

Age of the Winnebago Formation of North-Central Illinois as Determined by Optically Stimulated Luminescence Dating

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Prairie Research Institute
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Front Cover: *LiDAR image of a portion of Boone and Winnebago Counties.*

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CONTENTS

Abstract	1
Introduction	1
Methodology	5
Results	7
Site 1	7
Site 2	9
Site 3	9
Site 4	9
Site 5	12
Discussion and Conclusions	12
Acknowledgments	14
References	14
List of Tables	
1 Optically stimulated luminescence ages of the Beaver Creek Tongue in Boone and Winnebago Counties	6
List of Figures	
1 Generalized maps showing major changes in the mapping and classification of the glacial deposits of northwestern Illinois	2
2 Distribution of the uppermost diamicton members in north-central Illinois	3
3 Time-space diagram showing the relationship of the Winnebago Formation to younger and older formations	4
4 Distribution of the Beaver Creek Tongue of the Pearl Formation, and map showing the location of samples obtained for OSL dates	5
5 West-east cross section (A-A') through eastern Winnebago County and Boone County showing the extent of the Beaver Creek Tongue	6
6 Site 1: (a) Schlichting Quarry (State Street Quarry) Section and OSL sampling locations; (b) OSL sampling site Boone-A; (c) OSL sampling site Boone-B	8
7 Site 2: Home site in abandoned sand and gravel pit; OSL sampling site Boone-C	9
8 Site 3: Nimtz Quarry West Section: (a, b) OSL sampling site Winn-A; (c, d) OSL sampling site Winn-B	9
9 Site 4: (a) Nimtz Quarry Section, west wall (viewed from top); (b) Nimtz Quarry Section, northern portion of west wall (viewed from ground)	10
10 Site 4: (a) OSL sampling site Winn-C; (b) OSL sampling site Winn-D; (c) OSL sampling site Winn-E	11
11 Site 5: Schuld Road kame, OSL sampling sites Boone '09A and Boone '09B	12
12 Beaver Creek Tongue OSL dates from four sites, their mean pooled age, and position within the Martinson et al. (1987) deep sea oxygen-isotope record	12
13 LiDAR image of a portion of Boone and Winnebago Counties showing fluted topography and location of OSL sampling sites	13

Abstract

Stratigraphic investigations and detailed three-dimensional geologic mapping in the mid-1980s in Boone and Winnebago Counties, north-central Illinois, provided considerable new data allowing for revision of the stratigraphic framework, which had been controversial and unresolved for almost 100 years. Significant findings were (1) the Winnebago Formation was not deposited during the early Wisconsin Episode as had previously been thought, but rather was deposited during the late Illinois Episode, and (2) the discovery of a lowermost coarse, sorted member of the Winnebago Formation, named the Beaver Creek, which was interpreted to have been deposited by proglacial meltwater. An unresolved issue was the age of the Capron Member, the uppermost member of the Winnebago Formation.

This report provides results from newly sampled locations of the Winnebago Formation using optically stimulated luminescence (OSL) dating of quartz grains from sand. Eight OSL ages for the Beaver Creek confirm its late Illinois Episode (late marine oxygen-isotope stage 6) deposition as well as that of overlying Winnebago Formation diamictons. The mean pooled age of the eight analyses is $136,610 \pm 3,780$ years BP. Dates range from 150,000 to 128,000 years ago, with five of the dates clustered between 132,000 and 139,000 years ago. A single acceptable OSL date of 106,000 years ago from a kame atop Capron Ridge helps clarify the age of the Capron Member, but not totally; the younger than expected age is probably due to bioturbation or some other mechanism of mixing. Although this OSL date is not definitive, it does suggest an Illinoian age for the underlying Capron diamicton.

Introduction

Since the mid-1890s (e.g., Chamberlin 1894), the glacial deposits of north-central Illinois have been investigated, and an extensive body of literature (as reviewed by Frye et al. 1969) has reported on the stratigraphic complexity and difficulties of mapping in this region (Figure 1). An irregular bedrock surface, thin drift with few exposures, lithologically similar diamictons, extensive

erosion, and rarely preserved paleosols were the significant factors contributing to the complexity of the glacial succession and ambiguity of its age interpretation. Stratigraphic investigations and detailed three-dimensional geologic mapping in the mid-1980s (Berg et al. 1984, 1985) that focused on Boone and Winnebago Counties provided considerable new data, allowing for further revision of the stratigraphic framework. More than 1,800 new sediment samples were obtained from more than 300 localities, including samples from 3,550 ft (1,082 m) of unconsolidated core at 30 test-hole locations [to a maximum depth of 304 ft (93 m)]. Evaluation of drillers' descriptive logs of geologic materials documented on nearly 5,000 water-well records supplemented these data. Drift thickness and bedrock topography maps were refined, the stratigraphic relations of major diamictons and sand and gravel units were evaluated, the surficial (Figure 2) and subsurface distributions of deposits were remapped, and the regional correlations of glacial sediments were established (Figure 3).

Significant findings from the 1980s studies were

1. The Winnebago Formation was not deposited during the early Wisconsin Episode [Altonian—75,000 to 28,000 years before present (years BP), or the now-recognized marine oxygen-isotope stages (MOIS) 3 and 4] as had previously been thought (Willman and Frye 1970), but rather was deposited during the late Illinois Episode (prior to about 125,000 years BP, during MOIS 6). Several drilled and exposed locations showed that a paleosol, interpreted as the Sangamon Geosol, was formed in the uppermost Winnebago Formation diamicton (the Argyle Member), and this recognition led to a complete revision of both the rock stratigraphic placement and the geographic extent of the Argyle till. Based on particle size and clay mineral contents of hundreds of diamicton samples and regional stratigraphic evaluations, the Argyle Member and the entire Winnebago Formation (Figure 2) were restricted to Winnebago and Boone Counties and a small portion of northwestern McHenry County.
2. The youngest Illinois Episode Glasford Formation diamicton, the Esmond Member, previously thought to have been a unit of the Wedron Group deposited during the Wisconsin Episode, was discovered to occur below the Argyle. A Wisconsin Episode age was first assigned to the Esmond, as reported in Frye et al. (1969), based on one radiocarbon date of $23,750 \pm 1,000$ years BP from organic material beneath the unit at the Greenway School cores in Ogle County. However, because of increasing stratigraphic evidence and the likelihood of the Sangamon Geosol above the Esmond, the organic material below the unit was resampled by coring five new sites at the same Greenway School location (Follmer and Kempton 1985), and meticulous care was used in sampling and sample preparation to avoid possible contamination by younger organics. Results from two radiocarbon dates of >41,000 years BP confirmed the older age. The Esmond now is correlated with the Sterling and Radnor Members of the Glasford Formation, the latter of which has a widespread distribution in other regions of Illinois (Berg et al. 1985; Stiff 2007).
3. A diamicton recognized beneath the Argyle Member was named the Nimtz Member. It has a grain-size distribution similar to the Argyle [Argyle (304 samples): 53% sand-29% silt-18% clay; Nimtz (186 samples): 51% sand-31% silt-18% clay] but is consistently higher in illite [Argyle (174 samples): 61%; Nimtz (151 samples): 69%]. The Nimtz till is more compact than the Argyle till, and physical similarities between the two suggest deposition by the same ice advance. However, sand and silt separate the tills at some borehole localities, suggesting two ice-margin advances.
4. The lowermost coarse, sorted member of the Winnebago Formation was discovered and named the Beaver Creek Sand (Berg and Kempton 1985). (This unit is now formally named the Beaver Creek Tongue of the Pearl Formation.) Its distribution (Figure 4) covers much of the northern half of Boone County and extends into east-central Winnebago County, east of the Rock River. It underlies the Nimtz Member and overlies bedrock or older Glasford

