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Abstract

The transition from full glacial to interglacial conditions along the southern margin of the Laurentide ice sheet resulted in dramatic changes in landscapes and biotic habitats. Strata and landforms resulting from the Wisconsin Episode of glaciations in the area directly west of Lake Superior indicate a context for late Pleistocene biota (including human populations) connected to ice margins, proglacial lakes, and postglacial drainage systems. Late Glacial landscape features that have the potential for revealing the presence of Paleoindian artifacts include abandoned shorelines of proglacial lakes in the Superior and Agassiz basins and interior drainages on deglaciated terrains. The linkage between Late Pleistocene human populations and Rancholabrean fauna has yet to be demonstrated in the western Lake Superior region, although isolated remains of mammoth (*Mammuthus*) have been documented, as well as fluted pointed assigned to Clovis, Folsom, and Holcombe-like artifact forms. Agate Basin and Hell Gap (Plano-type) artifacts also imply the presence of human groups in Late Glacial landscapes associated with the Agassiz and Superior basins.

Introduction

Late Pleistocene landscapes in the Great Lakes region of North America are directly linked to changing glacial conditions. The glacial chronology serves as a framework for understanding the potential effects of landscape evolution and historical ecology on late Pleistocene biotic populations, including prehistoric human groups, entering ice-margin and recently deglaciated landscapes stretching from glacial Lake Agassiz in the west to the Superior basin in the east. The present geomorphologic setting, along with the stratigraphic relationships of the deposits that form this landscape, provides a means to evaluate the physical context for the Late Glacial and earliest postglacial paleobiotic communities of the region. The geomorphic processes occurring during the late Quaternary affected the age, distribution, and visibility of paleontological and archaeological sites in northeastern Minnesota. Their study provides an opportunity to highlight the potential of an earth-science approach to integrate various facets of the paleoecologic record (Rapp and Hill, 1998, 2006).

The remains of extinct mammals and the presence of artifacts and fluted and basally thinned lithic bifaces provides evidence for the existence of Late Pleistocene habitats that could sustain biotic communities associated with the late Rancholabrean land-mammal age in the Great Lakes region (Fisher, 1996; Haynes, 2002a, 2002b). Geologic contexts associated with deglaciated landscapes indicate associations between extinct Rancholabrean fauna and Late Pleistocene humans. For instance, intriguing discoveries of mastodon and mammoth remains potentially connected with Late Pleistocene humans have been reported for the southern Great Lakes (Fisher, 1984, 1987; Shipman et al. 1984; Overstreet and Kolb, 2003). Although rare, Clovis artifacts or other fluted points are known from the western Great Lakes region (Shane, 1989; Romano and Johnson, 1990; Mulholland et al., 1997; Mulholland, 2000). If these fluted points can be considered reliable indicators of the time of prehistoric human presence, they imply inhabitable landscapes starting at least by the Pleistocene/Holocene boundary, which is marked by the end of the Younger Dryas chronozone. In this study, the phase "Late Glacial" is applied to the time interval associated with the Late Pleistocene ("Woodfordian," including the Late Glacial Maximum and ending with the Younger Dryas chronozone) and early Holocene (Preboreal chronozone, ~10,000-9000 ^{14}C yr B.P.) time-transgressive deglaciation of the western Lake Superior region.

This study is a review and interpretation of landscape evolution in the western Lake Superior region. It examines the potential relevance of understanding the dynamics of historical ecology to connect prehistoric human groups to Late Glacial environmental events. The chronologic framework for these events is also appraised by integrating information based on stratigraphic and geomorphic relationships with radiocarbon ages of regional paleoecological records and their correlation with time-diagnostic Paleoindian artifacts. Radiocarbon dates are used to evaluate the chronologic framework for environmental change and to infer the possible temporal ranges for artifact assemblages, based on diagnostic point forms.

