invisible in the sound part. An analogous process may also be seen in the grand cañon of the Yellowstone River, where the rhyolites have been weathered into a white or yellowish, mealy-textured rock along the great fissure, which allowed a freer passage to, and still emits, in diminished quantities at the bottom of the gorge, heated water and steam from the dying-out volcanic furnace below.

So along the Armenian lava-flow water easily got in from the surface, or followed the longitudinal cracks in the rapidly cooled rock, and, being itself heated by the process, acted upon the silicates, and carried off the more soluble portions. A diminution in volume accompanied the process, and the reduced rock broke up.

May be the old valley down which this lava flowed was an ancient outfall of Lake Gokcha before its rim had been built up as high as it now stands. Perhaps at one time some of the water of the lake found its way through fissured masses to lower levels, and carried on the work of destruction within the rock itself.

We want many more facts respecting this most interesting district—we would like to know the depth of the lake, the direction of any observed lines of fissure, and if there is any evidence of the waters of the lake having ever been suddenly drained off into the valley of the Araxes. We hope, therefore, that Mr. Loewinson Lessing, whose knowledge and skilful arrangements enabled us to see so much of the district, and whose courtesy and thoughtfulness made our excursion so pleasant, may be able to carry on the work for which he is so well qualified, and will communicate to the world the result of his further investigations.

T. MCKENNY HUGHES.

PERIODIC ORBITS.

FOR some years past, Prof. G. H. Darwin has been engaged on the numerical solution of a particular case of the problem of three bodies, and at different times he has given some account of the progress he has made. He has now collected his very extensive material, relating to both the mathematical methods employed and the discussion of the numerical results, into one compact summary under the title of "Periodic Orbits," which appears in *Acta Mathematica*, vol. xxi. The special case treated by Prof. Darwin refers to one of three classes into which M. Poincaré has divided the periodic solutions of this problem. In this class, the motion is entirely in two dimensions, and the excentricity of the planet's orbit is very small; but Prof. Darwin further supposes the perturbed body to have infinitely small mass, and the planet's orbit to be absolutely circular. The discussion of even this one class has had to be restricted in the course of the work, on account of the heavy arithmetical labour which the method of tracing the orbits by mechanical quadratures involved. Retrograde orbits have not been considered, and the motion of superior planets is still engaging Prof. Darwin's attention. Some thirty examples of periodic orbits have, however, been examined; and though the author may speak of his results very modestly, there is no doubt but that his conclusions will be welcomed as a most interesting contribution to the study of celestial mechanics.

Prof. Darwin defines a periodic orbit as one in which a third body can continually revolve so as always to present the same character relative to the two other bodies of the system. These orbits are not necessarily confined to a single revolution round the primaries, or round any other point in space, but the difficulty of the determination of the path increases with the number of circuits described, and on that ground the present treatise is confined to the examination of "simple periodic orbits," or those which are re-entrant after a single circuit, though loops may, and do, occur in the orbit. In the system considered, the distance between the sun and the principal planet, here called Jove, is taken as unity, and the ratio of the mass of the sun to that of the planet as 10 : 1. This hypothesis differs considerably from the actual circumstances prevailing in our system, but it offers the advantage of exaggerating all the phenomena of perturbation, and permits the clear exhibition of the deductions in diagrams that are easily appreciated. Some of the stellar systems may offer conditions more nearly parallel to those here assumed. A looped orbit has been suggested in the case of one of the components of ζ Cancri, though possibly with insufficient data, and in some other cases, the presence of a disturbing body seems likely to produce an orbit of very irregular form.

We have accustomed ourselves to consider the relations of superior and inferior planets and of satellites to be fixed and definite, but Prof. Darwin traces the conditions under which these forms cease to be permanent, and when consequently the third body of a system can assume the characteristic motion of either an inferior planet or a satellite. With a particular value for the constant of relative energy, it is possible for both kinds of planetary and satellite motion to become confused, and for a body which originally started in one way to exhibit the peculiar motion of either of the other two. Prof. Darwin began his numerical work by an assumed case in which it was possible for an inferior planet and satellite to interchange their parts. The satellite was made to start at right angles to a line joining the sun and Jove, at a distance of 1·08 from the sun, Jove's distance being unity. The resulting orbit is fully drawn and shows how the body hangs in the balance, between the two centres, before the elliptic form of the orbit asserts itself, as the body approaches the sun. Starting the satellite from a conjunction remote from the sun, but at slightly different distances from Jove, it is found that the resulting orbits show a great diversity of character, which cannot always be foreseen. Perhaps the most remarkable curve in this family arises when the satellite starts at a point 1·095 from the sun. After making a loop, the satellite recrosses the line of conjunction and moves directly towards the planet, so that it is impossible to determine its subsequent path without very accurate computation. "I do not think," says Prof. Darwin, "any one could have conjectured how the body should have been projected so as to fall into Jove." The positions which give rise to periodic orbits are shown by the distances from the sun at which the curve meets the line of conjunction after one complete circuit. If for two selected points of projection, the curve returns to this line at places alternately nearer to and more remote from the sun than those from which it originally started, then there must be some point intermediate between these selected points at which the curve will be re-entrant. Other forms of orbits giving rise to distinct families, have been computed, and drawn, when the satellite is projected from points intermediate between the sun and Jove, and also from conjunction on the side remote from Jove. Most of these orbits do not possess the character of stability, a point which the author has considered with as much care as the form of the orbit itself. It has been questioned whether all orbits are not essentially unstable, if the number of revolutions be sufficiently great. The result of the present investigation is to show that orbits may be stable if the perturbation of Jove by the planet can be neglected. This is the only approximation that Prof. Darwin has permitted himself, and he remarks "that for a very small planet the instability must accordingly be a very slow process, and I cannot but believe that the whole history of a planetary system may be comprised in the interval required for the instability to render itself manifest."