

such a source. In outcrops of an Archæan granite, the feldspar and mica are usually as perfect as when made in Archæan time, excepting a thin layer of surface alteration. So in many of the outcrops of trap, the pyroxene and labradorite are still unchanged pyroxene and labradorite; and this, though millions of years have intervened since the outflow; and millions of years of uniformity are sufficient to prove stability. The thin layer of surface alteration indicates the depth of permeation, and to this depth there is alteration, but not metamorphism. Buried in subterranean waters, the conditions would be the same except that even surface alteration would be prevented; for a sandstone that will fall to pieces when exposed to the air will make durable underwater abutments. A trap ledge that decays to a depth of two or three feet, when it is above the tide-level, will remain solid and wholly unaltered below low tide. Pyrite and other iron-bearing minerals oxidize, and help on the decay in the outer layer where it is exposed to the air; but below this they remain unchanged. White marble, although a more porous rock than most others, usually retains its whiteness perfect through the body of the rock, its pyrite and other imbedded minerals losing nothing in their luster or composition.

2. *Heat above the ordinary temperature usually necessary.* — Lyell attributed metamorphism to the heat of the earth's interior. The rocks bore evidence, in the position of the beds, of upturnings and of great pressure; and those which were left deepest as a consequence of the movements became crystalline or metamorphic. They were hence also called by him *Hypogene* rocks. Effects from dynamical forces were here recognized, but the heat was statical heat.

This continued to be the theory of geologists until 1868, when Henry Wurtz, of New Jersey, in the *American Journal of Mining*, announced the principle that metamorphism was due to heat derived from the friction attending the upturning of the rocks, that is, to heat of dynamical origin. In the editions of this work since that date this theory of regional metamorphism, through heat of a dynamical source, has been adopted. But it has also been recognized that heat of a dynamical source has been more or less supplemented by heat from the earth's interior, that is, by statical heat. At the same time statical heat has been referred to as also the source of local metamorphism. It should be observed here that it is the heat that is dynamic, not the metamorphism; for the metamorphism is the same whatever the source of the heat, whether dynamical or statical, except in some minor points due to pressure, as explained beyond.

3. *The presence of moisture.* — All rocks are permeated by moisture, and this permeating moisture is sufficient for all metamorphic results. The amount ordinarily present is stated on page 205. If 2.67 per cent, which is less than the average, the amount would correspond to two quarts of water for each cubic foot of rock. At one per cent it would be one pound, and, therefore, one pint of water to 100 pounds or two thirds of a cubic foot of rock; and, since a pint contains 29 cubic inches of water, this amount would