have been melted to produce the supply, since all rocks of the supercrust contain traces of moisture (page 205). But this is not the chief source of the vapor of water.

Among the other materials of the vapors, *sulphurous acid* ($SO_2$) is probably the most abundant. It has the smell of burning sulphur. It is always present, and probably comes from iron sulphides in the melted rocks, since they are often sparingly present in the solid lavas. *Hydrogen* is sometimes present; it may come from the dissociation of the elements of water ($H_2O$), or from any oxidation in the lava in which the oxygen used is derived from water. *Hydrochloric acid* (HCl) is one of the gases when sea water gains admission to the hot lavas. *Carbonic acid* ($CO_2$) may be emitted if any limestone ($CaO.CO_2$) exists below in proximity to the melted lavas. *Carbonic oxide* (CO) has been detected by W. Libbey in spectroscopic observations of the flames, 1, 2, or 3 feet high, that appear about the lava vents of Kilauea. The above, with more or less of atmospheric air, are the chief gases of the melted lavas. There are other vapors given out by solfataras, but these take no part in the eruptive work of the volcano.

The mechanical work of the vapors is due almost wholly to the vapor of water. In view of the relation on Hawaii between times of eruptions and the rainy season, and between length of lava-column above the sea and projectile force, there is strong probability that *fresh* waters are in many volcanoes the chief agent. Whenever subterranean waters in their descent below the surface approach the hot rocks about the lava-column, they are converted into steam; and the amount of steam generated from even a small continued supply of water would be so large (in view of the fact that at the ordinary pressure one cubic foot of water will yield 1700 cubic feet of steam) that it could not all escape outward through the rocks, but in part would be forced into the rising lavas of the conduit. Moreover, it has been experimentally demonstrated by Daubrée (1879) that, under such circumstances, a molecular absorption of the steam would take place against any pressure outward that might exist within the heated column.

3. *Effects of vapors.* — (*a*) *Projectile effects.* — The escape of vapor and its expansion encounter resistance in consequence of the cohesion of the liquid material, which resistance is proportional to the strength of this cohesion, or is conversely as the degree of liquidity. Water, in boiling, lets very small bubbles of steam through easily; and the elastic force of the steam of the bubble makes low jets, one or two inches in height. But the elastic force of a small bubble of vapor is too feeble to break its way through lava; enlargement, therefore, goes on until the force is sufficient to overbalance the resistance; then comes the break of the liquid lava-shell of the bubble, and the projection of its fragments vertically or nearly so into the air, — vertically, because the shell is thinnest at top. The projectile force thus depends largely on the size of the bubble, or, what is equivalent, on the viscidity of the liquid lava, and on the rate of supply of vapors seeking to escape.

On account of the remarkable liquidity of basaltic lavas, the projectile force required to break a way through may be so small as to throw the lava