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Isopach map and regional correlations of the Fire Clay tonstein, central Appalachian Basin

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ABSTRACT

A tonstein that occurs within the Middle Pennsylvanian Fire Clay coal zone is a widespread marker bed that has been used for correlation purposes since the early 1900's. Seiders (1965) first demonstrated that this tonstein is an altered volcanic air-fall ash deposit. Lyons and others (1992) have correlated the tonstein across Kentucky, West Virginia, Virginia, and Tennessee on the basis of mineralogical and geochemical "fingerprinting". The correlation of the tonstein, herein often referred to as the Fire Clay tonstein over this four-state area, and the abundance of thickness data on this tonstein permit construction of an isopach map that depicts its distribution. In general, the tonstein thins from Tennessee, where it is up to 12 inches (30 cm) thick, northeastward to central West Virginia, where it is less than 4 in. (10 cm) thick, and its preserved area is about 14,300 sq. mi. (37,000 sq. km). The preserved volume is 0.90 cu. mi or 3.7 cu. km. The compaction ratio of ash to rock is 6:1, so the original ash volume deposited in this area was 5.4 cubic miles (22.2 cubic kilometers). The trends in thickness suggest the source of the ash was a volcano in the Yucatan tectonic plate, which, had it not moved relative to the North American Plate since the Pennsylvanian, would be located in the present Gulf of Mexico, south of Louisiana. The thickness and extent of the tonstein appears to have been controlled partly by winds and partly by the surface on which it landed. Its absence in some areas indicates that the ash was not preserved, probably because it floated downstream as pumice.

INTRODUCTION

Statement of the problem

A flint clay in the Fire Clay coal zone in Kentucky, West Virginia (formerly named the Chilton and the Hernshaw coal bed) (Blake, 1994), and Virginia (where it is also known as the Phillips coal bed), and within the Windrock coal bed of Tennessee, herein called the Fire Clay tonstein, has been known for many years as a distinctive lithologic unit and marker bed. Seiders (1965) and especially Lyons and others (1992) have shown that the tonstein is an altered volcanic ash bed composed principally of well-crystallized kaolinite and microcrystalline quartz. The phenocrysts in the tonstein are 60 to 85 percent quartz (SiO2) and 12 to 39 percent brookite (TiO2). The brookite proportion is diagnostic of the Fire Clay tonstein because none of the other tonsteins in the Pennsylvanian section of the Central Appalachian Basin contain such a large proportion of brookite. In Tennessee, the tonstein of the Windrock coal bed is accepted by Englund (1968) as a correlative of the tonstein of the Fire Clay coal bed. Lyons and others (1992) showed that the tonstein near the top of Walnut Mountain coal bed which occurs near the top of Walnut Mountain, Tennessee, is also a correlative of the tonstein of the Fire Clay coal bed. The nomenclature of regionally correlative Pennsylvanian stratigraphic units below and above the Fire Clay tonstein is shown in figure 1.

This study was undertaken to determine the regional distribution and thickness variation of the Fire Clay tonstein in order to delineate the paleo-direction of the source volcano and to complete a regional correlation of this marker bed in the central Appalachians.

Figure 1. Stratigraphic position of the Fire Clay tonstein within the Fire Clay coal bed; Blue indicates regionally correlated marine zone.
Abbreviations: c, coal; cz, coal zone; Mbr., member; mz, marine zone; Sh., shale.

			Age (my)	Tennessee	Kentucky	Virginia	West Virginia
PENNSYLVANIAN (UPPER CARBONIFEROUS)	Middle Pennsylvanian	Atokan	312				
				Sharp cz			
				Magoffin mz.	Magoffin mbr.	Magoffin sh.	Winifrede Sh. Mbr.
					Taylor c.		
				Big Mary c.			
			313	Windrock	Fire Clay	Fire Clay (Phillips)	Fire Clay (Hernshaw)
		Morrowan		U. Pioneer c L. Pioneer c.	Whitesburg cz.		Cedar Grove c.
				Jordan c.			
				Elk Gap c.			
				Kendrick mz.	Kendrick Mbr.	Kendrick Mbr.	Dingess Sh. Mbr.
				Lick Fork c.	Williamson c.	Williamson c.	Williamson c.
			314	Jellico c.	Upper Elkhorn No. 3 c.	U. Cedar Grove c.	
				Blue Gem c.	Upper Elkhorn No. 2 c	L. Cedar Grove c.	
				Black Wax c.	Upper Elkhorn No. 1 c.	Alma c.	
				Swamp Angel c.	Lower Elkhorn c.	Campbell Creek c.	
					Betsie Shale	Betsie Shale	Betsie Shale
			315				