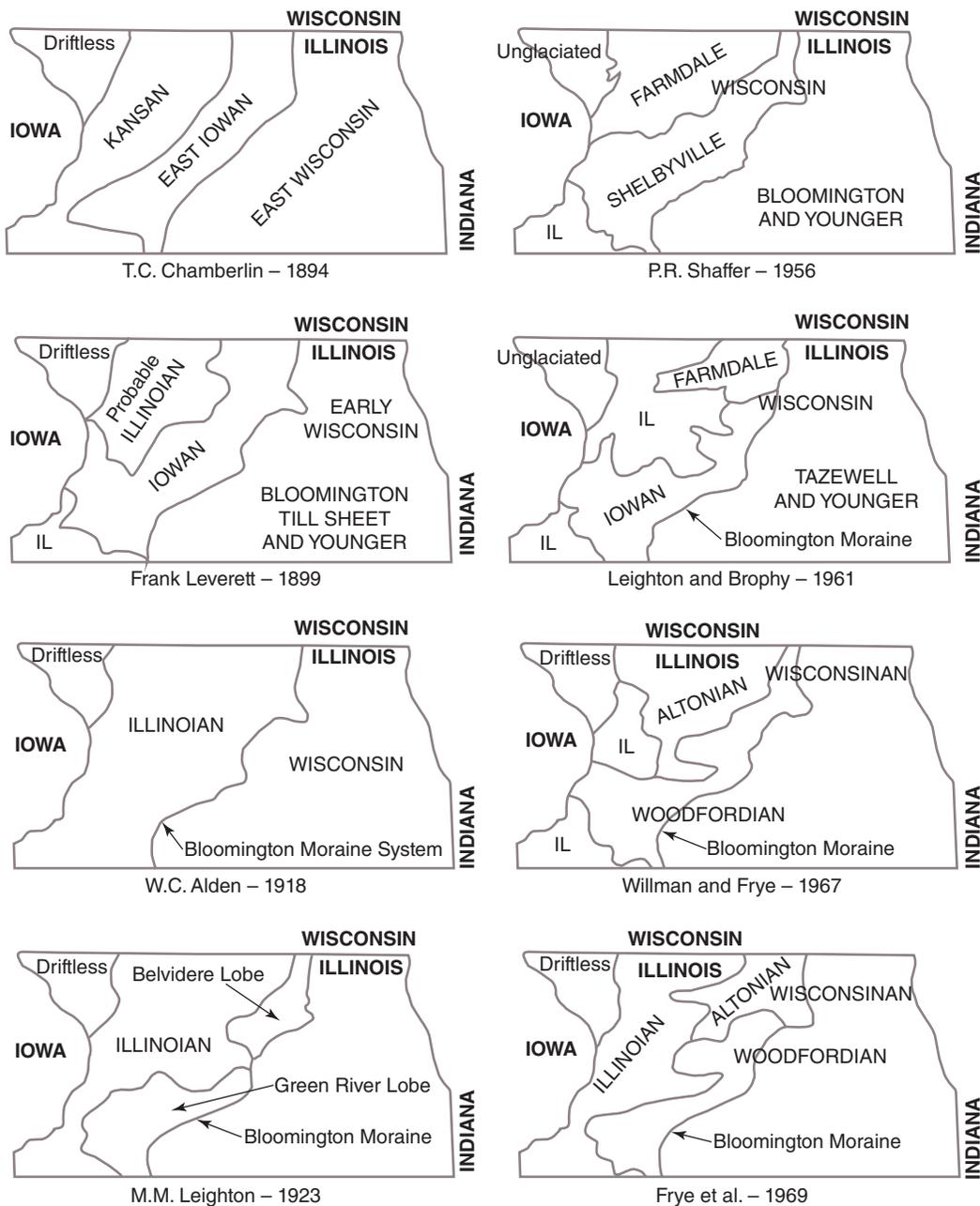


Figure 1 Generalized maps showing major changes in the mapping and classification of the glacial deposits of northwestern Illinois (from Frye et al. 1969).

Formation diamictons and lacustrine units (Figure 5). Primarily composed of sand and gravel, the unit was interpreted to have been deposited by proglacial meltwater from the ice advance that deposited the Nimtz Member.

5. An unresolved issue was the age of the Capron Member, the uppermost till member of the Winnebago Forma-

tion, and its stratigraphic relationships (Krumm and Berg 1985). Situated in the northeastern corner of Boone County and northwestern McHenry County in Capron Ridge, it overlies the Argyle Member, and because a weakly developed weathering zone in the Argyle was identified in two borings, an Altonian age (early Wisconsin Episode—75,000 to 27,500 years BP;

Willman et al. 1975) was favored by Krumm and Berg (1985). Deposition during the Illinois Episode was considered unlikely because that time-stratigraphic placement depended on a tenuous correlation of the Capron with the portion of the Clinton Member of south-central Wisconsin (Fricke 1976; Canfield and Mickelson 1985) that contains the Sangamon Geosol.

