b. Where the areas of these materials are in structural continuity with the Hardyston, are found together with the Hardyston, or are on the higher slopes or tops of pre-Cambrian hills they should be considered as having been formed by replacement of the Hardyston.

The above quotation clearly shows that some of the jasper associated with the iron ore has been formed by the replacement of quartz of the sandstone. However, recent observations seem to indicate that most of the jasper has been formed by segregation of silica as replacements of part of the argillaceous beds that overlie conformably the basal sandstones. Between Mountainville and Emmaus the jasper seems rather definitely to overlie the main sandstone beds. Some large masses of jasper are in place only a few feet from the sandstone. The sandstone beds dip beneath the jasper masses, in which stratification lines have been mainly obliterated.

The nearest approach to an exposure of any of the argillaceous beds is seen in a sandstone quarry northeast of Hellertown, Northampton County. The strata are weathered and porous, which seems to indicate that some soluble material has been removed. It may well be that the slates or shales were originally calcareous and similar to those calcareous shales of New Jersey described below. At the same time that underground water removed some of the material from the shales, or later, the jasper and iron minerals were segregated.

George W. Stose and Anna Jonas Stose believe that the jasper was formed by the replacement of limestones at the base of a great overthrust block that pushed great masses of gneiss over the limestones. This theory seems untenable as will be discussed in the chapter on Structure.

Shales.—In scores of places limonite iron ore has been mined in the past from the Hardyston, as will be described in a later chapter. The ore was generally found in a matrix of yellow, red, white or black clay. An examination of numerous old mine dumps reveals many angular blocks of jasper, ferruginous chert and occasional sandstones. The occurrence leads to the conclusion that the ore bodies lie within this formation and it, therefore, is necessary to account for the origin of the clay. The siliceous types of rocks described above can not have been the source of the clay so it seems necessary to assume that the Hardyston contains much shale, especially in the upper portion, although the writers have never seen any development of shale in the formation in this region such as must have been present to explain the large deposits of clay. An exposure of calcareous shale near the top of the formation is reported in the bed of a brook near the old Thatcher Mine east of Stewartsville, N. J.

H. M. Chance (1908), who operated some of the mountain-side iron ore mines more than 20 years earlier, drew two sections illustrating the occurrence of the ore. He showed a thickness of about 150 feet of sandstone overlain by about 450 feet of slate. Within a depth of 100 to 300 feet from the surface the slate has changed to clay. The ore is represented as occurring in definite layers roughly parallel to the bedding of both the sandstones and the overlying unaltered slates. Since Chance had opportunities to see the deposits in place, a situation that no longer exists, it seems that his sections may be relied upon