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Although relatively common in southern Minnesota and in the Great Lakes region (Stauffer, 1945; Cleland et al., 1998; Holman, 2001) Rancholabrean fossils are rare immediately west of Lake Superior. *Mammuthus jeffersoni* (Jefferson's mammoth) *Mammuthus primigenius* (woolly mammoth) and possibly *Mammut americanum* (American mastodon) are also documented from the area west of Lake Superior and the Agassiz basins (Stauffer, 1945; Harington and Ashworth, 1986). Thus, isolated discoveries of extinct Pleistocene fauna and artifacts apparently dating to the late Pleistocene suggest the presence of inhabitable Late Glacial landscapes in the region. Based on studies elsewhere in the Great Lakes region, there is potential evidence for links between Late Pleistocene human populations and Rancholabrean fauna without the presence diagnostic artifact forms (cf. Fisher, 1984; Holman, 2001; Overstreet and Kolb, 2003). Here, a review of the landscape evolution is used to highlight the value of using an integrated geoarchaeological approach for investigating the Late Glacial (generally the end of the Wisconsin Episode; Karrow et. al, 2000) paleoecology and human adaptations of the area west of Lake Superior.

Two radiocarbon data sets are used to evaluate the potential geoarchaeological relationships in the region: radiocarbon ages from geologic and paleoecologic contexts in the western Lake Superior region, and radiocarbon ages that help to estimate the temporal range of time diagnostic artifact forms (Holliday, 2000). Besides the stratigraphic and taphonomic contexts, interpretation of the radiocarbon ages takes into account factors such as the material dated and the size of the standard deviation (1- and 2-sigma confidence interval ranges). Stratigraphic and geomorphic relationships and radiocarbon ages are used to assess the framework of Late Glacial landscape change in the western Lake Superior region. These chronologic relationships are ultimately compared and integrated with temporal information based on time-diagnostic artifact forms. Thus, an integrative contextual or ecological approach is used to evaluate temporal relationships associated with the deglaciation chronology, as well as specific landscape settings that can be linked to Late Glacial human populations and Rancholabrean biotic communities.

Background

Linkages between environmental conditions and Lake Glacial human populations have been the subject of studies in both the Great Lakes and Lake Agassiz regions. Examples of the use of geoarchaeological perspective in the Agassiz basin include Pettipas and Buchner (1983), Buchner and Pettipas (1990), and Ross (1997). Studies by Farrand (1977), Storck (1988), Julig (1991), Phillips (1993), Cleland et al. (1998), Kuehn (1998), Anderton (1999), Jackson et al. (2000), and Julig and McAndrews (1993) illustrate the potential of linking environmental change and Pleistocene human populations in the Great Lakes region.

The linkage of glacial geology and geomorphology with studies of the Paleoindian archaeology of northern Minnesota was part of several research projects initiated by the Archaeometry Laboratory starting in the 1970s. Some examples include studies of the ecologic, geomorphic, and paleogeographic settings associated with Paleoindian localities along the Cloquet River (Hill et al., 1985; Huber and Hill, 1987; Hill, 1994, 19895a, 1995b; Harrison et al. 1995); Lake Quaternary contexts of the Big Fork River valley and Agassiz basin (Hill et al., 1995; Rapp et al. 1995; Hill and Huber, 1996); and the potential for predicting the location of Paleoindian sites along abandoned shorelines within the Lake Superior basin (Hill, 1994; Phillips and Hill, 1993, 1994a, 1994b, 1994c, 2001, 2004).

Study Area

The focus of this article is the region immediately west of Lake Superior in northern Minnesota and Ontario. Some discussion of adjacent areas, including the Lake Agassiz basin and the area south of Lake Superior, is included because stratigraphic and geochronologic data from these areas are crucial to the interpretation of the glacial chronology and paleoecology of the Pleistocene/Holocene boundary in the western Lake Superior region.