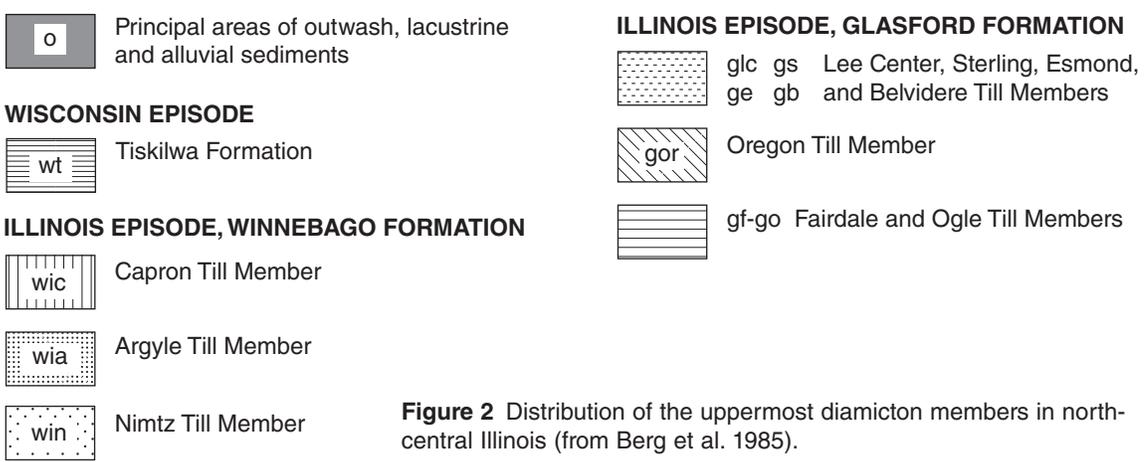
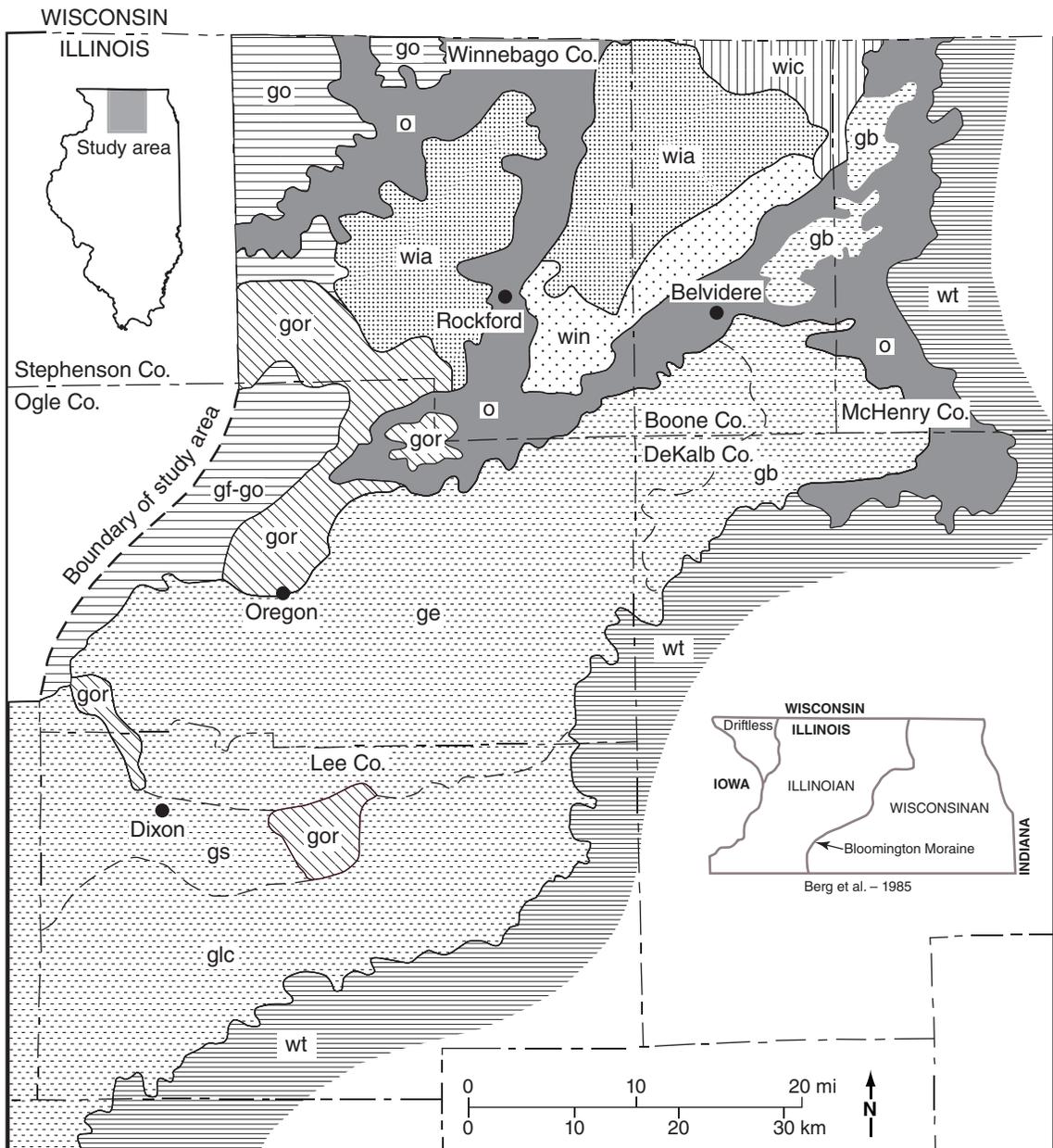


Figure 2 Distribution of the uppermost diamicton members in north-central Illinois (from Berg et al. 1985).

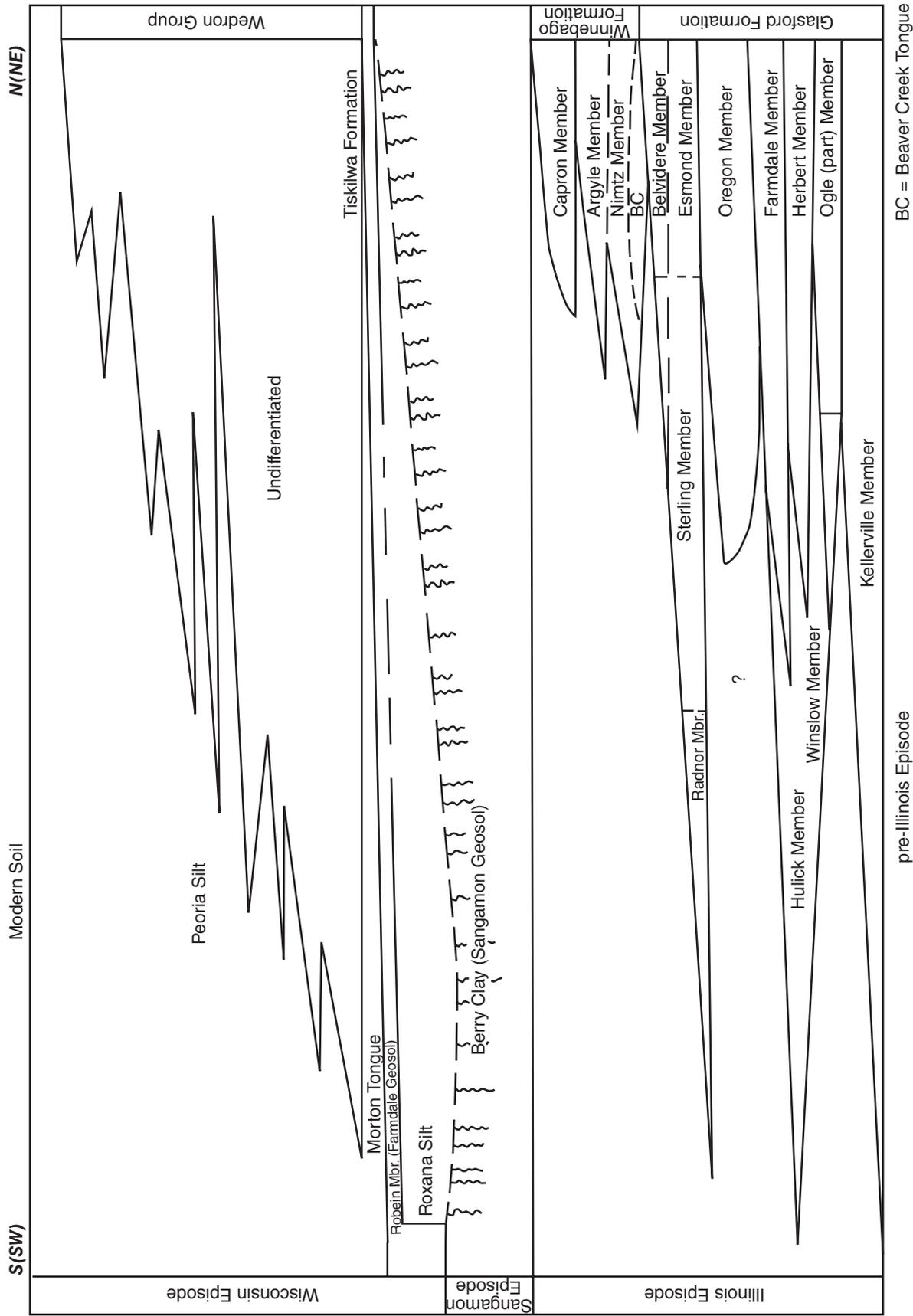


Figure 3 Time-space diagram showing the relationship of the Winnebago Formation to younger and older formations (modified from Berg et al. 1985).

