SIX RIVERS, FIVE GLACIERS, AND AN OUTBURST FLOOD:
THE CONSIDERABLE LEGACY OF THE ILLINOIS RIVER

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INTRODUCTION

The waters of the modern Illinois River flow gently through looping meanders bordered by quiet backwater lakes and drop only a few inches in each river mile. Concealed beneath this gentle river is geologic evidence that the Illinois descended from ancient rivers with surprising and sometimes violent histories. The geologic story of the Illinois River is not only an account of an interesting chapter of Earth history, but it also reveals a rich geologic legacy of valuable and vulnerable resources that should be managed and used wisely.

Modern, detailed, geologic field mapping has enabled new insights into the river's history. Begun in 2000 by the Illinois State Geological Survey (ISGS), geologic mapping in the Middle Illinois River Valley area (Fig 1) was undertaken to aid planning for an expansion of Illinois Highway 29 between Chillicothe and I-180 west of Hennepin. Mapping was focused initially on the western bluff and valley bottom west of the river near the present highway but has since been expanded to more than 275 sq mi in Putnam, Marshall, and Peoria counties. Funding was provided by Illinois Department of Transportation (IDOT) and by ISGS. Several maps are scheduled to be published (McKay and others 2008a, 2008b, 2008c).

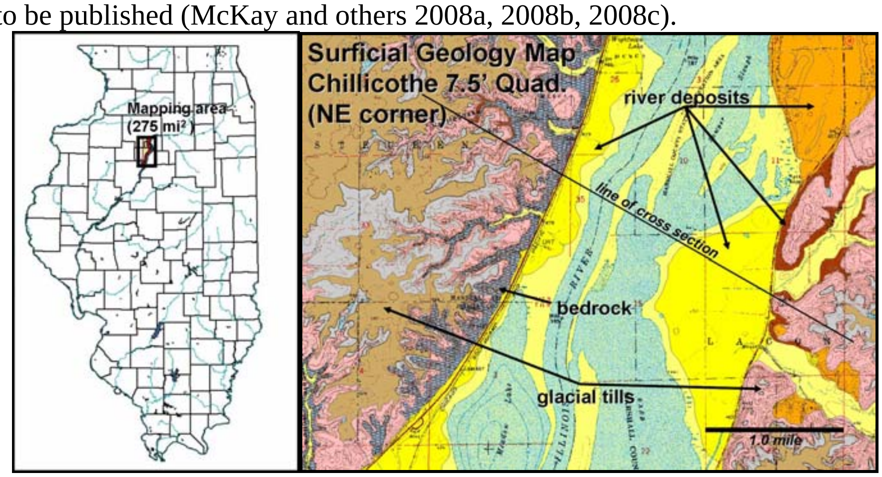

Figure 1. Location of recent and ongoing geologic mapping area in the Middle Illinois River Valley region of north-central Illinois (left) and northeastern portion of the Chillicothe 7.5-minute surficial geology map (right) showing areas of river deposits, glacial tills, and bedrock where they occur at land surface.

The processes of data collection and interpretation undertaken for geologic mapping lead to greatly improved understanding of the geology. In the course of mapping, results of previous studies are compiled, and records of thousands of boreholes drilled for water wells and other purposes are collected and evaluated. New boreholes are drilled, and cores of deposits and rock collected. Geophysical profiles are run in order to image the subsurface without drilling, and samples of deposits are analyzed to characterize physical, mineralogical, and geochemical properties and to determine age. All of these data are entered into databases and used to produce 3-dimensional geologic models and digital maps that reflect latest understanding.

Geologic map products include: (1) Surficial Geology map that shows geologic materials found at ground surface (Fig 1), (2) Bedrock Topography map that shows contoured elevation of the bedrock surface, (3) Drift Thickness map that shows the thickness of glacial and river deposits that overlie bedrock and (4) Cross Sections (Fig 2) that portray vertical slices through the mapped deposits. Accompanying each map are descriptions of mapped units and commentary on the applicability of the map to a variety of applied uses.

Geologic maps are useful to resource managers, planners, developers, and regulators, as well and the general public. They document natural resource occurrences and natural hazards and provide a fact basis for resource assessment, economic development, planning, environmental protection, and sustainability decisions.

