DETERMINATION OF DISTINCT HYDROGEOLOGIC UNITS WITHIN THE MISSISSIPPI RIVER VALLEY ALLUVIAL AQUIFER BASED ON GROUND-WATER

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INTRODUCTION

The Mississippi River Valley alluvial aquifer (herein referred to as the alluvial aquifer) in parts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee is a major source of ground water for agriculture, yielding an average of 7 billion gallons per day. Eighty percent of the land overlying the alluvial aquifer is dedicated to agriculture. This important aquifer is often assumed to be hydrogeologically homogenous, yet evidence suggests that the alluvial aquifer includes distinct hydrogeologic zones (units). In 1991, the U.S. Geological Survey (USGS) began implementation of the National Water-Quality Assessment (NAWQA) Program to provide a consistent description of the Nation's ground- and surface-water resources. In 1994, the USGS began the Mississippi Embayment NAWQA study which includes parts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. Included in that study was an investigation of historical ground-water data from the alluvial aquifer. A better understanding of varying hydrogeologic properties will provide information useful for improving management practices.

The alluvial aquifer is actually an accumulation of many different units that have been deposited in different environments throughout the Pleistocene and Holocene. Three main groups of units include the Pleistocene complexes, the more recent Pleistocene valley trains, and the Holocene alluvium formed from major rivers in the alluvial plain (Figure 1). This report focuses on the hydrogeologic difference between the Pleistocene valley trains and the Holocene alluvium based on previous investigations, drillers' logs, and historical nitrate and iron ground-water data.

Pleistocene valley trains underlie Holocene alluvium in many places. The previous investigations section of this report describes these as geologic subunits. In other parts of this report, Pleistocene valley trains and Holocene alluvium are described as hydrogeologic units (or aquifers) that are located coincident to the outcrop areas of the geologic subunits. This means that the Holocene alluvium, as an aquifer, comprises the Pleistocene valley trains geologic subunit underlying the Holocene alluvium geologic subunit in many places.

PREVIOUS INVESTIGATIONS

Geologic subunits of the Mississippi River Valley alluvium, which is the geologic formation corresponding to the alluvial aquifer, were identified and described by Autin and others (1991) and Saucier (1994). Below is a summary of the geologic description of the Pleistocene valley trains and the Holocene alluvium geologic subunits.

Pleistocene valley trains are massive deposits of glacial outwash deposited in a braided-stream environment during Wisconsin time. These valley-train deposits consist of massive quantities of sand and gravel that extend to the base of the Mississippi River Valley alluvium and are overlain by a thin (2 to 5 meters) top stratum of sandy clay and silt. As the Wisconsin ice sheet retreated, the braided-stream depositional environment also retreated northward leaving meander-belt and backswamp depositional environments in its wake. Meander-belt and backswamp depositional environments began about 12,000 years before present (B.P.) near the Gulf of Mexico. Some of the last braided-stream deposits occurred in present-day southeastern Missouri and reverted to meander-belt and backswamp depositional environments about 9,000 years B.P. (Saucier 1994).

Holocene alluvium are meander-belt and backswamp deposits. Meander-belt deposits consist of a top stratum of lenticular clay, silt, and fine sand deposited mostly in point-bar and natural-levee environments ranging in thickness from about 3 to 10 meters. Linear masses of clay and silt, as much as 40 meters thick, were deposited in abandoned channels and swales. The substratum of meander-belt deposits consists of silt, sand, and gravel representing point-bar and channel-lag deposits. The base of these deposits is indistinguishable from the underlying Pleistocene outwash. Backswamp deposits are overbank sediments deposited between meander belts and are composed of thick sequences of clay and silt. Thickness of backswamp deposits ranges from about 10 to 20 meters. The base of the backswamp sequence is usually represented by a sharp transition to the underlying coarse-grained Pleistocene outwash deposits (Saucier 1994). The Holocene alluvium generally is finer grained and contains more lignite than the Pleistocene valley trains.

Drillers' Logs

The USGS has compiled 4,211 drillers' logs that are located in either the Pleistocene valley trains or the Holocene alluvium in eastern Arkansas and southeastern Missouri. All logs have land-surface altitude and surficial confining-unit thickness information. Aquifer thickness data are available from 2,592 of these logs.