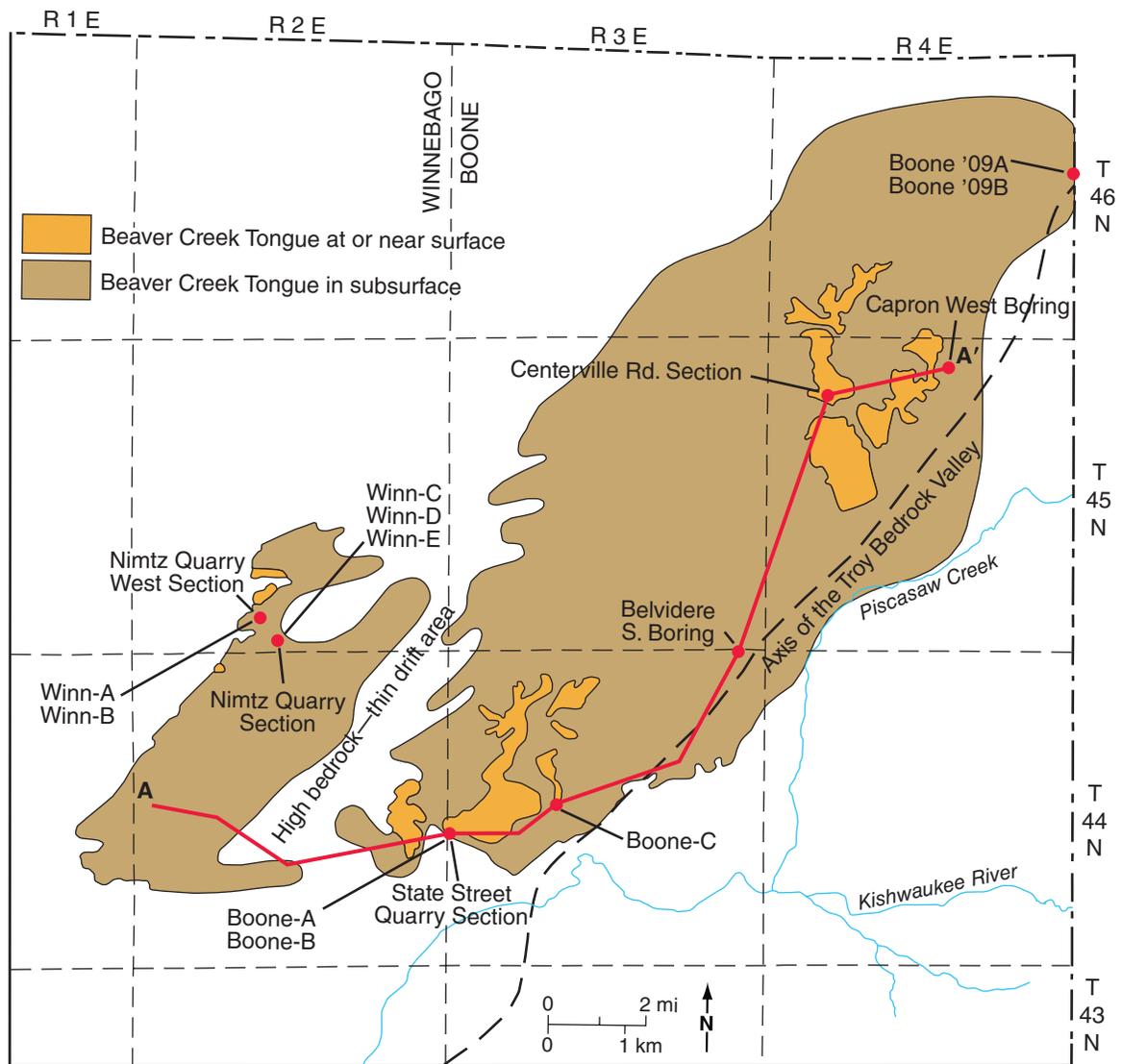


Figure 4 Distribution of the Beaver Creek Tongue of the Pearl Formation, and map showing the location of samples obtained for OSL dates (modified from Berg et al. 1985).

The purpose of this report is to provide results from locations in Boone and Winnebago Counties that have been newly sampled, with the explicit intent of determining the age of the Winnebago Formation by using optically stimulated luminescence (OSL) dating of quartz sand. The targeted geologic units are (1) sand correlated with the Beaver Creek Tongue that stratigraphically underlies Winnebago Formation diamictons and has been interpreted as a proglacial deposit of the glacier that deposited those diamictons, and (2) a kame overlying the Capron Member, the youngest member of the Winnebago Formation,

on Capron Ridge in northeastern Boone County. The former provides a maximum age for the Winnebago Formation, whereas the latter provides data on the age of the Capron Member.

Methodology

Eight samples of sand were obtained from deposits correlated with the Beaver Creek Tongue for OSL determinations—three from Boone County and five from Winnebago County (Table 1, Figure 4). Beaver Creek samples from Boone County were from that portion of the deposit east of the bedrock high and thin

drift region, whereas those from Winnebago County were from that portion of the deposit west of the bedrock high and thin drift region (Figure 4). In addition, two samples of sand were obtained from a gravel pit in a kame, presumed to overlie diamicton of the Capron Member of the Winnebago Formation atop Capron Ridge in Boone County.

Although sand textures were variable in the exposures, particular care was taken to sample zones of uniform fine to medium sand, as shown in the photographs of the sampling sites. The sampling sites were dug into with the

bleached. Quartz grains were separated using a density of 2.70 g mL^{-3} of lithium metatungstate liquid and etched using 48% HF followed by 2 M HCl for 50 minutes for each treatment. If necessary, a second HF-HCl pretreatment was applied for the same duration. Water contents were calculated by weighing the sample before and after 2 to 3 days of oven drying at 90°C . The single-aliquot regenerative-dose protocol (Murray and Wintle 2000; Wintle and Murray 2006) was used.