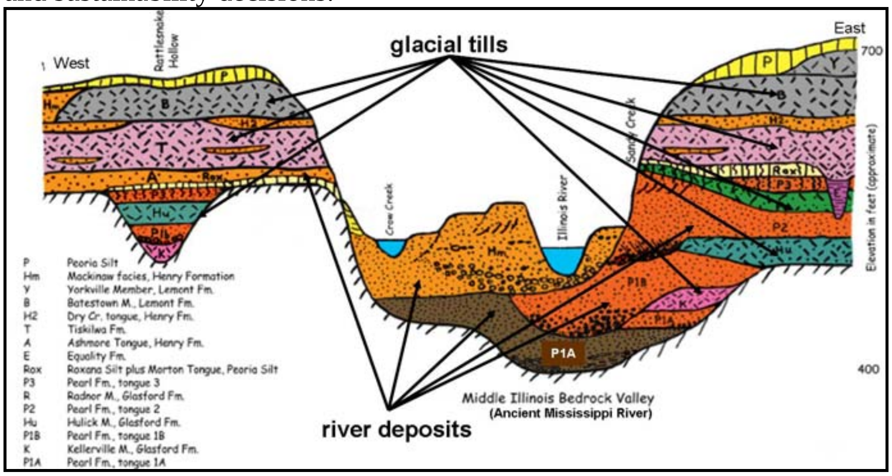

Figure 2. Geologic cross section showing the principal geologic units mapped in the Middle Illinois River valley and vicinity. The line of cross section is shown on Figure 2.

ICE AGES IN ILLINOIS

For somewhat more than a century, it has been common understanding in the scientific community that the Earth has experienced climate change several times in the recent geologic past sufficient to allow the development of widespread continental glaciers. Discussion of the history of the Illinois River Valley requires understanding of those Ice-Age events.

The Ice Age (Quaternary) spans roughly the last 2 million years of Earth history. Although it is likely that not all that time is represented by deposits in Illinois, the past half million years or so appear to be well represented. Quaternary time was characterized by large swings in global climate from glacial episodes with widespread continental ice sheet to warm periods, interglacials, similar to today. These cycles of cold-warm-cold-warm are clearly recorded in the chemistry of fossils from ocean sediments that show similar patterns and timing of climate change worldwide. Oxygen isotope values, for instance, are indicators of the global volume of glacial ice (Fig 3). Heavier and lighter isotopes of oxygen vary in relative abundance in the ocean and in precipitation, depending on temperature. The pattern of increase and decrease of oxygen isotopes as well as a wide variety of other parameters measured in the reefs, ice caps, cave formations, and sediments, consistently show that during the past 900,000 years, for instance, the Earth has swung through glacial and interglacial climates about 22 times. These Oxygen Isotope Stages (OIS) are numbered and correlated worldwide (Fig 3).

Ocean records of climate are clear and well documented, but geologic correlations of deposits on land to the ocean records are often uncertain. Continental records tend to be incomplete, discontinuous, and complex. Not all global glacial climates, for instance, produced glaciers of an extent sufficient to reach the latitude of Illinois. Glaciers did reach Illinois several times, and because Illinois is far from the spreading centers, the glaciers that reached here were some of the most extensive in the world. Thus, the challenge for glacial geologists and paleoclimate scientists in Illinois is to determine which of the many global glacial periods produced extensive glaciations and which warm periods are represented by buried landscapes and soils.

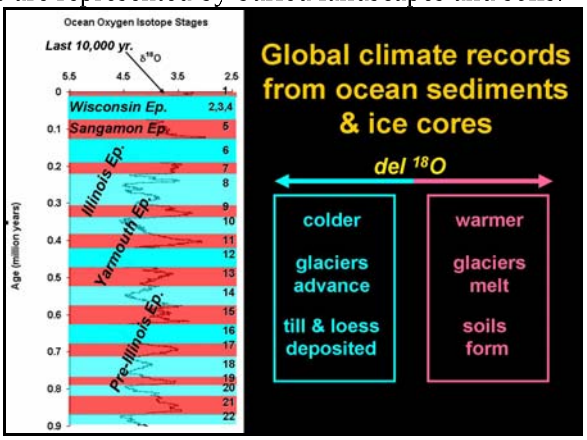

Figure 3. Oxygen Isotope variations are indicators of past climate change. Classified into numbered stages (1 through 22), these warm-cold swings in global temperature over the past 900,000 yrs have been correlated to geologic time units in Illinois with considerable uncertainty.

The climate of the last 10,000 calendar (cal) years before present (BP) has been a relatively warm and stable interglacial one. Weathering at the land surface during that time has produced rich fertile soils. The last cold period, the Wisconsin glacial episode, is well documented and although it started about 75,000 cal yrs BP, the glacier did not reach Illinois until about 29,000 cal yrs BP when it emerged from the south end of the Lake Michigan basin. It reached its maximum extent near Peoria and Charleston about 24,300 cal yrs BP. This Wisconsin episode ice covered the Ancient Mississippi Valley at least twice before it gradually retreated into the lake about 17,000 cal years ago.

