bottom, had by seismic action, and the contraction of the earth's crust in cooling, been thrown or puckered into folds of which the upper portions have since been worn away by erosion and the hand of time, leaving the present almost upright or vertical layers of rock, which have assumed a fan-like structure, or have become divergent at top, as shown in the accompanying figure, by the infiltration of water and earth, or gravel in the interstices or interfoliations.

Now, had this rock been of a solid nature, or, exfoliated as it is, had each stratum been monolithic or a solid bed or layer of stone, and attached or rooted as the layers may be supposed to be and are, to the underlying portions of the layers below *C E*, the 46,875 tons pressure against the cliff or wall at *D C* would have been impotent to move the cliff; but each stratum or vertical layer is divided by planes of cleavage into parallelopipedons, as usual in such schistous or slate-like formations.

Again, had these planes of cleavage been normal or perpendicular to the strata, or, as they would then have been—horizontal—the mass of rock *A C E B* could be assimilated to a wall or series of juxta placed walls made up of dry stone with horizontal beds. But neither in this loose state could the static pressure of the water in the crevasse *C D* have caused the cliff *A B E C* to move; for the co-efficient of friction of dry stone on dry stone, if taken as given by Coulomb, Morin and others at .5—a force equal to half the weight of the cliff moved forward, or the half of 120,169 tons (60,084½ tons) would have had to be exerted to overcome the friction and thrust the strata forward.

Now, as will be seen, the face of the cliff at *B E* leans forward 6 feet in 60 feet (1 in 10) as measured from *B* to *P* (top of the debris of the fallen or overthrown portion of *B F* of the cliff, by the 7 inch push it received from the rear by the movement forward of the unfallen portion *A B E C*). Moreover the planes of cleavage inclined forward some 20° on an average to the horizon. This added to the 7° which the rock leaned forward at *B E*, thus giving the planes of cleavage an inclination of 27° to the horizon, reduced the resistance to overthrowal to one-half of what it would have been had the joints been normal to the vertical or plumb line; since to move a body down an inclined plane to 27°, or of which the height is twice the base, requires only half the weight, or a counterpoise of half the weight, to hold it there.

The force required to move or thrust the rock forward was therefore reduced by half; so that while, with horizontal joints or planes of cleavage, it would have required .7 (coefficient of friction of starting or of repose) of the 120,169 tons, or 84,128.3 tons, it only required half of this, or 42,064.1½ tons (the coef. of friction in motion being .7 of what it is at rest, or .7 × .7=.49, say .5), and it has been seen that the pressure exerted by the water was 46,875 tons, or just a little more than adequate to push the rock forward, though the result may also have been partly brought about by the joints of cleavage being filled with an unctuous stratum of clayey substance, and thus rendered more slippery, and the coef. of friction less than that assumed.

The most incredulous must now be ready to admit, however reluctantly, that since a water pressure of, say 47,000 tons, has been able to thrust forward an almost solid mass of stone of 65 feet, or very nearly in thickness equal to two-thirds the height or depth of the impounded water, and weighing 120,000 tons, or more than 2½ times the pressure or weight of water, so much the more readily would it have moved the resisting mass had it been composed of mere ordinary masonry, of which the cementing matrix had become more or less deteriorated or destroyed by water infiltration, frost, or other atmospherical or chemical causes.

If the writer does not in this case of the Bouzey dam use the .7 coefficient of static friction instead of the kinetic .5, it is that it must be deemed more prudent to recommend such a ratio, as the least concussion, the least shock of an earthquake, which almost all the world is still subject to every now and then, might, added to the pressure of water, start the dam, and thus render it obligatory, so to say, to use the safer figure .5 instead of .7.

There has not been that amount of scientific curiosity or interest displayed by engineers or technologists in respect to this question of the Quebec landslide of 1889, which the magnitude of the phenomenon, or its reduction to mathematical computation, would warrant, but now that it is shown to bear so thoroughly, so directly on an almost identical case of the overthrow of the dam at Bouzey, with its disastrous consequences of some 130 or more lives lost (the number of casualties in the cliff case being over 50), engineers may feel more interest in an examination of the overthrow, and the writer will at any time be most happy to accompany any engineer or other scientist to the site of action, at the southwest end of Dufferin Terrace, Quebec, and point out to them the proof positive of the moving forward of the 120,000 tons mass of cliff by just so many inches; the stopping short of the motion forward being due to the fact that the moment the fissure opened, the water fell within it and at once reduced the pressure, which, therefore, not being continuous as with a reservoir, the action was, so to say, instantaneous, and with nothing to follow up the effect and cause the complete overthrow of the 120,000 tons of cliff.

In conclusion, it will be seen that if in addition to the cementing material being destroyed by infiltration, and which, when taking the coef. of friction to be overcome at .33 or ⅓, would require the weight of the dam above any point in its height to be three times that of the pressure or weight of water above same point or level; if in addition to this the dam be water-logged or buoyant, or liable to become so, and thus lose so much of its weight, the thickness will have to be further increased by a percentage equal to the difference.

For THE CANADIAN ENGINEER.

WATT'S DIAGRAM AND MULTIPLE EXPANSION ENGINES.

BY JOSEPH R. OLDHAM, M.E., CLEVELAND, OHIO.

This is the age of scepticism with regard to authors, scientists, and, possibly, inventors also. Shakespeare has been strongly and authoritatively accused of plagiarism, or at least of actions very much akin thereto. Newton was not, it is said, a great and original physical law giver, but only a clever and clear essayist or delineator of the thoughts and writings of more enlightened thinkers and investigators, and now James Watt is only allowed to be an inventor who added two or three mechanical devices to Newcomen's steam engine.

Bunyan, I think, has been left in undisturbed possession of his own works, perhaps because it is thought he suffered enough torture in a damp prison, without having his dry bones disturbed by frightful accusations