The equivalent dose (D_e) in quartz grains was obtained from the interpolation of sensitivity-corrected natural OSL signals from a sensitivity-corrected regenerative dose-response curve after unacceptable aliquots were rejected. The criteria for rejection included a recycling ratio of 10% and OSL signal saturation. To remove sample noise signals, aliquots were preheated from 240 to 260°C for 10 seconds, and then cut-heat temperatures of 200 to 220°C were applied, depending on individual dose recovery and thermal transfer tests. All D_e values were measured on aliquots in odd positions of the carousel in a Risø TL/OSL-DA-20 reader with a $^{90}\text{Sr}/^{90}\text{Y}$ built-in source, blue light-emitting diodes centered at 470 nm, a Hoya U-340 filter, and an EMI 9635 QA photomultiplier tube. The dose rate was determined using a low-background ORTEC GEM-40190P gamma spectrometer on pulverized samples weighing approximately 100 g and preheated at 450°C while being tightly held in Marinelli beakers. Samples were pushed down and packed to a fixed thickness using a laboratory-made plunger that perfectly fit the internal volume of the Marinelli beakers. The beakers were further sealed with layers of Parafilm for 3 weeks before measuring. No signs of disequilibrium were observed for at least four uranium isotope activities. The cosmic contribution to the dose rate was determined by attenuation of the cosmic ray dose rate with depth, as well as variation of the cosmic ray dose rate with altitude, latitude, and longitude. The soft, hard, and total cosmic ray dose rates were calculated by using a template from the Nordic Centre for Luminescence Dating (Department of Earth Sciences, Aarhus University, Risø National Laboratory,

Roskilde, Denmark). The OSL ages were also calculated using a template from the Nordic Centre for Luminescence Dating (Department of Earth Sciences, Aarhus University, Risø National Laboratory).

For samples dated at the University of Nebraska-Lincoln OSL Laboratory (UNL2237 through UNL2244), sample preparation was conducted under amber light conditions. Samples were wet sieved to extract the 90- to $150\text{-}\mu\text{m}$ fraction and treated with HCl to remove carbonates. Quartz and feldspar grains were extracted by flotation using a 2.7 gm cm^{-3} sodium polytungstate solution and then treated for 75 minutes in 48% HF, followed by 30 minutes in 47% HCl. The 30% water percentages shown in Table 1 were determined based on discussions between the authors and the University of Nebraska-Lincoln OSL Laboratory. The sample was then resieved and the $<90\text{-}\mu\text{m}$ fraction was discarded to remove residual feldspar grains. The etched quartz grains were mounted on the innermost 2 mm of 1-cm aluminum disks using Silkospray. Chemical analyses were conducted by Chemex Labs, Inc. (Sparks, NV) using a combination of inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectroscopy. Dose rates were calculated using the methods of Aitken (1998) and Adamiec and Aitken (1998). The cosmic contribution to the dose rate was determined using the techniques of Prescott and Hutton (1994).

Optically stimulated luminescence analyses were performed on a Risø Automated OSL Dating System (Model TL/OSL-DA-15B/C) equipped with blue and infrared diodes, using the single-aliquot regenerative-dose technique (Murray and Wintle 2000). The D_e distributions showed no evidence of partial bleaching, and the decision tree proposed by Bailey and Arnold (2006) indicated that the D_e values should be determined using the central age model (Galbraith et al. 1999).

Preheat and cut-heat temperatures of 240°C for 10 seconds and 200°C for 0 seconds, respectively, were based on preheat plateau tests between 180 and 280°C . Dose recovery and thermal trans-

fer tests were conducted (Murray and Wintle 2003). Growth curves were examined to determine whether the aliquots were below saturation ($D/D_0 < 2$; Wintle and Murray 2006), and D_e in excess of $2D_0$ were discarded from the data set prior to averaging. Average D/D_0 values for the aliquots used to calculate D_e for these samples were between 0.9 and 1.6. Optical ages were based on a minimum of 20 aliquots. Individual aliquots were also monitored for insufficient count rate, large errors in the D_e , poor recycling ratio, strong medium component versus strong fast component, and detectable feldspar. Aliquots deemed unacceptable based on these criteria were also discarded from the data set prior to averaging.

Results

Site 1

Two samples of the Beaver Creek Tongue were collected from overburden in the east face of Schlichting Quarry in the SW SW NW of T44N, R3E, Sec. 19 in Boone County, about 300 ft (91.4 m) east of the Winnebago County line. This locale is the type section for the Beaver Creek Tongue of the Pearl Formation and was called the State Street Quarry Section (Figure 4) in earlier work by Berg et al. (1985). The exposure contains 10 ft (3.1 m) of light brown sandy diamicton (Argyle and Nimtz Members) that overlies contorted sand and gravel beds of the Beaver Creek Tongue (Figure 6a). The Galena-Platteville Dolomite underlies the Beaver Creek. The diamicton was interpreted as mostly hard basal till. In Berg and Kempton (1985), and as similarly described for this investigation, the Beaver Creek Tongue exhibits considerable vertical variability, mostly consisting of calcareous cross-bedded yellow to tan medium-grained sand, but cobbles and boulders are common. Large inclusions of Winnebago Formation diamicton have been incorporated into the contorted beds, suggesting deposition in the near-ice-front environment and glacial overriding.

Two samples of the Beaver Creek Tongue were obtained: an upper sample at a depth of 21.3 ft (6.5 m) below the ground surface, and a lower sample 27.9 ft (8.5 m) below the surface (Figures 6a-6c).