Also well characterized is the last interglacial, the Sangamon Episode, 130,000 to 75,000 cal yrs BP, a climate period much like the recent that is distinguished by a widely preserved, strongly developed, weathering profile, the Sangamon Soil. Fossil plants and animals from that time reveal varying warmth and precipitation, at different times somewhat cooler or warmer and wetter or drier than today (Curry and Baker 2000).

Prior the Sangamon, a significant global cold period was accompanied by widespread glaciation. Glaciers that entered Illinois from the north flowed over 300 miles to the south, reaching the latitude of Carbondale. Advancing to the west, they reached eastern Iowa. So well are the deposits of this episode represented here that the glaciation is known worldwide as the Illinoian or Illinois Episode. Three times during this episode glaciers overrode the Ancient Mississippi River north of Peoria, and after each glacier melted, the river returned to a course near its former one. It has been debated whether the deposits and soils of the Illinois Episode represent one global glacial cycle or more. Until recently its beginning and duration were undated. Analytical results reported here are the first to provide definitive evidence that the Illinois Episode was a single glacial episode that can be correlated to one climate cycle from the ocean record.

Deposits and ancient soils older than the Illinois Episode are widespread in Illinois, but their ages are so poorly known that they have been grouped into a catch-all time period called the Pre-Illinois Episode, which includes all middle and early Quaternary time.

Research in Illinois and surrounding states and Canada indicates that during glacial periods, snow and ice accumulated in areas near Hudson Bay and spread from those centers. Some drained northward into the ocean. Other parts of the glacier streamed southward through the

Great Lakes basins. In fact, ice streaming through those lowlands scoured the bedrock, excavating the Great Lakes into the deep basins they are today. As ice emerged from the south end of the basins it spread into Illinois mainly from Lake Michigan, but also from the northeast via the Huron-Erie basins and from the northwest after crossing Iowa (Fig 4).

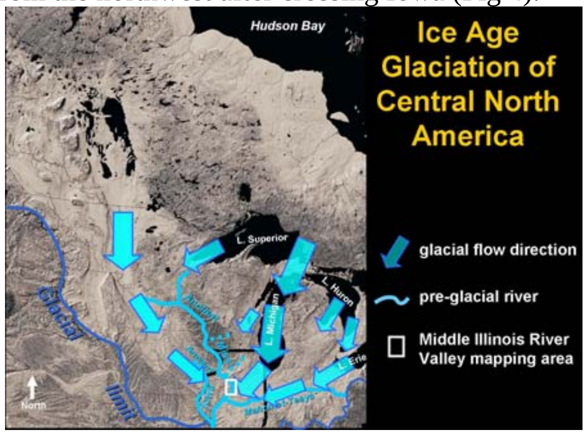

Figure 4. Shaded relief map of central North America showing the glacial limit, principal pre-glacial river systems, and main flow paths of Pleistocene glaciers that entered Illinois.

ANCIENT RIVER SYSTEMS

Prior to the earliest glaciation of Illinois more than half a million years ago, one of the principal rivers of the mid-continent flowed southward through rolling shale and limestone hills of central Illinois from its headwaters in southern or western Wisconsin (Anderson 1988, Baker et al 1998). On its way to the Gulf of Mexico, this Ancient Mississippi River, as it is known, was joined by other significant drainages, the Mahomet-Teays River, which entered just south of Peoria, the Ancient Iowa River near Grafton, and the Missouri River just north of St. Louis (Fig 5). These river valleys were wide and deep, and their setting, vegetation, and landscape would seem familiar.

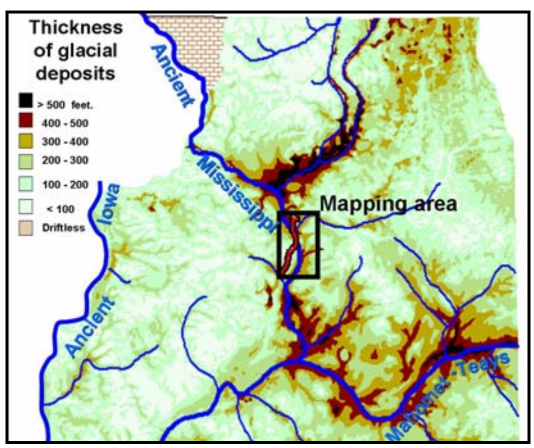

Figure 5. Thickness of glacial deposits in northern Illinois.

