's heat. The theory of Dr. Croll may be regarded as a compromise between the mathematicians, represented by Thomson, Tait and Newcomb, and the geologists of the uniformitarian school, represented by Playfair, Lyell, Darwin, etc. The principal points of this remarkable paper are:

1. That, as had been estimated by Sir William Thomson and others, but twenty million years' heat could be produced by the falling together of the sun's mass.

* Since this was written, a new determination has been made by H. F. Weber of Zurich, in which the different results agree with great accuracy. The result has been expressed in Siemen's units, and the comparison seems to have been made simply with a set of resistance coils and not with standards. The modern Siemen's units seem to be reasonably exact, but from the table published by the British Association Committee in 1864, it seems that at that time there was uncertainty as to its value. He obtains 1 S. U. = $\cdot 9550 \frac{\text{earth quad.}}{\text{sec.}}$, which is greater

or less than the British Association determination, according as we take the different ratios of the Siemen's to the British Association unit, ranging from $\cdot 14$ per cent above to $1\cdot 92$ per cent below. In any case the result agrees reasonably well with my own. The apparatus used does not seem to have been of the best, and the exact details are not given. But wooden coils to wind the wire on seem to have been used, which should immediately condemn the experiment where a pair of coils is used, seeing that in that case the constant, both of magnetic effect and of induction, depend on the distance of the coils. It is unfortunate that sufficient details are not given for me to enter into a criticism of the experiment.

2. That not less than five hundred millions of years have been required for the stratification of the earth's crust at the present rate of subaërial denudation; and hence that the gravitation theory of the origin of the sun's heat is incompatible with geological facts.

3. If we suppose two solid opaque bodies, each equal to half the sun's mass, to fall together in consequence simply of their mutual attraction, the collision would instantly generate sufficient heat to reduce the entire mass to a state of vapor. If, in addition to the motion resulting from their mutual attraction, we suppose the bodies to have had an original or independent motion towards each other of 202 miles per second, the concussion would produce 50,000,000 years' heat; a motion of 678 miles per second, together with that due to their mutual attraction, would generate 200,000,000 years' heat; and a velocity of 1,700 miles per second would generate an amount of heat which would keep up the supply at the present rate for 800,000,000 years.

4. The sun and all visible stars may have derived their heat from the collision of cold, opaque masses thus moving in space. The nebulae are the products of the more recent impacts, and the stars have been formed by the condensation of ancient nebulae.

5. This theory, while accepting the doctrine of the conservation of energy, indicates at the same time a possible supply of heat for several hundred millions of years; thus satisfying all moderate demands for geological time.

The mathematical correctness of the theory here stated will not be called in question. We shall consider merely the *probability* of the facts assumed as its basis. To the present writer the hypothesis seems unsatisfactory for the following reasons:

1. The existence of such sidereal bodies as the theory assumes is purely conjectural, unless it be claimed that lost or missing stars have become non-luminous, of which we have no conclusive evidence.

2. But, granting their existence, we have no instances of stellar motion comparable with those demanded by the hypothesis; the velocity being in most cases less than 50 miles, and in no case exceeding 200 miles per second.

3. If the two masses by whose collision the sun is supposed to have been formed were very unequal, as would be most probable, the amount of heat generated would be correspondingly less.

4. Such collisions as the theory assumes are wholly hypothetical. It is infinitely improbable that two cosmical bodies should move in the same straight line; and of two moving in different lines, it is improbable that either should impinge

against the other. Comets pass *round* the sun without collision against it.

5. But granting these difficulties removed, let us suppose that about 800,000,000 years ago two cold, opaque bodies, each containing one-half the matter of the solar system, were approaching one another in the same straight line, each at the rate of 1,700 miles per second;* that on meeting, their motion was transformed into heat; and that their united mass was at once reduced to vapor: the great question yet remains—How much of the period represented by these 800,000,000 years' heat can be claimed as *geological* time? The nebula formed by the collision would extend far beyond the present orbit of Neptune. The amount of heat radiated in a given time from so vast a surface would doubtless be much greater than that now emitted in an equal period. No considerable contraction could occur until a large proportion of the heat produced by the impact had been dissipated in space. It has been shown by Trowbridge† that with a temperature at the sun's surface of twice its present intensity the solar atmosphere would be expanded beyond the earth's orbit. The conclusion seems inevitable that much the greater part of the 800,000,000 years' heat must have been radiated into space before the planets were separated from the solar mass, and consequently, that the amount of geological time cannot, to any great extent, have exceeded the limits indicated by the researches of Sir William Thomson.

Upon the whole, it seems more difficult to grant the demands of Dr. Croll's hypothesis than to believe that in former ages the stratification of the earth's crust proceeded more rapidly than at present. The former, as we have seen, has no sufficient basis in the facts of observation. On the other hand, if our planet has cooled down from a state of igneous fluidity, the great heat of former times must doubtless have intensified both aqueous and atmospheric agencies in producing modifications of the earth's exterior.

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* This is the greatest velocity mentioned by Dr. Croll. An increased rate of motion would, of course, produce more heat, but the hypothesis would be open to the same objections.

† Proc. Am. Phil. Soc., vol. xvi, pp. 329-333 and National Quarterly Review, March, 1877, p. 292.

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