Lithologic data from drillers' logs in eastern Arkansas and southeastern Missouri indicate that the surficial-confining unit is thicker in areas where the Holocene alluvium crops out than where the Pleistocene valley trains crop out. The land-surface altitude is higher in the Pleistocene valley trains than in the Holocene alluvium. The combined effects of higher land-surface altitude and the relatively thin confining unit in the Pleistocene valley trains and heavy pumpage rates make the Pleistocene valley trains more likely to be areas of surface recharge and, therefore, more susceptible to contamination from surface sources than the Holocene alluvium.

Historical Ground-Water Chemistry Data

Historical iron and nitrate ground-water data from 1970 to 1995 from Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee were retrieved from the USGS data base to determine the possible chemical heterogeneities that might exist within the alluvial aquifer. The data were collected during different projects that had varying focuses. Iron and nitrate were selected as constituents because of the abundance and reliability of data and their ability to indicate differences in basic ground-water chemistry. Nitrate concentrations can indicate contamination from surface sources, serving as a frequently analyzed surrogate for other surface-derived constituents (U.S. Environmental Protection Agency 1996; Erwin and Tesoriero 1997; Vowinkel et al. 1996; and Ryker and Williamson 1996). Iron concentrations can suggest the proximity of the sampled water to the surface recharge area. As water flows farther from its point of recharge through the aquifer, dissolved oxygen concentrations decrease, allowing increasing amounts of ferrous iron to be dissolved in the ground water (Lovley 1987; and Stumm and Morgan 1970). Only data associated with wells of known depth and located well within the Pleistocene valley trains or Holocene alluvium (that is, at least 2,500 meters from the outcrop of an adjacent unit) were selected. The Holocene alluvium had water samples with nitrate data from 60 wells and iron data from 69 wells. The Pleistocene valley trains had water samples with both nitrate and iron data from 158 wells (Figures 2 and 3).

The water samples from the Pleistocene valley trains and the Holocene alluvium exhibited differences in nitrate and iron concentrations. In the Pleistocene valley trains, 44 percent of the wells had nitrate concentrations greater than the reporting limit of 0.1 milligram per liter (mg/L) as nitrogen (N). However, in the Holocene alluvium only 17 percent of the wells had nitrate concentrations greater than 0.1 mg/L (Figure 4). Water samples from the Pleistocene valley trains had statistically higher nitrate concentrations than samples from the Holocene alluvium (p-value of 0.0001).

Water samples from the Pleistocene valley trains had a statistically lower median iron concentration than samples from the Holocene alluvium (p-value of <0.00005). Water samples from the Pleistocene valley trains had a median of iron concentrations of 2.5 mg/L, and samples from the Holocene alluvium had a median of iron concentration of 6.1 mg/L (Figure 5).

The ground-water chemistry data are not evenly distributed throughout the study area. Data points in the Holocene alluvium, in particular, are more concentrated in the southern part of the study area (Figures 2 and 3). Data points are more evenly distributed in northeastern Louisiana, and statistical results from the subset of data within northeastern Louisiana are similar to the whole data set. In northeastern Louisiana, water samples from the Pleistocene valley trains had statistically higher nitrate concentrations than samples from the Holocene alluvium (p-value of 0.0008). Also in northeastern Louisiana, water samples from the Pleistocene valley trains had a statistically lower median iron concentration than samples from the Holocene alluvium (p-value of <0.00005).

DISCUSSION

Historical data provide evidence of differences in ground-water chemistry between the Pleistocene valley trains and the Holocene alluvium. The suspected higher susceptibility of the Pleistocene valley trains to surface contamination, based on hydrogeology, is supported by the higher nitrate concentrations in the Pleistocene valley trains than in the Holocene alluvium. The greater removal of the Holocene alluvium from its surface recharge area is supported by the higher iron concentrations in the Holocene alluvium than in the Pleistocene valley trains. Nitrate and iron concentrations are two basic hydrochemical indicators that bear out the differing chemistry of the two units. The Mississippi Embayment NAWQA study unit is planning to sample these two hydrogeologic units during the summer of 1998. Ground-water data collected from such a project would provide a more consistent data base than the historical data.

