and the river gorge, and/or a bending of the difference columns of the columnar rock like the bending of a laminated spring. I cannot accept this theory, however, as a complete explanation, because it is hardly conceivable that the country, under this assumption, could have remained intact during two and a half years' service after the water had been let into the headrace.

Again, the crack might have been attributed to the possibility that the pressure on the underlying strata at and near the power-house exceeded the crushing strength of these rocks, thus causing a rupture. If this were true, however, the movement should have continued when the very considerable hydrostatic pressure, due to water entering the crack, was added to the pressure that existed before the crack was formed. Furthermore, this explanation, which would have involved a permanent deformation of the rocks, does not conform with the fact that the disturbed block of the country, after the water had been lowered in the headrace, began to move back within a few hours and continued until the greater part of the distance towards its original position was covered. For the same reason it also seems unlikely that the crack is to be attributed to any settlement of the rocks due to a possible wash-out of fine material in the comparatively soft strata underlying the columnar rock.

It might finally be conjectured that the damage was due to the existence of open cracks in deeper strata, and that in these cracks water was impounded to a great pressure, consequent to an earth-movement closing the outlet from these cracks. I have not been able to prove beyond doubt that such causes of damage did not exist. Therefore this tentative explanation must not be overlooked with regard to remedial measures, even if it can be shown in the following that destructive forces due to other causes started to operate as soon as water was let into the headrace.

The primary cause of the rupture must, in my opinion, be traced back to the presence of water in the headrace. As the water cannot readily flow by gravity through the pores of the rock or in the narrow channels between different columns, the chief mechanical agent causing water to enter the rock must be attributed to capillarity.

The columnar rock at Arapuni, being of a porous nature, is particularly subject to the effect of capillary forces. This may be shown by the simple experiment of introducing a dry piece of the rock into water, when it is found that the liquid is avariciously absorbed. It is also easily conceivable that capillary action takes place in the joint planes between the different columns of the rock.

Capillary phenomena in natural ground assume many different aspects and constitute very complex problems. Every aspect of capillarity that may be conceived with regard to the case at Arapuni seems to contribute to a plausible explanation of the initial crack.

One of the most important characteristics of the columnar rock is the swelling of a dry piece of the rock when being saturated. Whether this is a direct or an indirect consequence of the capillary action is insignificant. It has been shown experimentally that the expansion per unit length due to saturation of a dry specimen is very great, amounting in one particular test to about 1 part in 2,000. Even allowing for the fact that probably most of the swelling takes place during the first stages of the saturation process, and the fact that tests have shown that the natural rock must have been nearly saturated before the water was let into the headrace, the residual swelling in the ground at Arapuni may account for considerable stresses between strata of unequal saturation.

Another aspect of the capillarity has reference to the presence of gas in the ground. There is every evidence that water has been brought by capillarity into the ground under the bottom of the headrace, thereby causing a compression of gases in the deeper strata. This aspect of capillarity may account for the eventual escape of remnants of air through the bottom of the headrace. It has not been possible to ascertain whether gases have also escaped from the deeper parts of the ridge. It is probable, however, that gases have also existed in these places, and that the gases have been compressed by the downward-travelling capillary water. The compressed gases have eventually tended to lift the overlying strata, and thus contributed to the cause of failure.