through the sieve faster. By again sifting the 4 ounces which had passed till 2 ounces passed, a further enrichment was found to have taken place. The 2 ounces were again sifted on the same sieve till 1 ounce had passed, which was again sifted till ¼ of an ounce passed. This was examined quantitatively, and found to consist of 54 per cent. of quartz and feldspar, and 46 per cent. of dense minerals. By vanning and submitting the residue to the action of a strong magnet, almost nothing but zircons and rutiles remained. It is needless to say that much remained with the sand, especially in the latter parts of the operation.

A current separater was tried, but it seemed more difficult to work, though perhaps it might answer better on a larger scale, where it might be set to work automatically. There was no difficulty in getting a considerable enrichment, but it was evident that a great deal of care would be required in "sizing" the particles before a good separation could be effected. The most hopeful method seemed to be that of washing away the medium-sized grains of sand and afterwards sifting the sediment.

Perhaps in some of the streams running through the Bagshot or other sands natural eddies may be found or formed artificially from which enriched sand may be dredged, or it may be got on the sea-shore under sand-cliffs.

The object of the present communication is to draw attention to the matter in hopes that some deposit richer in zircons than the Hampstead sand may be found. Much care must be taken in sampling, because the sands, having been deposited from currents, must vary in composition. A trial is easily made by anyone accustomed to use a microscope and who knows the minerals by sight under such circumstances. A thimbleful of such sand as exists at Hampstead is enough for a trial by vanning, but if one of the dense liquids be used, from 10 to 20 grains by weight of the sand will give a good microscopic slide of the dense minerals. It may of course prove that the Hampstead sand is a residue of denudation in which the denser minerals have accumulated. In that case it is not improbable that other similar deposits may be found, some, perhaps, much more zirconiferous.

On the whole it appears that the matter is worthy of further attention. In some future communication I hope to be able to give an account of the composition of the matter attracted by a strong magnet, and also of the grains of earthy-looking minerals over the density of 3·2, and of any richer deposit of zirconiferous sand of which I can obtain reliable samples.

ALLAN B. DICK.

THE ROLLING CONTACT OF BODIES.[1]

WHEN two solid bodies roll upon each other, points in the surface of one successively come into contact with corresponding points in the surface of the other in a way which differs essentially from that which occurs in sliding contact, and it is the nature of this rolling-contact that the lecturer proposed to discuss in an experimental manner.

In the first place, it is well to understand clearly the nature of the relative motion of the two points which come into contact when the surfaces are such that no appreciable distortion of them takes place, and for this purpose one of the two bodies must be at rest. These may respectively be taken as the plane surface of the ground and a circular disk rolling upon it. An approximate representation of this motion is given by the end of the spokes of a wheel without its tyre. In this case it is seen that a point of the rolling body, when it is just coming into contact with the fixed surface, does so in a direction at right angles to the surface at rest, and also leaves it in the same direction. This action is very similar in kind to that which occurs with the continuous circle formed by the tyre. The path of a point in the rim can be drawn in a way visible to the audience by means of a piece of apparatus consisting of two circular glass plates held together by a hollow brass spindle in which slides an arm carrying a brush. The brush traces the well-known cycloid, of which the only portion now to be considered is that where it directly approaches the surface beneath. This part is perpendicular to that surface, and when epicycloids are drawn, by rolling the disk upon the arc of a circle, the same fact is brought out.

One body may, however, not merely roll upon another, and a normal pressure be exerted, but they may exert a tangential force upon each other. It is convenient to keep these two cases separate; examples of them being respectively the wheels of a railway carriage and those of the locomotive which draws it along. It is to be noted that the object in the former case is to permit one body to move relatively to another without permitting sliding contact of their surfaces, whilst, in the latter case, in addition to this, the object is to obtain such motion. There are, however, many cases in which it is merely the motion of a body about one point which is required, such as when motion is transmitted from the edge of one rotating disk to another, and then this distinction still more closely holds, as the normal pressure is only obtained so as to insure the necessary tangential resistance. Thus the objects of rolling motion may be classed as being—

(1) To *allow* the relative motion of one body to another with which it is in contact without permitting relative motion of that part of their surfaces in actual contact.

(2) To *obtain* the relative motion of such parts of the surfaces of bodies as are not in contact by means of statical contact of the parts which are.

The lecturer then proceeded to consider the practical proofs of the smallness of the resistance to rolling in cases where the distortion of the surfaces in contact is very small, as illustrated by the small tractive force required for heavy bodies properly mounted on wheels or on roller-bearings; mentioning the case of a 12-horse-power engine, the shaft of which continued to rotate for three-quarters of an hour after the motive power was withdrawn; and another case, of a turntable weighing 14 tons, which was kept in motion by a weight of 3½ pounds acting upon it by means of a cord passing over a pulley. The small distortion of such surfaces when transmitting motion requiring expenditure of energy to maintain, was next made clear by giving certain facts as to the accuracy with which one surface was developed or measured out upon another. An account was given of experiments made with apparatus specially prepared by the lecturer to investigate this point. This apparatus consisted of two accurately turned brass disks properly mounted upon a frame, and the relative positions of these disks could be interchanged so that any minute differences in their peripheries could be detected. The experiments, which were very difficult to carry out accurately, showed that under the best circumstances, motion with an error of only 1 in 300,000 of the distance passed over could be obtained. This accurate measuring out of the surfaces one upon another was employed in various ways for purposes of measurement, and these, by means of models and diagrams, were briefly explained.

Although the foregoing facts prove that, under suitable conditions, distortion at the points of contact is very small, yet some resistance at these points *always* occurs, because no bodies are perfectly hard; and the nature of this distortion and consequent resistance was next discussed.

The explanation of the resistance opposed by a soft surface to a hard body rolling upon it, as first given by Prof. Osborne Reynolds, was applied by the lecturer to account for a very remarkable effect produced in the disk, globe, and cylinder integrator of Prof. James Thomson. This effect, which was the turning of the cylinder when the sphere was rolled along it in a horizontal direction, was reproduced by means of a large model. The action of a soft body rolling upon a hard surface was next considered, with the result of showing that the same reasoning would not account for the turning of the cylinder in the same direction as before with the above model, and the lecturer then proceeded, by means of diagrams, to offer an explanation of this and other phenomena. The various effects obtained with bodies of different relative degrees of hardness were discussed at length, but figures would be needed to make these points clear. Finally, an explanation was given of the cause of an error which always appeared in a certain important class of integrators caused by the slipping of the edge of a disk over a surface on which it rolled in circumstances under which it had apparently never been suspected that slipping did actually take place. This the lecturer had been enabled to discover and measure by means of a special piece of apparatus, a model of which was exhibited and the effects shown by its means.

The facts and reasoning, which were given in the lecture, all related to the rolling contact of bodies, and the lecturer ventured to think that, imperfect as the treatment of the subject had been, it was one of such importance, not merely from the point of view of the practical applications he had mentioned, but in its scientific aspect, dealing as it did from a novel point of view with the nature and properties of solid bodies, as to be worthy of being thus brought before the Royal Institution.

[1] Abstract of Lecture delivered at the Royal Institution, by Prof. Hele Shaw, on April 29.