Today, the Mahomet-Teays Valley is known only from wells drilled into the deposits that fill it to depths of several hundred feet. No surface expression of the bedrock valley remains. It was completely filled and buried by glacial deposits. Likewise, the Ancient Mississippi Bedrock Valley is buried in many areas, in some cases with more than 400 feet of sediment (Fig 5). The Mississippi River no longer flows through central Illinois. Questions of when and how the river's course was altered have been largely answered and those answers reveal the interplay of some of the immense forces of nature: major rivers and continental ice sheets.

PREVIOUS INVESTIGATIONS OF THE ANCIENT MISSISSIPPI RIVER VALLEY

In the 1940's and 1950's Leland Horberg published several important studies in which he mapped and discussed the bedrock valleys of Illinois and the deposits that fill them (Horberg 1945, 1950a, 1950b, 1953). Horberg developed and refined concepts of the origin and history of the buried valleys. In the Ancient Mississippi Bedrock Valley, he recognized a thick sand and gravel deposit in the Peoria region that he named the Sankoty Sand for its occurrence in the Sankoty water-well field north of Peoria (Horberg 1950a). He believed the deposit to be "Nebraskan" in age, which was the earliest glacial episode recognized at that time, and mapped its distribution along the Ancient Mississippi (Horberg 1953). In cross sections Horberg (1953) depicted the Sankoty deposit as thick, relatively uniform sand and gravel (Fig. 6).

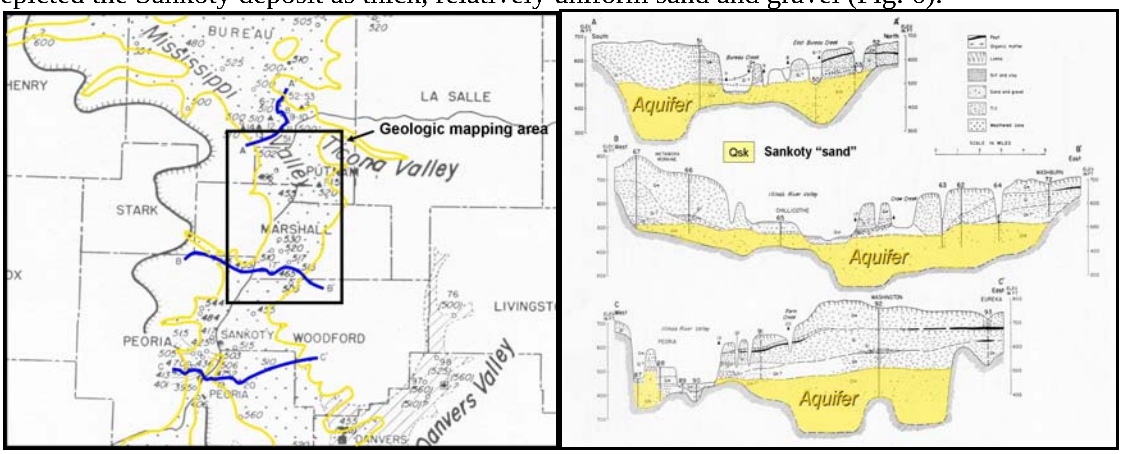

Figure 6. Areas underlain by Sankoty-Mahomet sand as mapped by Horberg (1953). Note three lines of cross section on map view. Cross sections (right) show stratigraphic relations of "Sankoty sand" and overlying units, as mapped by Horberg (1953).

Willman and Frye (1970) included the Sankoty Sand as a member in their newly named Banner Formation, which they considered to be of "Kansan" age, a glacial thought to follow the Nebraskan and precede the Illinoian. McKay and others (2005) studied the origin and timing of the sand and gravel in the Ancient Mississippi north of Chillicothe, indicated that the deposits in that area are a complex of several successions of valley fill interrupted by glacial deposits and lacustrine (lake) sediments, and suggested that the then undated deposits were likely composed of significant thicknesses of Illinois Episode and Wisconsin Episode deposits.

These academic questions of the deposit's age, origin, complexity, and composition are of practical significance. The "Sankoty Aquifer" is a prolific groundwater producer in most, but not all areas of the Ancient Mississippi. Discovery that it is compartmentalized into coarse water-bearing units of a variety of ages, separated by fine-grained barriers to groundwater flow, has importance in explaining and mapping variability of water yield from the aquifer and, therefore, in the planning for its use. Compositional variations mapped may also help in understanding observed variations in groundwater quality.

