Pennsylvania's
Fragipans

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INTRODUCTION

By

Edward J. Ciolkosz and William J. Waltman

Fragipans are of great interest to soil science. Particularly Pennsylvania soil science because they are found in soils that cover about 30% of Pennsylvania's land surface (Ciolkosz et al., 1999). Although very abundant, their distribution is not equal across the state (Figure 1).

Fragipans have been studied for decades, and a number of reviews have been published (Grossman and Carlisle, 1969; Smalley and Davin, 1982; Smeck and Ciolkosz, 1989; Glocker and Quandt, 1993; and Ciolkosz et al., 1995). The most recent of these reviews (Ciolkosz et al., 1995) is of particular interest to Pennsylvanians because it targets Pennsylvania's fragipans. In addition to this review, other information on fragipans in Pennsylvania soils has been gathered.

Figure 1. Percent of land area within various Pennsylvania physiographic areas that have fragipans in the soil.

Much of this information has been published, but some has not been published. Although much of the published and unpublished information is available, it is in diverse locations. Thus, the intent of this publication is to bring together this information. This will be done by presenting in this introduction a brief discussion of information (primarily unpublished) under the headings fragipan genesis and fragipan hydrology. In addition, three of the published papers with applications to soil genesis are also presented.

Fragipan Genesis

The genesis of fragipans as viewed by the authors is given in the last reprinted paper in this publication (Ciolkosz et al., 1995). In general, fragipans are viewed as pedologically rapidly developing horizons (Bx) that, once formed, degraded with time. Early in the study of fragipans, it was debated if a fragipan was geologic or pedologic? A part of this mindset was rooted in the fact that in the 1950's and 60's, fragipans in Pennsylvania and elsewhere were described as having both Bx and Cx horizons. The separation in the late 1960's was made on whether the material had intraprism clay films (mainly in the pores). The very coarse prismatic structure was not considered a factor in B vs C horizon separation. In 1973, during a field trip at Cornell University, Dr. Marlin Cline (he was retired at that time) was asked about the B vs C question, and he said that if the structure is pedogeneic, it is a B horizon. That statement convincingly indicated that the term Cx was inappropriate for fragipan material that had very coarse prismatic structure. Since that time, the Bx concept has pretty well been accepted, and the Cx dropped. This acceptance somewhat parallels the acceptance that Cca horizons (accumulation of illuvial $CaCO_3$ in soils with limited rainfall) are really Bca (now indicated as Bk horizons). These changes of mindset apparently have acknowledged the pedogenesis of both calcic and fragipan horizons in soils.

One aspect of Pennsylvania fragipans has been studied but as yet not published. This is the bulk density relations of fragipans. In 1993, the SCS (now NRCS) proposed that bulk densities of 1.60 (with ≥ 25% clay) to 1.65 (with clay content < 25%) be used to define a fragipan (Glocker and Quandt, 1993). Work on Pennsylvania fragipans (Figure 2) indicates that loess fragipans and the upper fragipan horizons in old alluvium have bulk densities less than 1.6. Thus, many Pennsylvania fragipans did not meet this 1.6 requirement. The bulk density proposal has not been implemented by the NRCS. The data in Figure 2 also shows that fragipan bulk density is higher in glacial till and colluvium than in loess, and it is somewhat in between these values in old alluvium (terrace deposits). In general, these data follow the conclusions given in Table 3 of Ciolkosz et al. (1995) (the last reprinted paper in this publication), which indicate that till, and colluvial fragipans show a greater degree of development than loess fragipans. This general observation needs to be tested more rigorously, and hard data is needed to support this

Figure 2. Mean (fine earth < 2 mm) bulk density of fragipan horizons (upper and lower) and overlying horizons grouped by parent material. Within each horizon, values followed by different letters are significantly different at p = 0.05.

apparent relationship. Although more study is needed, intuitively increasing fragipan development should be accompanied by increasing bulk density. Figure 2 also indicates that the first fragipan horizon is less dense than lower fragipan horizons. This also parallels field observations that indicates that the first fragipan horizon is a less well-developed fragic zone. These observations and data indicate that degradation is taking place in the upper part of the fragipan. Observations of loess fragipans in the middle and lower Mississippi River Valley show a much greater degradation in the upper part of these fragipans. This has lead the NRCS to define the fragipan as a zone that must have 60% or more of the horizon firm or very firm and brittle (Soil Survey Staff, 1999). Pennsylvania fragipans do not exhibit a large amount of none brittle volume in their degrading horizons.