Data sources

Data from 143 1:24,000 scale United States Geological Survey Geologic Quadrangle maps in Kentucky were compiled at a scale of 1:500,000 (see references cited). West Virginia County Reports (Hennen, 1914, 1915, 1917, 1919; Krebs and Teets, 1913, 1914; Krebs, 1914, 1916; Hennen and Reger,1914; and Reger,1915, 1920a, 1920b), are the primary sources of data from West Virginia. Data for Virginia are largely from USGS Geologic Quadrangle maps along the Kentucky-Virginia border. Point data for Tennessee is largely from Glenn (1925) and Englund (1968). USGS Bulletin reports (Englund, 1955; Adkison, 1957; Welch, 1958; Bergin, 1962; Patterson and Hosterman,1962; and Adkison and Johnston,1963) provided abundant point data for specific quadrangles in Kentucky. Additional data came from logs of drill holes in Huddle and Englund (1966) and Alvord (1970), published measured sections in Stevens (1979) and Eble (1988), sections measured during the course of our tonstein studies (Lyons and others, 1992), and unpublished drill hole logs in our possession.

Geologists working in eastern Kentucky were aware of the Fire Clay tonstein as one of the three most distinctive marker beds in the Pennsylvanian (McFarlan, 1943; Huddle and others, 1963; Huddle and Englund, 1966). However, on their published maps, they usually reported only the lithology and maximum and minimum observed thicknesses of the bed. Some mappers outlined the details of the distribution of the bed in their quadrangles and also specified where it was absent, as did Alvord and Holbrook (1965) and Jenkins (1967). Geologists preparing the West Virginia County geologic reports were aware of the tonstein of the Chilton and Hernshaw coal beds (equivalent to the Fire Clay tonstein of this report). The occurrence of the flint clay in their measured sections at some places was noted simply as a pavement under the coal; thicknesses were rarely reported. Nevertheless, the geologic quadrangle maps and the county reports provided a general outline of the distribution of the Fire Clay tonstein. Bascomb Blake and Alan Keiser, of the West Virginia Geological and Economic Survey, graciously supplied recent locations and thicknesses of the Fire Clay tonstein over a large area of West Virginia from their unpublished data.

The U.S. Geological Survey Bulletins prepared during coal studies in Kentucky (1955-1960) contain large amounts of data that are useful for paleogeographic analysis of the Fire Clay tonstein. Also, closely spaced measured sections provided abundant control for isopachs in the Salyersville North (Adkison and Johnston, 1963), White Oak (Adkison, 1957), Seitz (Bergin, 1962), and Cannel City (Englund, 1955) quadrangles. Certain sections, identified on the map as USGS sections, were measured and sampled during a mineralogical and geochemical study of the Fire Clay tonstein (Lyons and others, 1992). The point data and the general information from the geologic quadrangle maps are sufficient for the construction of an isopach map of the Fire Clay tonstein.

DISCUSSION

The isopach map of the Fire Clay tonstein is shown in figure 2, the data on which the isopach map is based are shown in figure 3, and the areas covered by published sources of the data are shown in an index map (fig. 4). The tonstein extends from Tennessee northeastward into West Virginia, is thickest in Tennessee, (12 inches (30 cm)) and thins to generally 4 inches (10 cm) or less in southern West Virginia.

Figure 2. Isopach Map of the Fire Clay tonstein (flint clay) Contour interval 5 centimeters