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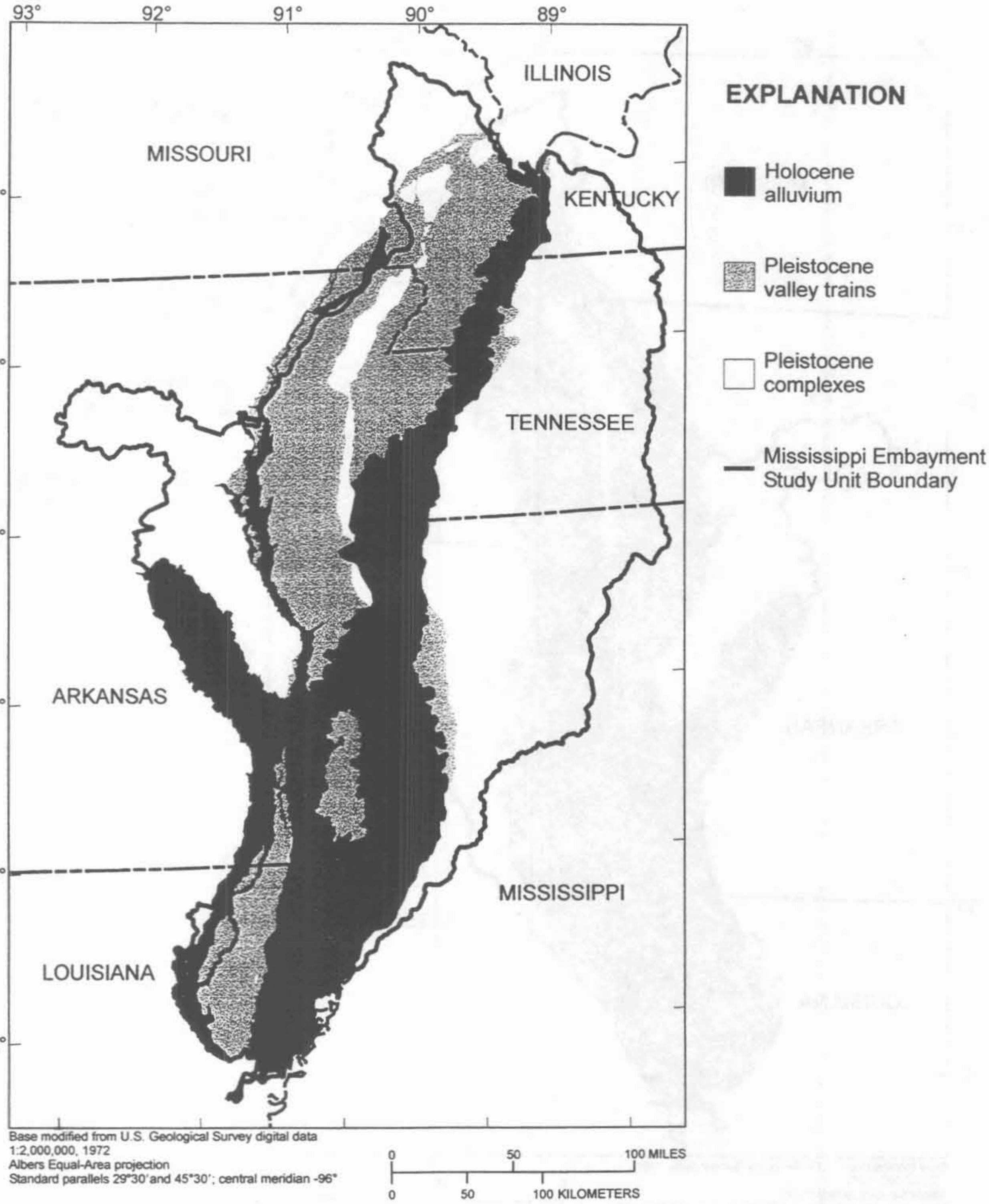

Figure 1. Study unit boundary and the extent of the Holocene alluvium, Pleistocene valley trains, and Pleistocene complexes within the Mississippi River Valley alluvium (Quaternary geology and physiography modified from Saucier, 1994).