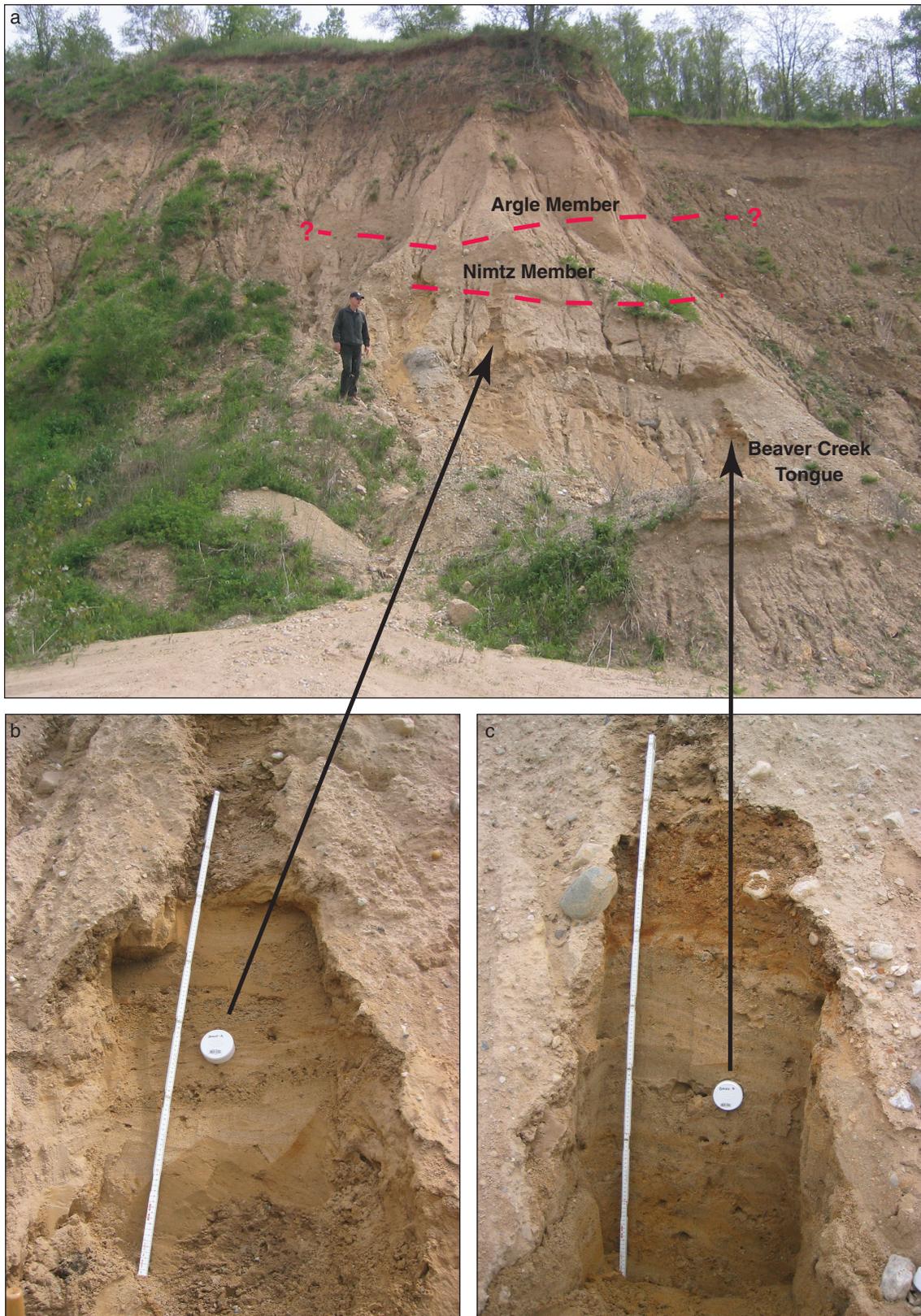


Figure 6 Site 1: (a) Schlichting Quarry (State Street Quarry) Section and OSL sampling locations; (b) OSL sampling site Boone-A; (c) OSL sampling site Boone-B. Photographs by E.D. McKay.

The uppermost sample yielded an OSL age of 143.8 ± 10.9 ka (thousand years ago), and the lower sample yielded an age of 133.1 ± 10.8 ka.

Site 2

A small excavation in sand and gravel for home construction, just southeast of the intersection of Beaver Valley Road and Moan Road, in the SW NW SW of T44N, R3E, Sec. 16 in Boone County, exposed approximately 10 ft (3.1 m) of horizontally bedded Beaver Creek Tongue at land surface. A sample that was estimated to be approximately 10 ft (3.1 m) below the original land surface (Figure 7) yielded an OSL age of 132.3 ± 11.0 ka.

Site 3

Two Beaver Creek Tongue samples for OSL determinations were obtained from a sand and gravel pit in Winnebago County in the NW NW of T45N, R2E, Sec. 33 just east of Forest Hills Road and south of Harlem Road (Nimtz Quarry West Section). The first sample was obtained 5 ft (1.5 m) below the top of a highwall on the east side of the site (Figures 8a, 8b), and it yielded an OSL age of 133.2 ± 9.8 ka. The second sample was obtained near the middle of the site on the pit surface, where a small gully exposed the sand (Figures 8c, 8d). We estimate that approximately 10 ft (3.1 m)



Figure 7 Site 2: Home site in abandoned sand and gravel pit; OSL sampling site Boone-C. Photograph by E.D. McKay.

of sand and gravel had been excavated from the sampling location and that the overall burial depth was 12.1 ft (3.7 m). This second location was lower in the section and yielded an OSL age of 150.4 ± 11.1 ka.

Site 4

Three Beaver Creek Tongue samples were obtained from the Nimtz Quarry Section, also in T45N, R3E, Sec. 33 about 0.5 mi (0.8 km) southeast of Site 3. This site contains the most extensive (>0.5 mi long) Quaternary section in the two-county area, exposing 33 ft (10.1 m) of

the Argyle and Nimtz Members as well as older Glasford Formation diamicton members (Berg et al. 1985), all overlying Galena-Platteville Dolomite. It is the type section for the Nimtz Member. When the site was visited to obtain samples for OSL determinations, a fresh Quaternary exposure above the western portion of the south quarry wall (NW SW SE of T45N, R2E, Sec. 33; Figure 9) was exposed for the first time at this site: the Beaver Creek Tongue was revealed beneath Argyle and Nimtz diamictons. Three samples at depths of 75.5 ft (23 m), 12.8 ft (3.9 m), and 17.7 ft (5.4 m) yielded OSL ages of 128.2 ± 10.8 , 138.9 ± 11.6 ,

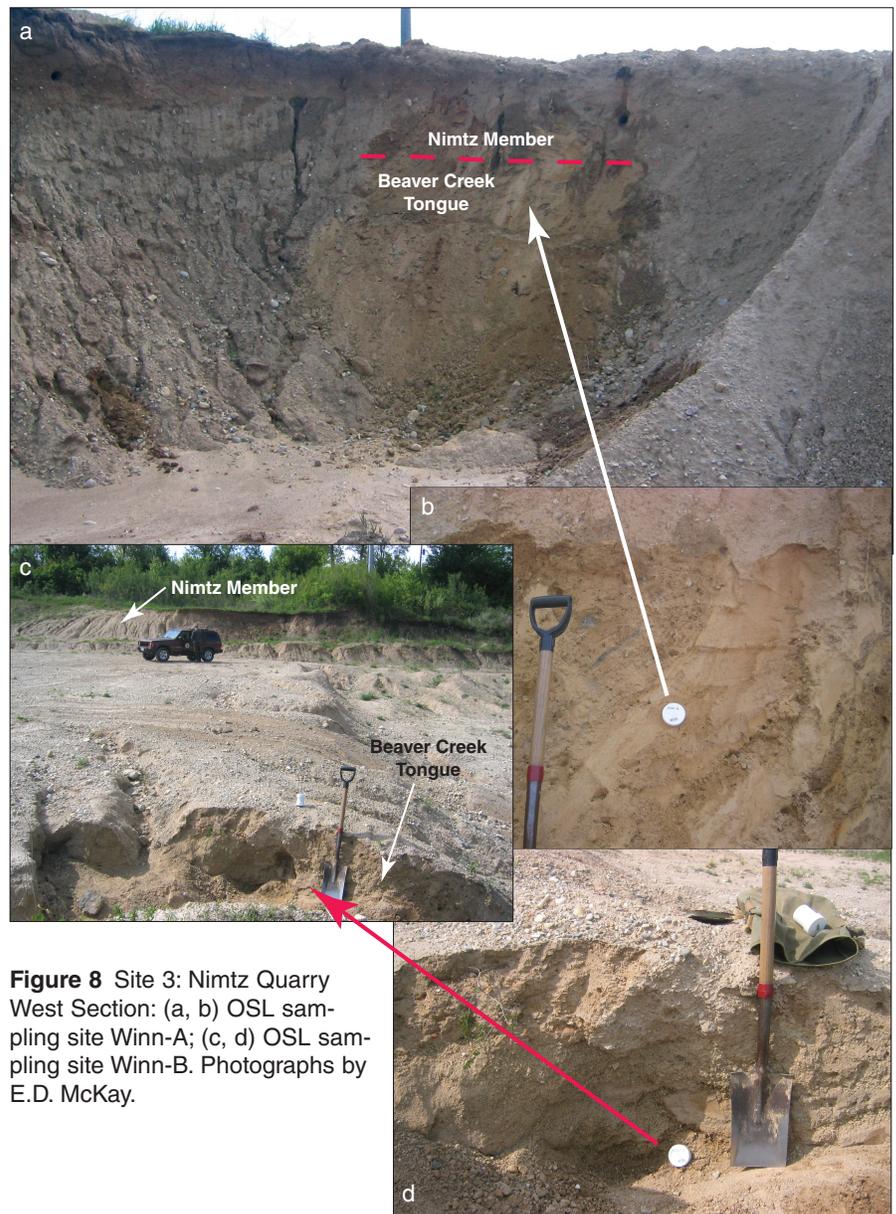


Figure 8 Site 3: Nimtz Quarry West Section: (a, b) OSL sampling site Winn-A; (c, d) OSL sampling site Winn-B. Photographs by E.D. McKay.