NEW METHODS AND DATA

Recent studies have had the benefit of new equipment and technology that have brought to light information not available to earlier workers. New drilling and sampling equipment have become available and have been used to collect nearly 20 continuous cores of the deposits that fill the Ancient Mississippi Bedrock Valley. New techniques have made it possible to determine the age of deposits older than are datable with radiocarbon (^{14}C). Refined over the past decade, dating methods using the luminescence of mineral grains are commercially available and produce results consistent with of well tested methods, like ^{14}C. Optically stimulated luminescence (OSL) uses laser light with a narrow range of wavelength to induce luminescence in quartz sand grains. The luminescence property results from exposure of quartz to gamma radiation, which occurs naturally in the ground. Chemical analysis of the sample and assumptions about its exposure to cosmic rays and about water content, which reduces exposure, allow calculation of the rate at which the sample was dosed with radiation. Measurement of luminescence, essentially light created when radiation induced stored energy is released as photons when stimulated by the laser, allows back calculation of age in years from luminescence effect per dose rate.

RESULTS

Results from three key cores pulled from Ancient Mississippi River deposits answer a range of important questions about the deposits and history of the river (Fig 7). All were drilled on uplands adjacent to the Middle Illinois River Valley but penetrated into the fill of the much wider bedrock valley.

Reaching a depth of 301 feet, the **Shoepke #1** borehole drilled in June, 2004, penetrated three Wisconsin Episode tills, Wisconsin loess, the Sangamon Episode buried soil (Sangamon Geosol), three Illinois Episode tills, thick lake sediment, and 100 feet of sand and gravel resting on Pennsylvanian coal (Fig 8). The OSL age of the upper part of the sand and gravel is 171,100 cal yr BP (calendar years before present) with a calculated uncertainty range of ± 14,700 cal yr BP.

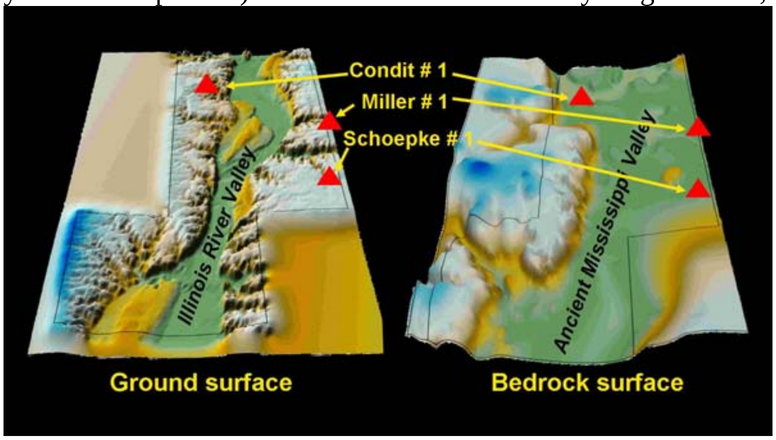

Figure 7. Locations of three key cores collected recently in the study area. Image on the left shows borehole locations on a relief map of ground surface topography. Image on the right shows borehole locations with respect to the bedrock surface topography. Drilled in the modern uplands, the three boreholes penetrated deep parts of the Ancient Mississippi Bedrock Valley.

Drilled and sampled to a depth of 345 feet in May 2006, the **Miller #1** borehole penetrated two Wisconsin Episode tills, Wisconsin loess, the Sangamon Episode paleosol, and two Illinois Episode tills, the lower of which was over 170 ft. thick, extraordinarily thick for a single till unit in this area (Fig 8). Two OSL age determinations from sand 13 feet thick beneath that till yielded ages of 185,200 ± 16,400 and 193,200 ± 16,300 cal yr BP.

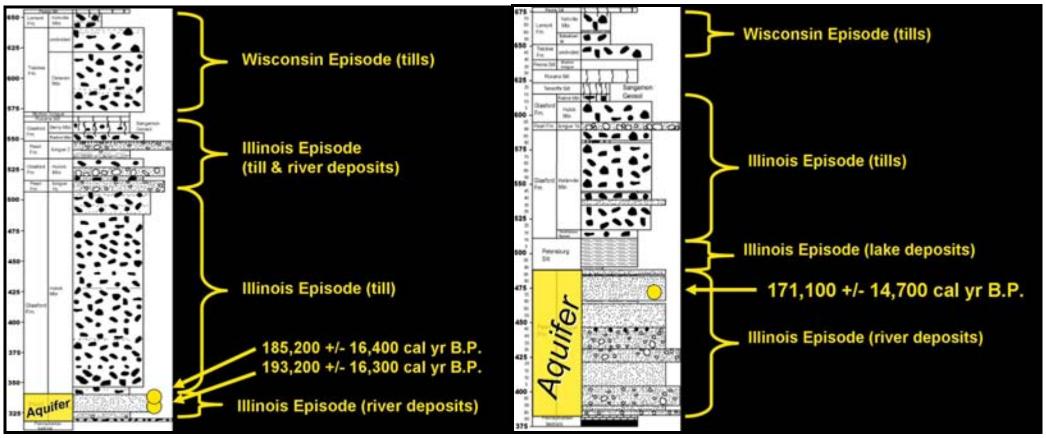

Figure 8. Graphic logs of boreholes Miller #1 (left) and Schoepke #1 (right) showing the principal stratigraphic units, the major aquifer, and OSL age determinations.