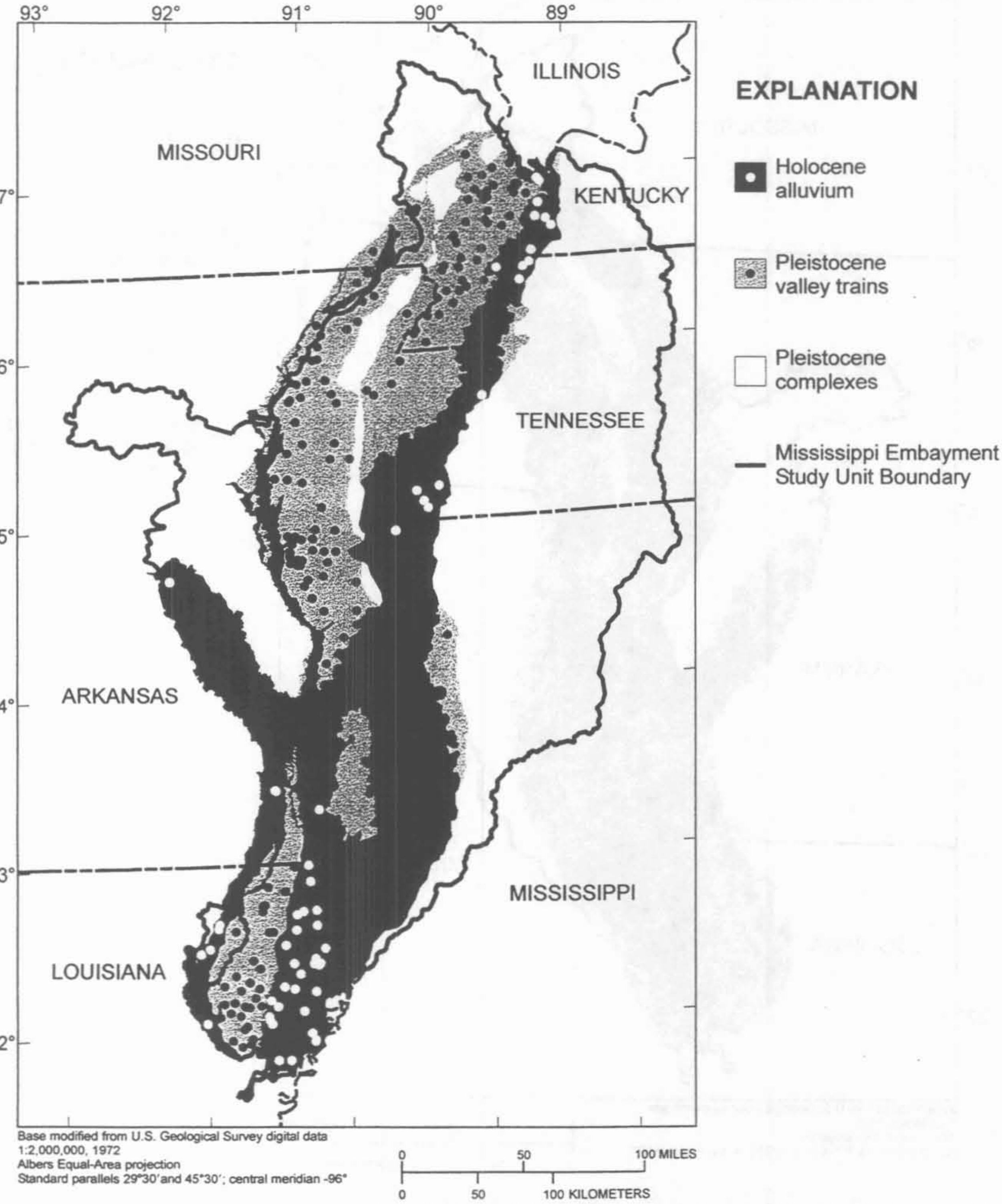

Figure 2. Location of ground-water samples of nitrate in Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee, 1970 to 1995.