Figure 9 Site 4: (a) Nimtz Quarry Section, west wall (viewed from top); (b) Nimtz Quarry Section, northern portion of west wall (viewed from ground). Beaver Creek Tongue is exposed at the base. Photographs by E.D. McKay.

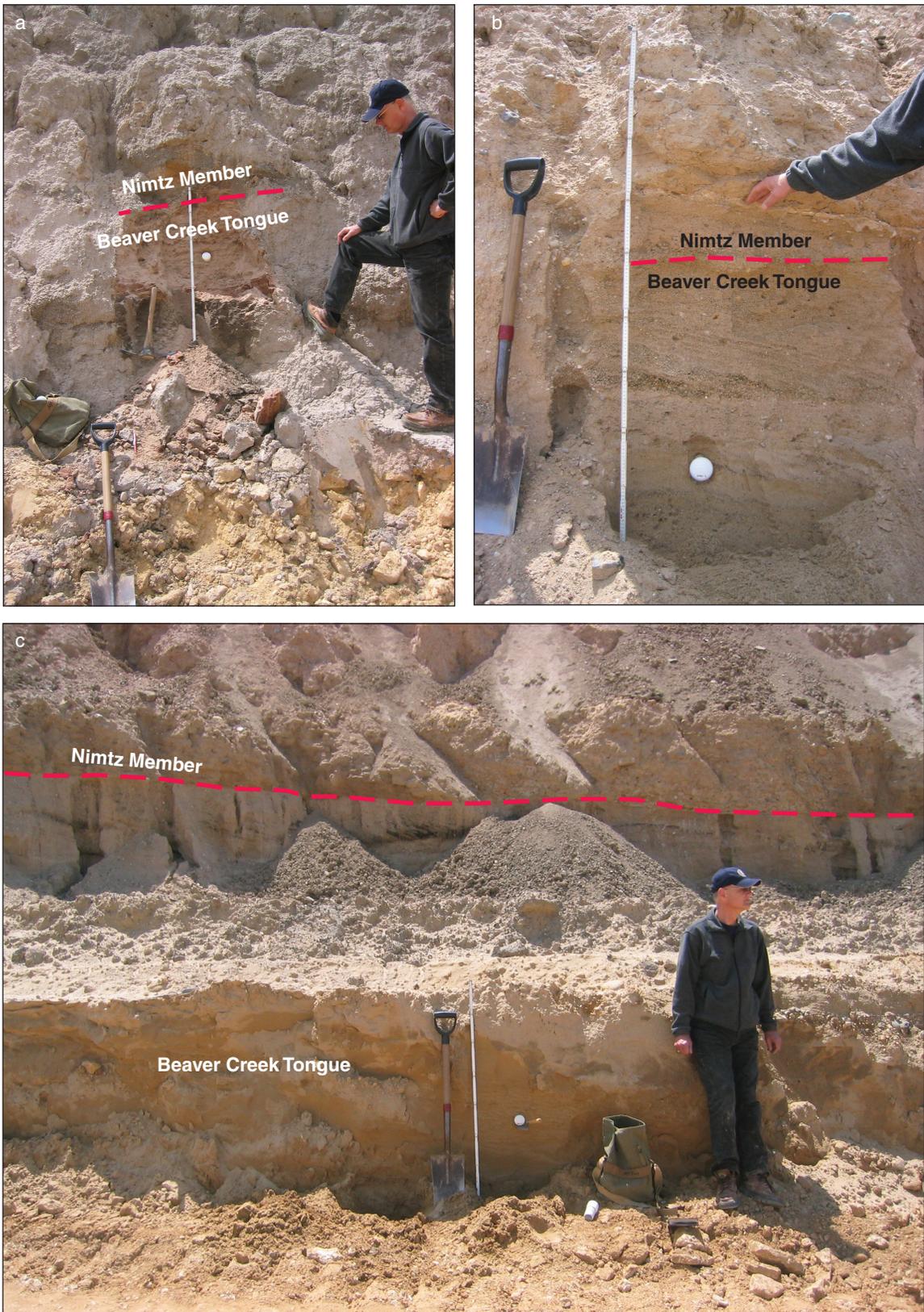


Figure 10 Site 4: (a) OSL sampling site Winn-C; (b) OSL sampling site Winn-D; (c) OSL sampling site Winn-E. Photographs by E.D. McKay.

and 134.8 ± 9.9 ka (Figures 10a, 10b, 10c, respectively).

Site 5

Two samples of sand were collected from an abandoned gravel pit on Schuld Road atop Capron Ridge in Boone County in the NE NE NE of T46N, R4E, Sec. 24 (Figure 11). The sampling location, on a kame, is the only known exposure of the sand deposit atop Capron Ridge. The first sample, taken 6.5 ft (2 m) below land surface, yielded an OSL age of 106 ± 8 ka, whereas the second sample, at a depth of 16.4 ft (5 m), yielded an OSL age of only 3.8 ± 1.4 ka. At the time of sampling, it was suspected that this lower sample might yield a very young date because it was from a fan of sand that may have slumped off a formerly steeper sandpit face. It was not possible to dig deep enough through the apron of slumped sand to obtain an in-place sample. This very youthful date is considered to have been reset and is not reflective of the age of the deposit.

Discussion and Conclusions

Berg et al. (1984, 1985) determined that the age of Winnebago Formation diamictons was late Illinois Episode based on stratigraphic correlations and evidence that the Sangamon Geosol was developed into these deposits. In this investigation, the eight OSL ages obtained for the Beaver Creek Tongue confirm a late Illinois Episode deposition of the Beaver Creek and of overlying Winnebago Formation diamictons. The mean pooled age of the eight OSL ages is $136,610 \pm 3,780$ ka (Figure 12), which is within a 1 sigma error of the last significant period of global ice (137,500 to 140,000 years BP) during MOIS 6 (Martinson et al. 1987). These dates further suggest a final late Illinois Episode glacial advance into Boone and Winnebago Counties during this time. Still uncertain is the origin of the ice lobe and whether it originated from a more northerly direction from the Green Bay lowland or a more easterly-northeasterly direction from the Lake Michigan basin. Strong northeast- to southwest-oriented fluting in the surface of the Argyle Member in eastern Winnebago County and northern Boone County (Figure 13)



Figure 11 Site 5: Schuld Road kame, OSL sampling sites Boone '09A and Boone '09B. Photograph by E.D. McKay.