Cored continuously from ground surface to a depth of 239 ft. in May 2002, the **Condit #1** borehole penetrated two Wisconsin Episode tills, 83 ft. of sand and gravel of indeterminate age, and 5 ft. of an unknown till (Fig 9). A ^{14}C age determination on wood 10 ft. above the base of the upper till yielded an age of 28,310 ± 400 cal yr BP, confirming it to be Wisconsin Episode. Four OSL ages in the lower 50 ft. of the sand and gravel yielded ages ranging from 23,160 ± 2520 to 26,080 ± 2340 cal yr BP. The uncertainty envelopes for the four dates overlap indicating that they are statistically the same. An average of the four is 24,740 cal yr BP. The sand and gravel unit is, therefore, clearly Wisconsin Episode and much younger that the coarse deposits dated in the Schoepke and Miller cores.

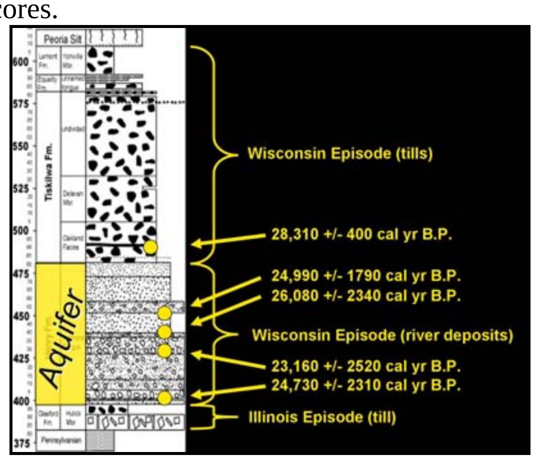

Figure 9. Graphic log of borehole Condit #1 showing the principal stratigraphic units, the major aquifer, and ^{14}C (uppermost) and OSL (lower 4) age determinations.

DISCUSSION

Recent age determinations using OSL on sand samples and ^{14}C on wood from cores of deposits of the Ancient Mississippi and the Illinois Rivers provide insight into the timing of geologic events in those valley systems in central Illinois (Fig. 10). The oldest deposits, which are from near the base of the fill in the Ancient Mississippi Valley, date to about 190,000 cal yr BP and fall into the earliest part of oxygen isotope stage (OIS) 6 or late in OIS 7. OIS 6 was a significant global glacial episode, and OIS 7 was the previous interglacial. These data suggest that the oldest river deposits in the Ancient Mississippi Valley in the reach between Chillicothe and

Hennepin are much younger than earlier researchers thought. Because the dated deposits are overlain by and interfinger with all of the Illinois Episode tills known from central Illinois, the dates for the first time determine that the Illinois Episode in Illinois was an OIS 6 glacial and refute suggestions that the Illinois Episode spanned multiple glacial cycles.

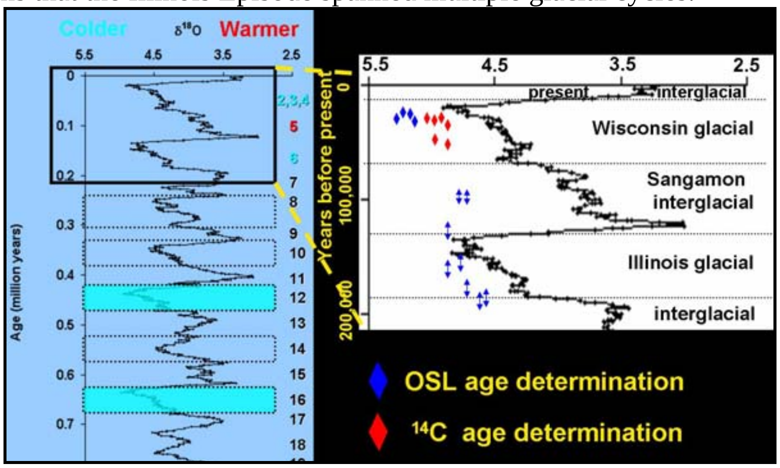

Figure 10. Recent age determinations on Ancient Mississippi River Valley deposits using ^{14}C and OSL methods fall within OIS 2,3,4, 5, and 6, indicating that the Illinois Episode in its type area is an OIS 6 event.