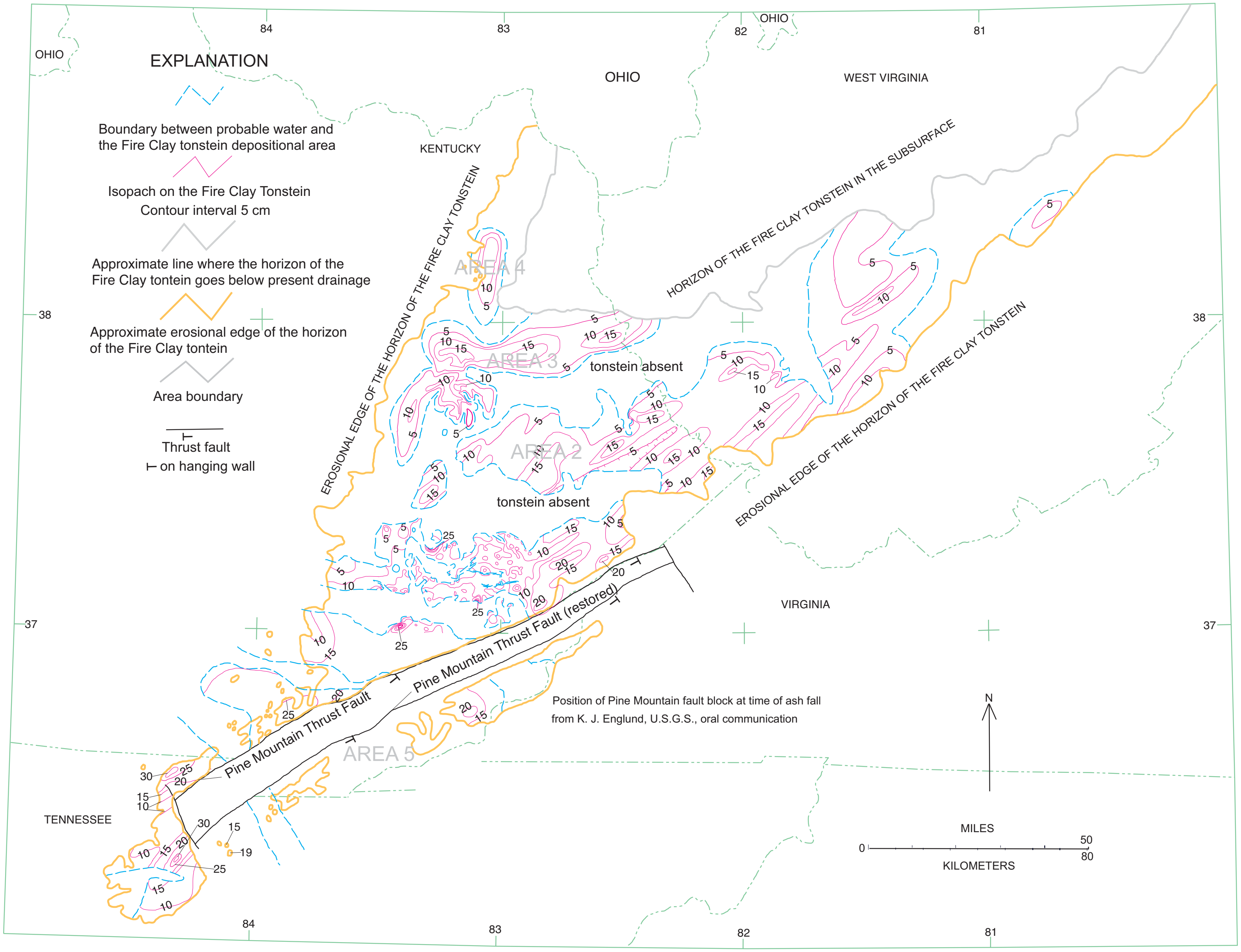


Figure 3 Distribution of thickness data (in centimeters) for the Fire Clay tonstein