Late Glacial Human Ecology

Clovis and Folsom fluted points and related artifact assemblages are the oldest clearly defined archaeological entities in Northern America (Lepper, 1999; Holliday, 2000). Human groups using Clovis artifacts existed as part of a Rancholabrean biota, including mammoth (*Mammuthus*), while Folsom artifacts have been recovered with extinct forms of bison (*Bison antiquus*). Plano-type Paleoindian point forms are generally assigned to latest Glacial and postglacial (but pre-Altithermal) paleoenvironmental contexts. Paleoindian artifact assemblages are generally considered to reflect human populations living in small nomadic bands with a subsistence strategy based on hunting and foraging. Plano-type Paleoindian artifact assemblages in the Great Lakes region are believed to be younger than

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fluted-forms and to reflect a subsistence strategy partially based on the procurement of caribou and generalized foraging (Cleland, 1965; Jackson, 1988, 1989; Kuehn, 1998).

The chronologic status of Late Glacial artifacts in the Agassiz-western Great Lakes region is based primarily on comparisons with Paleoindian artifacts dated on the Great Plains (Irwin and Wormington, 1970; Holliday, 2000; Sellet, 2001). Paleoindian artifacts have been placed into two groups—an "early" set consisting of fluted forms and a "late" set consisting of nonfluted lanceolate forms. Fluted points from the Agassiz-Superior region include a Clovis point from Island Lake within the Cloquet River drainage (Romano and Johnson, 1990) and a fluted point from Round Lake (cf. Mulholland et al., 1997; Mulholland, 2000). A fluted point from northern Wisconsin has been described as either Clovis (Mires, 1989) or Holcombe (basally thinned; Dudzik, 1991), and other Holcombe-like points have been reported for northeastern Minnesota (Mulholland et al., 1997). Nonfluted lanceolate artifacts (Plano-type, "Late" Paleoindian) are also distributed over the region (Harrison, 1995; Mulholland et al., 1997; LeVasseur, 2000; Mulholland and Shafer, 2000; Okstad et al., 2000). The occurrence and distribution of Paleoindian artifacts associated with the Agassiz basin in southern Manitoba and south of Lake Superior in Wisconsin are described by Buchner and Pettipas (1990), Cleland et al. (1998), Dudzik (1991), and Kuhen (1998).

The region west of Lake Superior contains an artifactual record that, by typological correlation, can be assigned chronologically to the Pleistocene/Holocene boundary (approximately the interval of the Allerod-Preboreal chronozones, 12,000-9,000 yr B.P., cf. Eriksen, 1996; Haynes, 2002a). For example, one model for the temporal relationships between Paleoindian artifacts for the Great Lakes region proposes that the change between the Clovis and Folsom fluted forms is 11,000 yr B.P., and a transition between Folsom-Holcombe forms and unfluted points (the Agate Basin variant of Plano) is about 10,200 yr B.P. (Deller and Ellis, 1992). It may be useful to estimate the temporal range of artifact forms by taking into consideration the standard deviations associated with the radiocarbon ages assigned to these diagnostic artifacts. Although sometimes depicted as a developmental sequence with artifact forms occurring during discrete intervals, the radiocarbon dates appear to indicate a chronologic overlap of the diagnostic artifact types (Holliday, 2000; Sellet, 2001). For instance, northern Plains Paleoindian assemblages, based on 1-sigma standard for deviations, show an overlap of the fluted and unfluted forms for the Pleistocene/Holocene boundary. Although the general ranges are approximately 11,200-10,000 yr B.P. for Clovis, 10,900-10,200 yr B.P. for Folsom, and 10,500-9500 yr B.P. for Agate Basin Hell Gap (Holliday, 2000), the standard deviations indicate the potential for notable overlap between these sets of radiocarbon ages. Clovis components have been found in contexts indicating they are older than Folsom; however, they have a 1-sigma range of about 11,700-10,200 yr B.P. Folsom assemblages appear to generally coincide with the Younger Dryas chronozone; on the northern Plains, this set has a 1-sigma range of about 11,000 to 9600 yr B.P. Most of the radiocarbon ages for Agate Basin and Hell Gap assemblages range from about 10,500 to 9500 yr B.P.; however, at 1-sigma, an Agate Basin component at the Hell Gap locality might even be older than 11,000 (the 1-sigma standard deviation indicates a range from between 11,400 and 10,300 yr B.P.). At a 2-sigma (standard deviation, 95% confidence interval), the chronologic overlap would be even larger between the sets of radiocarbon ages associated with Clovis, Folsom, and Agate Basin-Hell Gap assemblages. This pattern may be reflected by sites in the Great Lakes region that appear to link Rancholabrean fauna with human populations prior to 12,000 yr B.P. to possibly as late as about 9200 yr B.P., although the younger ages are considered to be anomalies (Fisher, 1967; Laub and Haynes, 1998; Overstreet and Kolb, 2003).