A new west-east geologic cross section of the Ancient Mississippi River valley shows glacial, fluvial, and lacustrine sediments that fill the bedrock valley (Fig 11). In many places the lower half of the valley fill is sand and gravel, whereas the upper half is mostly glacial diamicton (till). It resembles Horberg's cross section (Horberg 1953) but in specific is quite different. Till deposits interfinger with the sand and gravel and in the case of the Miller core, nearly replaces it. Significant thicknesses of lacustrine (lake) deposits occur in several areas. Thus, the aquifer is revealed to vary significantly in thickness, to be much coarser in some areas than others, and to be compartmentalized by till and fine-grained lacustrine sediments.

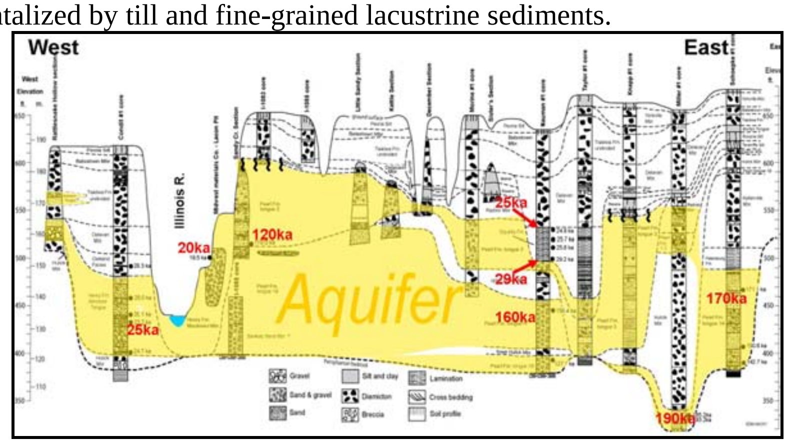

Figure 11. New geologic cross section of the Ancient Mississippi River valley showing principal stratigraphic units, aquifer materials, and OSL and 14C ages.

OSL ages from these deposits further suggest multiple significant episodes of sand and gravel deposition occurred during the Illinois Episode, namely about 170,000 cal yr BP proglacially to diamicton of the Kellerville Member and about 160,000 cal yr BP during deposition of diamicton of the Hulick Member. Evidence from fluvial deposits at the top of the Illinois and/or Sangamon Episode successions, i.e. those with the Sangamon Geosol in their upper part, suggests that late Illinois and Sangamon Episode alluvial surfaces were high, up to elevation 550 ft. (Knapp #1on

Fig. 11) and perhaps as high as 600 ft (Sandy Cr. Section on Fig. 11), where the deposits date at about 119,000 cal yr BP. Several of the new dates are from deposits of the Wisconsin Episode. At the Nauman #1 site, lacustrine sediments date the filling of a lake with sediment between about 29,000 cal yr BP and 25,000 cal yr BP. This dates the aggradation of the Ancient Mississippi valley as sediment load exceeded the capability of the river to transport it during the advance of late Wisconsin ice. This period is well known as the initial phase of deposition of the late Wisconsin Episode Peoria Silt (loess) whose sediment was deflated by wind erosion from bars in the braided river, transported, and deposited on adjacent uplands. The 25,000 cal yr BP date at the top of the lake deposits agrees with dates elsewhere for the timing of the blockage of the river by the Lake Michigan glacial lobe and diversion of the Mississippi into its modern channel. The lake that is dated at the Nauman site likely occurred in a tributary or backwater area of the valley. As the Lake Michigan glacier pushed westward across the Ancient Mississippi, it pushed the river against the western bluff constricting flow in a narrowing channel. Gravels at the Condit site (Fig. 11) date closely to the 25,000 cal yr BP age at the top of the Nauman lake deposits, and these gravels at Condit are interpreted to be the last deposited by the Ancient Mississippi before it was diverted permanently to its modern course.

Dates available elsewhere indicate that the Wisconsin glacier began its retreat from it maximum position about 24,000 cal yr BP (Hansel and Johnson 1992), which when compared with the above dates suggests that the Wisconsin glacier lingered at its maximum advance position for about 1000 years. Upon retreat of the glacier, Mississippi drainage did not return to central Illinois but entrenched itself in its modern channel. Drainage from the glacier margin and from land that emerged from beneath the glacier in northeastern Illinois gathered and found a course approximately where the Illinois River valley is today. The river eroded into the newly exposed deposits and about 17,000 cal yr BP as the ice neared the present southern border of Lake Michigan a series of large floods were released. These outburst floods incised the valley and deposited large gravel bars that were sculpted into terraces. One hypothesis suggests that most of the large landforms and the overall shape of the modern valley date to those floods. A date from the upper part of the high terrace just north of Lacon places those deposits at 19,500 cal yr BP, somewhat older than the suggested age of the floods (Fig. 11). More dating is needed.