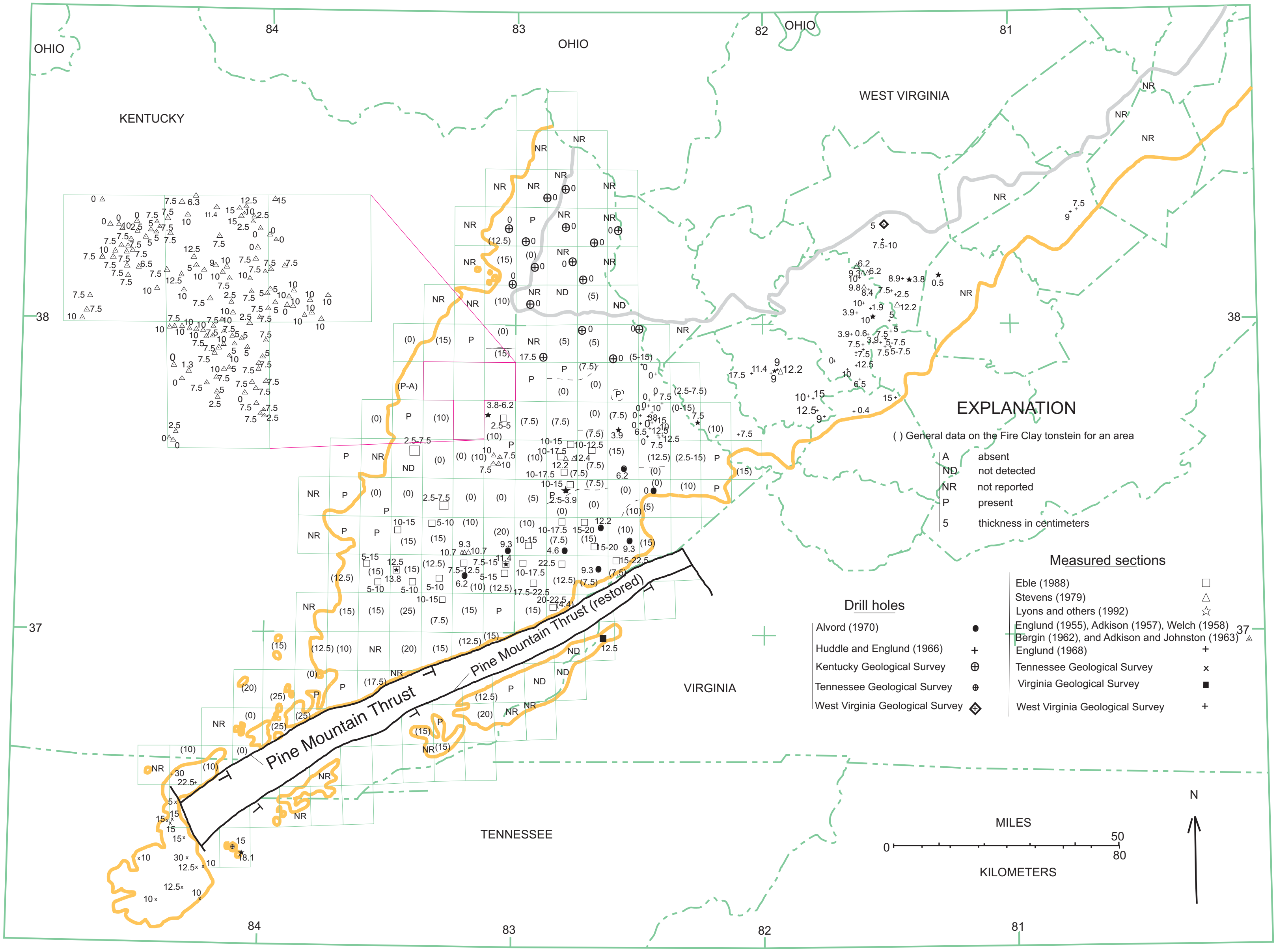
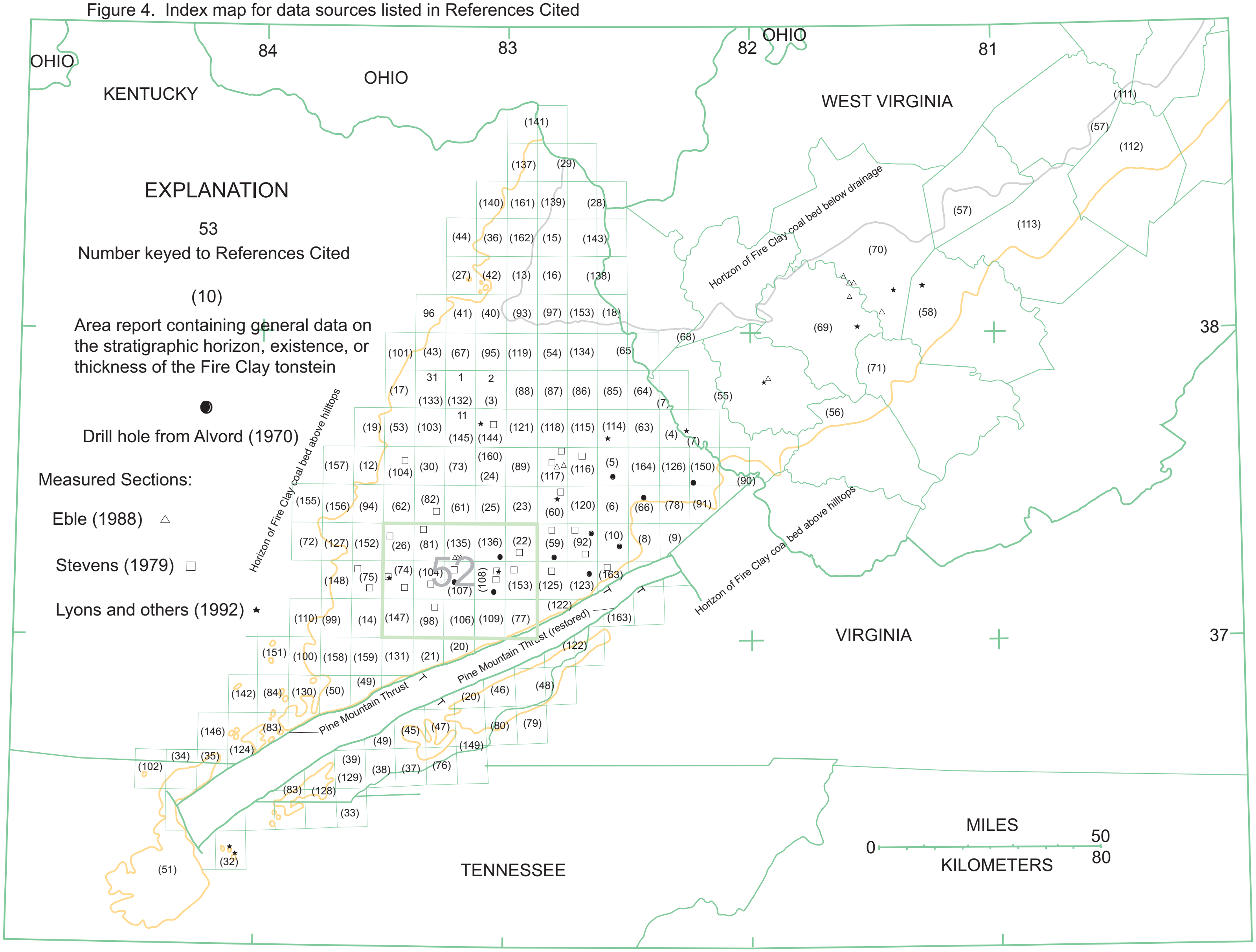