The last subject on fragipans to be discussed is their genesis with time. With few exceptions, there is very little discussion in the literature on what happens to fragipans with time. The conclusions and model (Figure 3) of Ciolkosz et al. (1995) indicates that if the landscape stays stable, fragipans will degrade with time. They will degrade faster in well drained soils than in poorly drained soils. The study by Waltman (1981) of somewhat poorly drained Wisconsinan and Pre-Wisconsinan glacial till fragipan soils showed a distinctive degradation of the fragipan when the young fragipans were compared to the old fragipans. Waltman (1981) presented a number of indicators of degradation (pedogenesis) which included clay mineral weathering, iron oxide accumulation, clay accumulation, and interestingly, a decrease in bulk density with increased age of the fragipan. It is hoped that a complete presentation of this study will be forthcoming. Another interesting note on the amount of time required for a fragipan to form is the conclusion of Cremeens et al. (1998) that a fragipan has formed in alluvium in the Lock Haven area in 4,500 years. This study site was visited while it was being investigated, and no

Figure 3. Sequential developmental model for well drained soils developed in glacial till in Northeastern Pennsylvania. Please see Ciolkosz et al. (1995) for a detailed discussion of phases 1-4.

zone was observed that was identified as a fragipan. Although no fragipan was observed at the site, there was a zone that had some features that indicated that a fragipan was forming. This site was somewhat similar to the Atkins site of Bilzi and Ciolkosz (1977) in which some fragipan character was noted in the Bw horizon of the soil that was dated at 1955 ± 80 years BP. In addition, bulk density measurements were made from samples above and in the pan-like zone at the Lock Haven site by the Penn State Soil Characterization Laboratory, and no difference was noted in bulk density between these two zones. Thus, it was concluded that the zone that was called a fragipan at the Lock Haven site would better be called a protofragipan (proto-meaning earliest phase of).

Fragipan Hydrology

The most important impacts that a fragipan has in a soil is its effect on root growth and the water regime of the soil. These impacts greatly affect the use of fragipan soils for purposes that range from sewage drain fields to agriculture production. Following will be a brief mention of the information both published and unpublished on this general subject area for Pennsylvania fragipans.

Fragipans restrict the down growth of roots through restricted root penetration and the creation of seasonal saturated conditions. Subsoiling has been proposed to increase the effective root depth of fragipan soils. Stout and Ciolkosz (1974) tested this proposal in a laboratory study. In this study, broken fragipan material (untreated and treated with aggregating agents to stabilize the broken material) was subjected to wetting and drying cycles. They concluded that aggregating agents can increase the rooting depth; but with time, the fragipan material disperses and the material becomes impermeable. The untreated material dispersed immediately. Thus, in the short run, in the field the aggregating agent approach may be useful, but with time, the treatments would fail, unless natural processes such as structure formation would stabilize the material.

Field studies on Pennsylvania fragipan hydrology have been conducted by Palkovics et al., 1975; Palkovics and Petersen, 1977; Daniels, 1992; Daniels and Fritton, 1994; Day et al., 1998; Calmon et al., 1998; and Jabro and Fritton, 1990).

The studies of Palkovics and Petersen (1975, 1977) in colluvium in the Ridge and Valley area, Calmon et al. (1998) in glacial till in the northeast area, and Latshaw and Thompson (1972; also see Simpson, 1979) in the southeast area document the season trends of saturated conditions above the fragipan in leaf off (late fall, winter, and early spring) seasons in Pennsylvania. In a slightly different type of flow study, Day et al. (1998) measured the amount of lateral flow above the fragipan and between the prism faces in a glacial till fragipan in Wayne County (northeastern PA). They concluded that 63% of the input water moved laterally above the fragipan and 10% moved laterally through the prism face area of the upper 50 cm of the fragipan. The remaining 27% moved laterally below 50 cm or vertically through the fragipan. Observations (primarily in Ridge and Valley sideslope colluvium) indicate that fragipans may not be continuous on the landscape; therefore, there may be sumps that drain water downward within a fragipan landscape. The lack of continuity in fragipans of the Ridge and Valley was observed in colluvial parent materials in which the parent material changed rapidly, which apparently did not allow fragipan formation in some of the material. In addition to having sumps, fragipans tend to have an irregular surface. This irregularity is usually not noticeable in soil pits, but it is on lower side slopes in roads cuts (relatively fresh) in the spring as the top of a wet zone (darker color) as lateral flow discharge from the cut surface and runs down the ditch bank.

The study of Daniels and Fritton (1994) documented that a water mound can build up above a fragipan in conditions similar to septic tank drainage fields. This build up is due to the low permeability in the fragipan. The low permeability of fragipans, as pointed out by Olson (1985), may be in part due to a relatively large amount of fine low water conducting pores and a small amount of coarse high water conducting pores. With few exceptions (Jabro and Fritton, 1990; Palkovics, 1973), little data is available on the hydraulic conductivity of Pennsylvania fragipans. Although this is the case, there have been percolation tests done on many Pennsylvania soils (many of which have fragipans) as a part of the soil characterization program in Pennsylvania (Ciolkosz et al., 1998), and the data are available in the Penn State soil characterization lab database (Ciolkosz, 2000). The leap from percolation rate to saturated hydraulic conductivity is great, and as yet, no one has attempted to distill any hydraulic conductivity information from this source.

The effect of a perched water table on surface runoff of a fragipan soil is presently being studied by Brian Needleman (Needleman, 2002). This study is being conducted in the USDA ARS watershed in eastern Pennsylvania; and in the near future, these results will be available.

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