CONCLUSION

Recent geologic mapping and associated studies in the area of the Middle Illinois River Valley between Chillicothe and Hennepin have revised and refined knowledge of the distribution, thickness, composition, and age of sand & gravel deposits (aquifers) that infill the Ancient Mississippi Bedrock valley (Fig. 12). This principal aquifer in the region, the "Sankoty aquifer", has been determined to contain significant internal complexity, stemming from its multi-stage fluvial and glacial-fluvial origins that resulted in multiple stacked sedimentary sequences interrupted by significant unconformities (erosion/scour surfaces) and fine-grained interbeds (tills and lake deposits) that function as barriers to groundwater flow (aquitards). The fact that the coarse deposits comprise a significant groundwater resource is unaltered by new findings, however, recent work has highlighted that the distribution of the deposits is incompletely known and their composition is more complex than previously thought. The informal stratigraphic term 'Sankoty sand' and formal term "Sankoty Member" are oversimplified geologic concepts that do not represent the actual setting, stratigraphy, or composition of the unit. They are poor terms for the deposits of the Ancient Mississippi River in this area. The work reported here found, in fact, no definitive evidence of "Sankoty sand" or 'Sankoty Member", as originally defined, in the deposits of the Ancient Mississippi River beneath the Middle Illinois River Valley. Continued use of the term Sankoty aquifer is, however, recommended because the term is well established among the various user communities (drillers, planners, developers, government agencies, etc.) and because it describes a body of sediment, however complex sedimentologically or stratigraphically, that functions as an aquifer.

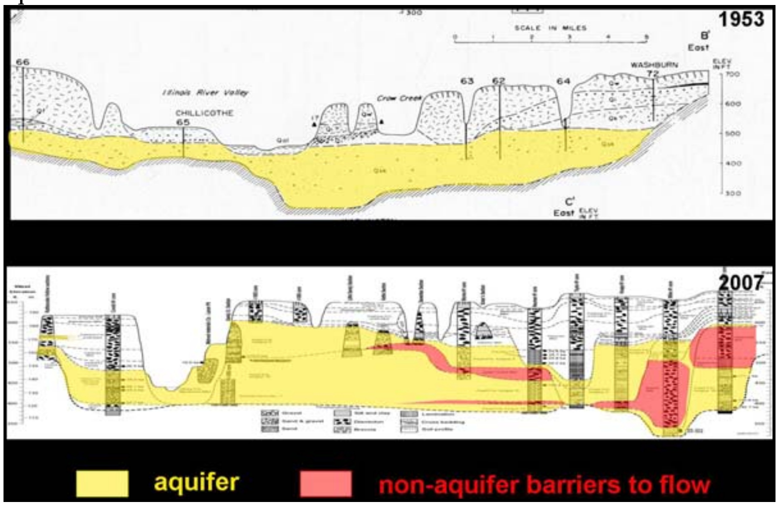

Figure 12. Comparison of Horberg's (1953) and this study's (2007) cross sections of the valleys, showing the increased complexity of the geometry and composition of the aquifer that has become known with new geologic mapping of the area.

OSL age determination is an important new tool that aids understanding of the timing and processes of deposition of sand and gravel up to at least 200,000 cal yr BP. OSL ages obtained for samples of old sand and gravel beds collected for this study are the first such application of that relatively new technique to age determinations on aquifer material in Illinois. These results have demonstrated value of the OSL method for study and correlation of sand and gravel aquifers in Illinois, deposits that have been otherwise difficult to correlate quantitatively based on mineralogical, chemical, or sedimentary composition or other analyses. These ages firmly establish the previously debated age of Illinois Episode glaciation in its "type" region -- central Illinois -- and confirm correlation of Illinois Episode to a global cold period, OIS 6 (~195,000 to 130,000 cal yr BP).

Geologic mapping and related study can improve understanding of distribution, composition and complexity of glacial and fluvial aquifers, but with only a fraction of the Illinois and Ancient Mississippi river systems mapped geologically, much work remains before the aquifer systems become well mapped and understood.

Latecomers to this geologic story, humans entered the region after most of the events described had happened, and for 10,000 years or slightly more humankind has made homes and, more recently, farms and factories, in and near the Illinois River valley. The ancient sands, buried long before we arrived, are a considerable fresh water resource worthy of protection. Gravel in the outburst-flood-carved terraces of the river is a valuable commodity mined widely. Realizing that sustainability of our lifestyle depends on use of these resources; we must continue to strive for better understanding of their occurrence, capabilities, and limits in order to benefit from the legacy of the ancient rivers.

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