Figure 4. Index map for data sources listed in References Cited



The northeastward extension and the thinning of the deposit from Tennessee into West Virginia are clear. The Pine Mountain overthrust block is restored on the map to its approximate position (Englund, personal communication) at the time of the ash fall. The age of the ash is 313 +/- 1 Ma as determined by Lyons and others (1997) from Pb/U ratios in zircons from the ash.

The margins of the tonstein deposit are poorly defined because the featheredge is practically impossible to identify in the field. However, in some areas the tonstein is clearly absent and its absence across thickness trends is not readily explainable by non-deposition or lack of data. It is likely that the ash fall (pumice) was carried away by streams.

Reports on the coal resources of the Cannel City (Englund, 1955), White Oak (Adkison, 1957), Salyersville North (Adkison and Johnston, 1963) and Seitz (Bergin, 1962) quadrangles contain 129 measured sections that include the Fire Clay coal bed. The inset map on figure 3 shows the distribution of the sections in the four quadrangles.

Greb and others, 1999, in a detailed study of 15 quadrangles between 37 degrees and 37 degrees, 22 minutes, 30 seconds north latitude and 82 degrees, 52 minutes, 30 seconds and 83 degrees, 30 minutes west longitude show the extreme variability in thickness of the ash fall.

CONCLUSIONS

The Fire Clay tonstein covers an area of 14,300-sq. mi. (37,000-sq. km.) and has a preserved compacted volume of 0.90 cubic miles (3.7 cubic kilometers). The compaction ratio is estimated as 6 to 1 by Lyons and others (1992) so the original ash volume deposited in the region was 5.4 cubic miles (22.2 cubic kilometers).