Glacial Dynamics and Chronology

Late Glacial Landscape Evolution

The landforms west of Lake Superior reflect the advance and melting of ice lobes of the Laurentide ice sheet as modified by postglacial events. Glaciers have advanced over the region from three directions (cf. Wright and Watts, 1969; Richmond and Fullerton, 1983; Attig et al., 1985; Matsch and Schneider, 1986; Wright, 1998). Ice originating from the northeast within the Superior basin is designated the Superior Lobe. Ice that advanced from southern Canada and through northeastern Minnesota, generally form the northeast, has been designated the Rainy Lobe. The Koochiching Lobe (including the St. Louis sublobe) extended from southern Manitoba and northwestern Minnesota southeastwards toward the Superior basin.

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Superior Lobe

There were several major phases of the late-Wisconsin glacial episode (Wright and Watts, 1969; Lannon and Matsch, 1987; Leher and Hobbs, 1992; Johnson and Mooers, 1998; Karrow et al., 2000). The relative order for the major advances from the Superior basin is St. Croix, Automba, Nickerson, and Marquette. The St. Croix phase has been linked to the Woodfordian terminal moraine in the western Great Lakes (Peterson, 1986). The age of the St. Croix phase can be estimated by radiocarbon measurements from Wolf Creek. Noncalcareous deposits overlying St. Croix phase deposits at Wolf Creek date to about 20,500 yr B.P. Although lignite was not observed (Birks, 1976), the presence of pre-Quaternary microfossils may indicate some contamination of this sample (Clayton and Moran, 1982). An overlying radiocarbon age implies the absence of St. Croix phase ice by about 15,000 yr B.P. (Birks, 1976).

The Superior Lobe advanced to the Mille Lacs and Highland moraines during the Automba phase (Wright and Watts, 1969; Matsch and Schneider, 1986; Leher and Hobbs, 1992). Deposits in Koitranta and White Lily Lakes overlie a moraine attributed to the Split Rock phase, which is interpreted as a facies of the melting Automba phase ice (Lannon and Matsch, 1987). Basal organic sediments from Koitranta Lake have a 2-sigma (95% confidence interval) range of about 17,250-15,500 yr B.P., while organic sediments from White Lily Lake have a 2-sigma radiocarbon age of 15,700-14,800 yr B.P. Silty clay overlying the Highland moraine at Cloquet Lake has a 2-sigma range of 17,260-15,640 yr B.P. (Huber, 2001). Thus, assuming the potential for some contamination by older carbon, the Automba phase may have been over by about 15,000 yr B,P.

Ages estimates for the Nickerson phase are based on materials recovered from sediments overlying Nickerson phase till and correlations with radiocarbon dated wood overlying St. Louis sublobe-Albron phase sediments. The 2-sigma range for radiocarbon dates on plant debris and organic sediments from Jacobsen and Andersen Lakes (Wright and Watts, 1969) is about 11,400-9800 yr B.P., with an overlap interval from about 11,000-10,200 yr B.P. Based on the correlation with the wood dates above Alborn phase till at Aitkin, the 2-sigma range is about 12,400-10,800 yr B.P (Farnham et al., 1964).