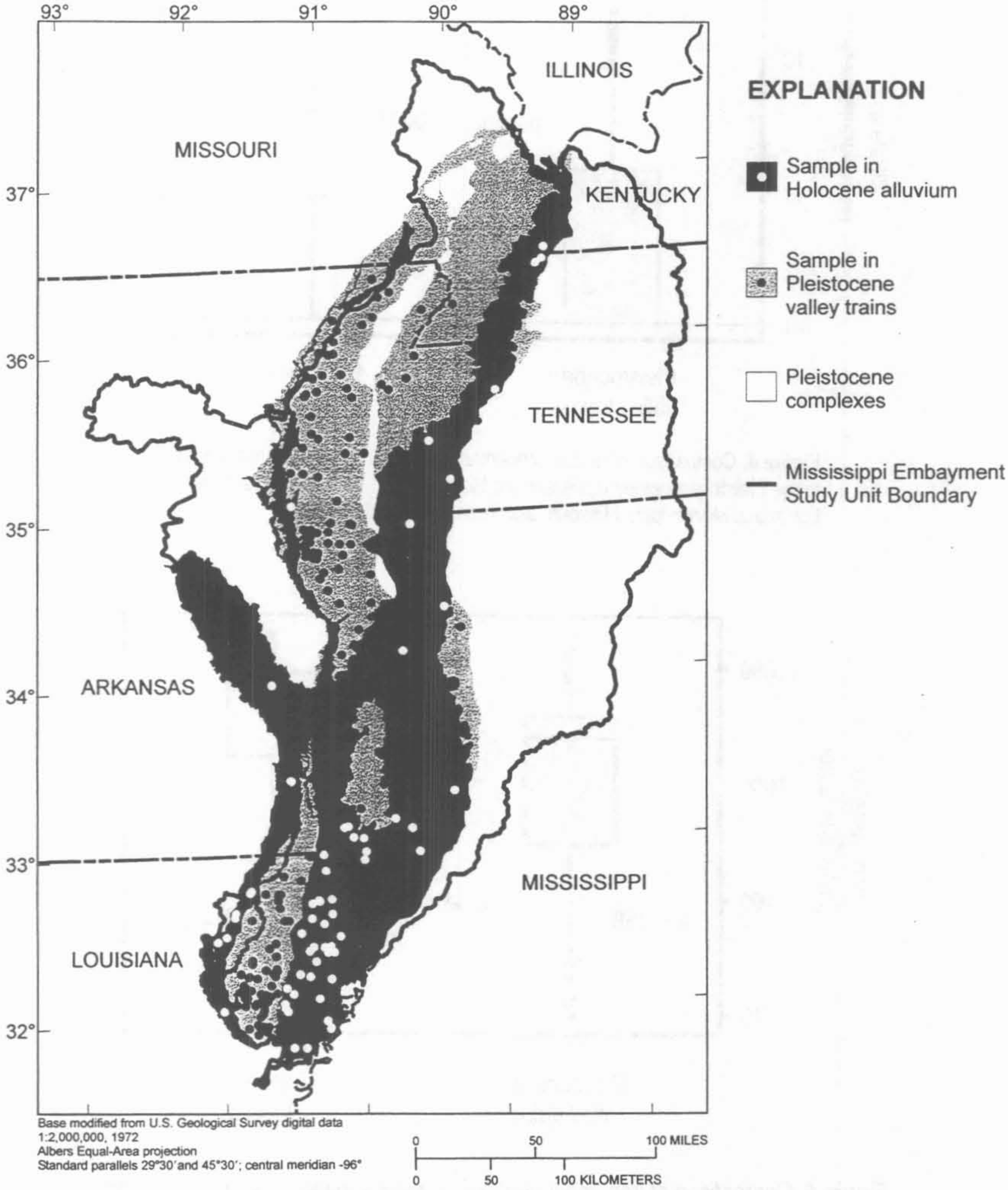

Figure 3. Location of ground-water samples of dissolved iron in Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee, 1970 to 1995.

