In the valley-ore mines, tubes of limonite that enclose more or less sand are common. This variety is known as pipe ore and was the principal ore mined in many places. The largest tubes are a foot in diameter, although most of them range from one to two inches. Pieces more than eight inches long are rare but as the pipes are invariably broken at each end they may originally have been several feet long.

Fragments of limonite in the form of irregular particles or plates are invariably present in large quantities. They represent broken pieces of all the kinds of ore that have been described. As the rock disintegrates and clay and iron ore are formed, there is a tendency for the entire mass to move down the slopes, which results in the breaking of the more fragile pieces of ore. The loss in bulk that takes place as the rock undergoes changes in composition also permits the downward settling of the material and the breaking of many of the masses of ore. The larger pieces of the fragmental ore are recovered in the washers, but the finer ones are lost. Ore of this kind is known as "wash ore."

**Chemical Composition**

*Minerals associated with the ores.*—The composition of the limonite ores is extremely variable and depends largely on the physical character of the material. The presence of certain minerals closely associated with the limonite also determines the composition. The impurities in the ore comprise only a small number of minerals, principally quartz, jasper, clay (kaolin), pyrite, pyrolusite, and wavellite.

Siliceous matter of different kinds can be detected in almost all the mountain ores. In some places it represents the fine grains of sand of the original sandstones or sandy limestones, in others secondary chert or jasper, and in still others vein quartz. Clay fills many of the cavities in the ore, and much of it is not removed in passing through the log washers. Very small particles of pyrite can be seen with the naked eye in some specimens, particularly in the ore from the lower levels of certain mines.

Pyrolusite is intimately associated with the limonite and is generally detected by the dark color of the ore. Occasionally dendritic crystals of pyrolusite form a thin cover to the limonite. In general the mountain ore contains a higher percentage of manganese than the valley ore.

Most of the phosphorus in the ore is probably contained as aluminous and iron phosphates, such as wavellite [(AlOH)$_3$\cdot$(PO_4)\cdot$5H$_2$O] and cacoxenite [FePO$_4$\cdotFe(OH)$_3\cdot$4H$_2$O].

*Mountain ores.*—Although the sulphur usually is low, some mountain-ore mines had a large amount of pyrite in the lower levels. It is probable that deeper workings may show an increase of pyrite in almost all the mines, but the decrease in the content of iron and the increased expense of mining has prevented the exploration of the lower portions of the ore bodies in most places. Examination of hundreds of analyses made by the chemists of the Thomas Iron Co., the Bethlehem Steel Co., and the Crane Iron Co. shows that the mountain ores average about 40 percent iron, 20 percent silica, 0.4 percent phos-