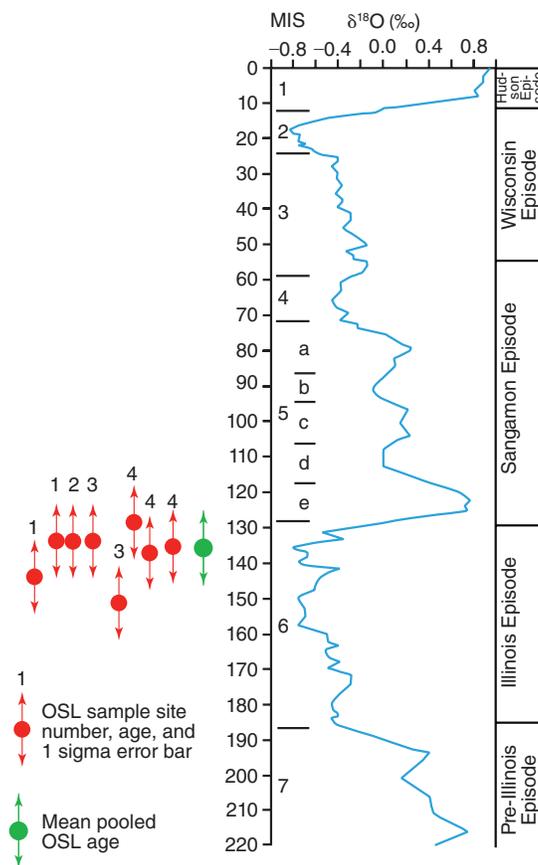


Figure 12 Beaver Creek Tongue OSL dates from four sites, their mean pooled age, and position within the Martinson et al. (1987) deep sea oxygen-isotope record.

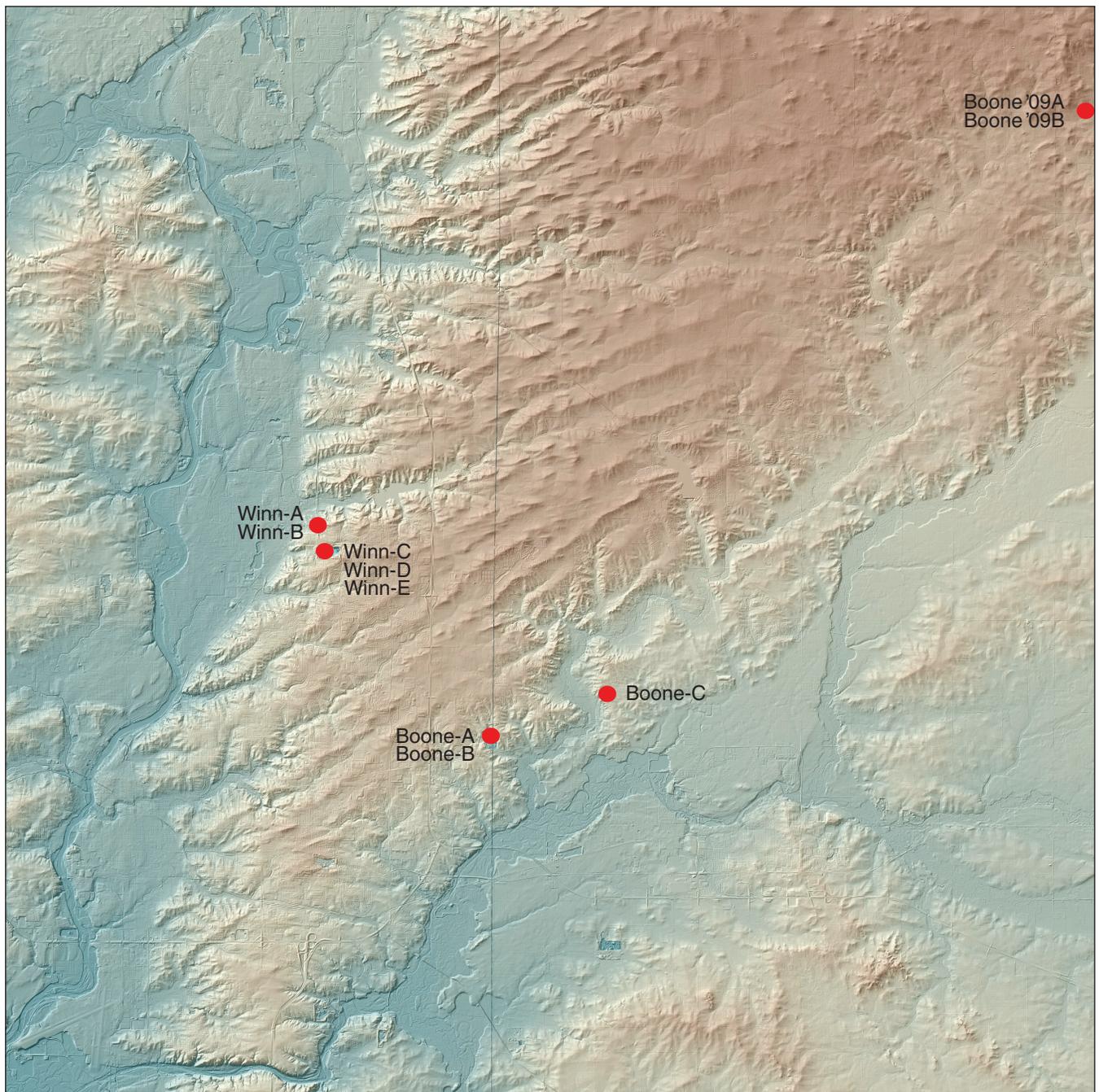


Figure 13 LiDAR image of a portion of Boone and Winnebago Counties showing fluted topography and location of OSL sampling sites.

suggests glacial flow from the northeast and an origin from the Lake Michigan basin. Miller (2000) also suggested a Lake Michigan glacial lobe origin based on work in south-central Wisconsin. However, a northerly ice direction is suggested by (1) the distribution of the Winnebago Formation as a younger geographically distinct deposit from older

Lake Michigan lobe Illinois Episode diamictos, (2) its extent and correlation with diamictos in south-central Wisconsin, and (3) till fabric measurement orientations by Canfield and Mickelson (1985) for the Clinton Member in Wisconsin, which stratigraphically overlies the Allens Grove Member in Wisconsin (Argyle Member equivalent), indicating

flow from the north-northwest. Frye et al. (1969) first suggested that the Argyle was deposited by the southward-flowing ice by way of Green Bay based on the orientation of shale pebbles, the scarcity of black shale, and the lower illite and higher vermiculite contents. Additional research is needed to clarify the issue.

The single acceptable OSL date from the kame atop Capron Ridge helps clarify the age of the Capron Member, but not precisely. Krumm and Berg (1985) discussed the time-stratigraphic placement of the Capron and favored an Altonian age based mainly on possible weak soil formation below the Capron, the lack of the Sangamon Geosol in its surface, dissimilarities with a younger diamicton (Tiskilwa Formation) to the east, and geomorphic differences indicating that Capron Ridge “looked” to be an older landform than the younger (20,000 years BP, MOIS 2) Marengo Moraine to the east, with the Tiskilwa comprising this younger moraine. The 106 ± 8 ka age for the uppermost sample above the Capron diamicton dates to the middle of the Sangamon Interglacial (MOIS 5). This younger than expected age might be evidence of an unrecognized disturbance of the deposit during mining or perhaps bioturbation. Therefore, although this OSL date is not definitively Illinois Episode, it is consistent with an Illinois Episode MOIS 6 age for the underlying Capron diamicton. Additional dates are needed to confirm the age, and additional research will be required to discern the stratigraphic relations between the Capron Member and the Argyle Member in Illinois and the Clinton Member in Wisconsin.

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