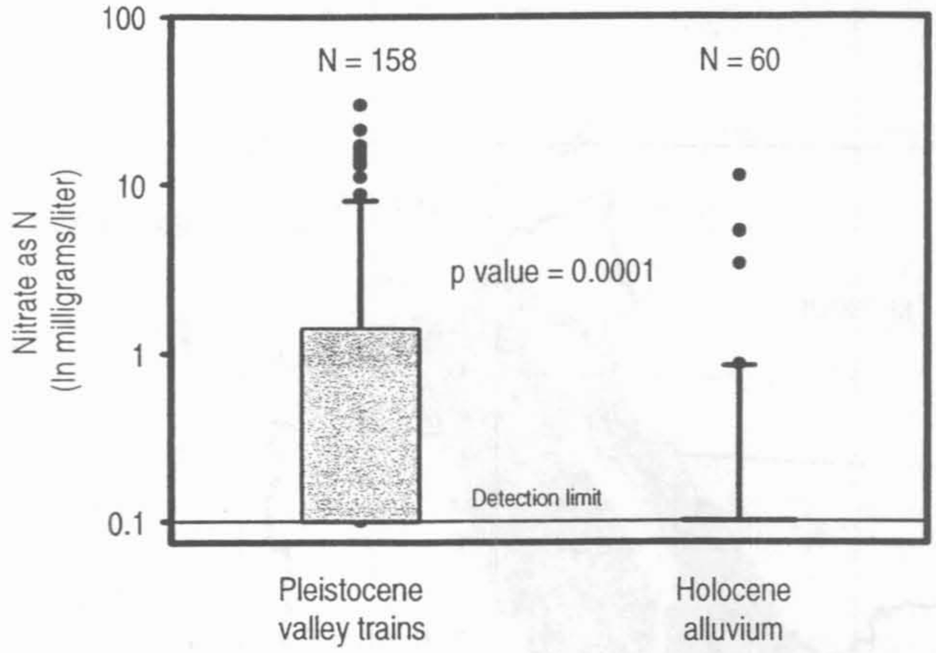

Figure 4. Comparison of nitrate concentrations in water samples from wells open to the Pleistocene valley trains and the Holocene alluvium, Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee, 1970 to 1995.

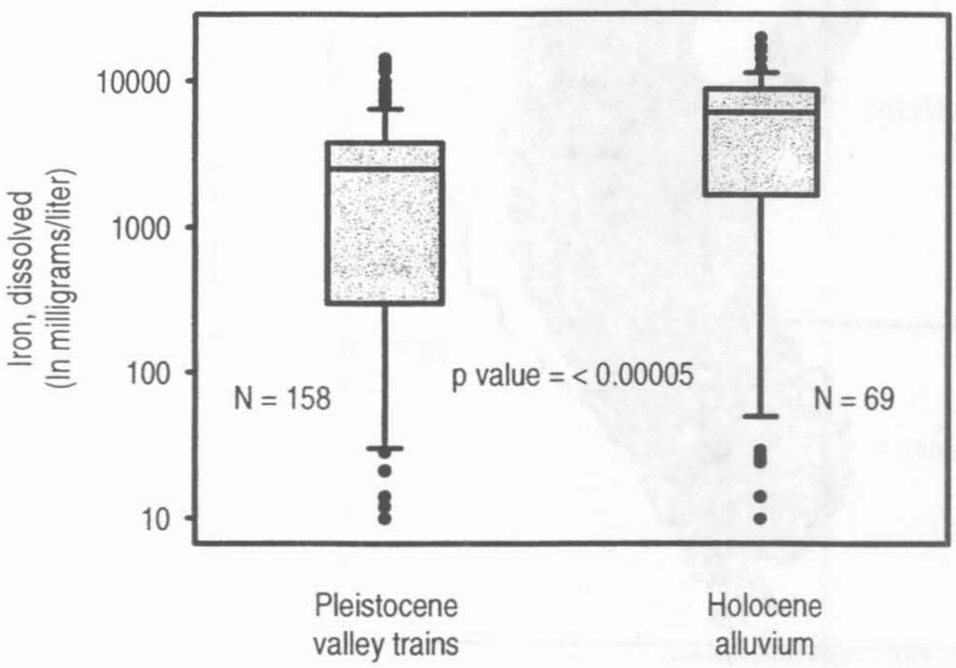

Figure 5. Comparison of iron concentrations in water samples in wells open to the Pleistocene valley trains and the Holocene alluvium, Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee, 1970 to 1995.