The last advance of the Superior Lobe into the region has been linked to the Marquette phase. This advance blocked the eastward drainage of the Agassiz basin by about 10,000 yr B.P, (LeVasseur, 2000). South of the Lake Superior basin, the Marquette advance buried the Lake Gribben forest (Hughes and Merry, 1978; Lowell et al., 1999; Pregitzer et al., 2000). Radiocarbon ages from wood and needles indicate that the spruce forest was present from perhaps 10,200-9900 yr B.P. (although the 2-sigma range is about 10,930-9250 yr B.P.), until being buried by the Marquette advance. Radiocarbon ages from the southwestern margin of the basin have been used to trace the Marquette advance westward from the Marquette Gribben forest area westward towards Duluth (Hack, 1965; Brubakeder, 1975l Black, 1976; Peterson, 1982; Clayton, 1984; Attig et al., 1985; Lowell et al., 1999). Marquette phase southeast of the Superior basin may have reached the inner margins of the Nickerson and Thomson moraines (Moers et al., 2005).

Rainy Lobe

The Superior and Rainy lobes merged to form one large ice sheet during the St. Croix phase. During this phase, the combined Superior and Rainy lobes advanced to the St. Croix moraine (Wright and Watts, 1969; Wright et al., 1973; Matsch and Schneider, 1986). Age estimates for the advance of the St. Croix phase Rainy Lobe are in the range of 20,000-15,000 yr B.P., based on the Wolf Creek sequence and radiocarbon-dated sediments at Weber and Kylen Lakes. Pre-Quaternary microfossils in the Kylen Lake sediments indicate some redeposition of older materials, although no lignite was observed (Birks, 1981). Perhaps the most reliable constraint on the earliest deglaciated habitats after the melting of the Rainy Lobe is an age on aquatic moss from Kylen Lake with a 2-sigma range of 14,500-13,300 yr B.P. (Lund and Banerjee, 1985), and an age on moss from Weber Lake with a 2-sigma range of 15,560-13,900 yr B.P. (Florin and Wright, 1969). The Rainy Lobe melted back to the Giants Range-Vermilion Lake Region, forming the Vermilion moraine complex (Glover et al.). This complex consists of the Allen, Wampas, Big Rice, Wahlsten, and Vermilion moraines (Leher and Hobbs, 19992). Radiocarbon dates from localities within the moraine complex form Heikklla and Lempia Lakes (Bjork, 1990), and Big Rice Lake (Huber, 1988), suggest deglaciated terrain by before 12,500 yr B.P., although the dates are on sediments low in organics or organic rich clays. Based on the presence of Koochiching Lobe that the Vermilion moraine is older than the St. Louis sublobe (see also Richmond and Fullerton, 1983). If this relationship is valid, the Vermilion phase could be partly

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contemporary with the Automba phase of the Superior Lobe. Deposits from near the United States-Canada boundary at Lake of the Clouds (Stuvier, 1975) indicate deglaciation before 9600 yr B.P.

Continued retreat of the Rainy Lobe formed several moraines in southern Canada. Based on radiocarbon dates on low organic sediments from Rattle Lake (Bjork, 1985), the Rainy Lobe was near the Eagle-Finlayson-Brule moraine sometime around 11,310-10,910 yr B.P. (2-sigma range). Radiocarbon ages of 10,250 (ETH-31430) and 10,190 (Beta-195959) yr B.P. north of the Brule moraine may provide an indication of the timing of deglaciation (Loope et al., 2006). By the time of the Superior Lobe Marquette advance (which formed the Marks ice margin in Ontario), the Rainy Lobe may have been in the vicinity of the Hartman-Dog Lake moraine, although Bjork (1985) has proposed that the Sioux Lookout moraine is correlated with the Marquette advance, based on radiocarbon dates from Sioux Pond. A radiocarbon age on wood from Cummins pond (Julig et al., 1990) indicates this region was deglaciated sometime before 9400-9120 yr B.P. (2-sigma range). There are older ages from Cummins and Oliver Ponds, but they are on marls. A series of recessional moraines show continued retreat to the Whitewater moraine perhaps slightly before 9000 yr B.P. (based on radiocarbon dated organic matter from Indian Lake; Bjork, 1985; Dredge and Cowan, 1989; Klassen, 1989).

