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V.—THE PLASTICITY OF ROCKS AND MOUNTAIN BUILDING.

By R. M. DEELEY, M. Inst. C. E., F.G.S.

BRITISH geologists must have read Professor Coleman's Address to the Geological Section of the British Association with great pleasure and interest. As Professor Coleman remarks, geology finds some of its most seductive problems in the neglected extremes of the earth's history. Out of the apparent tangle of the 'drifts' and Archæan Gneisses Canadian geologists are now evolving an orderly sequence which must exercise considerable influence upon the progress of geology in other lands. The seemingly unnatural conjunction of Pleistocene and Archæan, Professor Coleman states, has furnished the clue to certain puzzling problems of the Archæan.

During a trip from Regina to Winnipeg this summer I had the pleasure of riding at the end of a Canadian Northern train with a young railway engineer, and discussing with him the problems that

have to be faced to keep the line in good condition during the winter. In many places the line passes over areas of waterlogged ground. During the winter the cold penetrates the earth and freezes this water to depths of 10 feet or more. The ice thus formed expands, raises the earth into domes and makes the road bed very irregular. It is the business of the engineer to see that these irregularities are made good by packing up the line, a troublesome task with the temperature many degrees below zero F.

The 'Canadian shield' consists of a base of granite or gneiss rising into numerous domes which are somewhat irregularly scattered over the area. Upon them rest the Keewatin and newer rocks. After the deposition of the Keewatin Series the land rose and formed a great mountain system, which was afterwards almost completely destroyed by denudation.

The rising of this mountain system seems to have been due to the heating up of portions of what are now known as the Laurentian granites, rather than to crushing or folding. We must regard the mountain ranges as floating upon the earth's crust, their lightness being due either to their high temperature bases or small relative density. Crushing and folding, apart from the heating that may result from it, do not seem competent to alone form high mountain systems; for the folds would not cause a great rise of the surface—the mass would sink as do the sediments deposited upon a sea-bottom. It seems most reasonable to regard mountain ranges as being due to the high temperature of the deep-seated rocks causing an uplift by expansion, just as the railway track is lifted by the freezing of the water beneath. If this view be the correct one, then it follows that the disappearance of the mountain range must have been due to the cooling down of the Laurentian rocks beneath; for otherwise the mountain peaks would have risen as fast as they were denuded.

Professor Coleman gives a very interesting explanation of the reason for the formation of the dome-shaped masses of granite and gneiss upon which the Keewatin rocks rest. He suggests that the lower rocks became plastic, that the Keewatin above was unequally heavy, and that the granite rose in domes where the lightest loads were situated.

It must be admitted that the formation of great depressed areas, such as that of Lake Superior, is a difficulty. Here it is considered that the granite below became so fluid that it was ejected at the edges and allowed the area from beneath which it came to sink bodily. But if such be the case, how is it that this portion of the earth's crust did not rise again? It may be that to some extent the explanation is that the deeper portions of the earth's crust are plastic, not viscous. Plastic materials do not flow unless the stress exceeds some particular limit. A mountain range may therefore be stable although its height may be hundreds of feet greater or less than is warranted by the density of the crust at the spot.

Professor Coleman recognizes that the weight of the ice which once rested on the 'Canadian shield' depressed it, and that since the ice melted away there has been a rise of the area. He says these sinkings and risings must be accomplished by plastic flow outwards from

beneath the loaded area, and inwards towards the area relieved of its load. He rightly uses the word plastic here. And here is another contrast between the properties of the ice-sheets which played an important part in the formation of some Canadian deposits and the rocks themselves. The ice moved much as a truly viscous liquid would have done whilst the deep-seated rocks underwent plastic deformation. The ice formed and maintained an almost level upper surface like that of the Antarctic Plateau, whilst the plastic rocks allowed themselves to be cut into hill and dale until the stresses produced were sufficiently great to allow of plastic flow. Plastic solids never reach a condition in which the stresses are equal in all directions; they cease to flow when the stress falls below some particular value. Although it is true that the solid, liquid, and gaseous states are continuous, the liquid differs from the plastic solid inasmuch as it yields to any stress however small, whereas the solid does not begin to deform continuously until the unbalanced stress reaches some particular value depending upon the nature of the material and the temperature. With rise of temperature this limiting stress becomes smaller and smaller, and when it falls to zero the solid becomes a liquid. For all practical purposes, however, substances which flow (shear) under very small stresses may be regarded as viscous (liquids). Professor Coleman shows that although the 'Canadian shield' was depressed by the weight of the Pleistocene ice resting upon it, it has not risen as much as might have been expected considering the weight of ice melted away; probably this is also owing to the *plastic* nature of the earth's crust.

There is another interesting property of plastic substances which might be referred to. When a test bar of iron or steel is drawn out to some extent in a testing machine and its length then measured, it will be found that, after giving it a light blow, it will have shortened again somewhat. If the bar has suffered compression it will have lengthened again. In many cases it has been found that an earthquake has resulted in a rise or fall of the land locally. May it be that the jar of the strained plastic crust has released strains in a similar manner and given rise to sudden change of form?

VI.—NOTE ON THE TYPE-SPECIMENS OF *AMMONITES CORDATUS* AND *AMMONITES EXCAVATUS*, J. SOWERBY.

By G. C. CRICK, F.G.S., British Museum (Natural History).¹

J. SOWERBY'S type-specimens of *Ammonites cordatus* and *Ammonites excavatus* have been dealt with comparatively recently by Miss M. Healey in the *Palaeontologia universalis* (sér. II, fasc. 1, August, 1905, Nos. 94, 94a, and 92, 92a, 92b respectively), but her statements require a little modification in some details. Both specimens are in the British Museum collection, and were described and figured in the *Mineral Conchology*.

1. *Ammonites cordatus*.—Miss Healey gives the date of publication of this species as 1812, and observes that "The date 1813 is given on the plate, but on the title page the date is 1812". From this remark

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