Figure 5 shows the distribution of the Fire Clay tonstein in paleogeographic context. The areal distribution and thickness variations suggest a source somewhere to the present-day southwest of the central Appalachian basin. Scotese (1985) suggests a counter-clockwise rotation of the North American plate since the Middle Pennsylvanian (Westphalian), which would imply a westward paleo-direction for the source volcano of the Fire Clay tonstein. Lyons and others (1992) report that the composition of granite in the Yucatan peninsula matches that of glass inclusions in quartz phenocrysts in the Fire Clay tonstein and suggest a Yucatan block origin for the Fire Clay tonstein, which is consistent with the isopachous data.

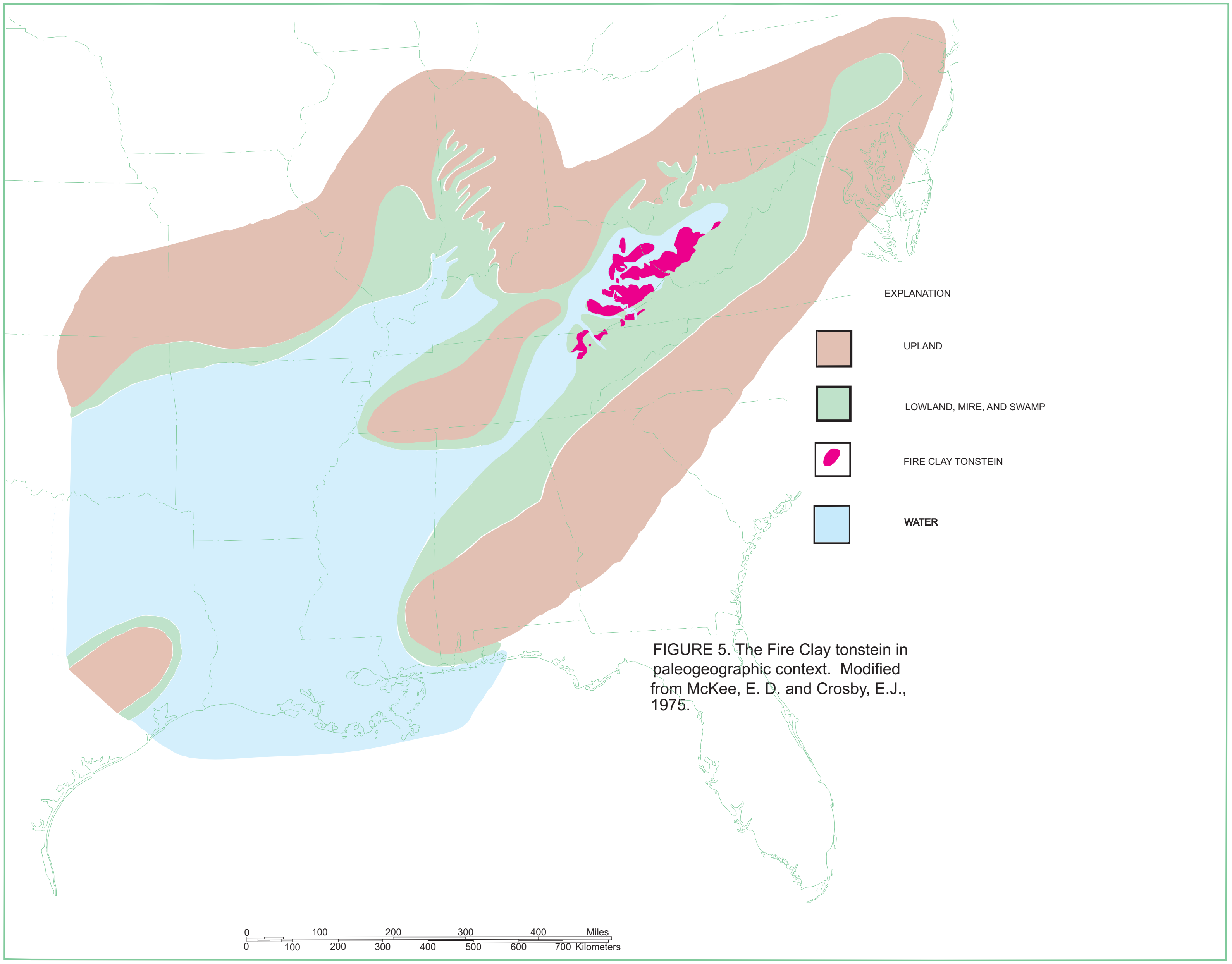


FIGURE 5. The Fire Clay tonstein in paleogeographic context. Modified from McKee, E. D. and Crosby, E.J., 1975.

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