Koochiching Lobe and St. Louis Sublobe

The ice of the Koochiching Lobe expanded eastward into the region west of Lake Superior. During the Alborn phase, the St. Louis sublobe advanced from the northwest, incorporating sediments from the Lake Aitkin and Upham basins that were deposited after the melting of the Rainy Lobe. Radiocarbon dates from Mariska Mine on wood from sediments indentified as St. Louis sublobe-Albron phase till (Winter, 1971) have a combined 2-sigma range of about 12,000-10,300 yr B.P. Wood from deposits overlying Albron phase till at Aitkin (Farnham et al., 1964) has a 2-sigma range of about 12,400-10,800 yr B.P. One hypothetical chronology would thus include an advance of the St. Louis sublobe sometimes after 12,000 yr B.P. with melting and the presence of some unglaciated terrain in the region by about 11,000 yr B.P, and perhaps earlier. There are several buried soils stratigraphically between the Alborn phase till the lake deposits with the radiocarbon dated wood at Aitkin (Farnham et al., 1964). These paleosols reflect landscapes that would have been available after the melting of the St. Louis sublobe before the formation of the lake. Melting of the St. Louis sublobe and other Koochiching Lobe ice led to the formation of the lake in the Upham basin (Hobbs, 1983).

Late Glacial Landscape Settings

Regional Late Glacial deglaciated terrains and ice margin environments included abandoned lake shorelines in the Superior basin and interior lake and fluvial settings. The Cloquet River drainage and settings associated with transgressions and regressions in the glacial Lake Agassiz basin. Summaries of the extensive literature pertaining to changing lake levels in the Superior basin (Farrand and Drexler, 1986) are presented by Phillips and Hill (1993, 1994a, 1994b, 1994c, 2001, 2004) and Phillips et al. (1994). Proglacial lake sediments were likely deposited during the melting of the St. Croix phase ice sheet because they were incorporated into the younger Automba phase deposits. High abandoned lake shorelines may indicate separate glacial lakes or a single extensive lake along the north and southwest shores of the Superior basin prior to and during the Marquette phase (Phillips and Hill, 2001, 2004). Shorelines thought to be associated with isolated high lakes and along the Superior basin, such as Lake Nemandji and Ontonagon, may have been present sometime after 11,200 yr B.P. For instance, a log in lake clay with a 2-sigma radiocarbon age range from 11,220-9220 yr B.P. is associated with glacial Lake Ontonagon in Michigan. It has been correlated with an early stage of Lake Duluth (Lake Nemandji; Crane, 1965). The older shorelines would not have been destroyed by the Marquette advance if the glacial margin did not reach their locations. Thus, they are surviving features potentially dating to before 10,000 yr B.P. For example, south of Lake Superior, Saxon moraine till associated with the Marquette advance and located below glacial Lake Duluth shorelines contains wood with a 2-sigma range of 10,300-9900 yr B.P.

High (older) abandoned shorelines are preserved southwest of Duluth and extend along the north and south shores of Lake Superior. Shoreline features at Duluth are present at elevations around 338-348 masl (meters above sea level). Some of these features are present directly north of the Math-Geology Building at the University of Minnesota-Duluth. Lake evaluations were likely higher than or at the Duluth level (~327-330 masl) in the southwestern part of the basin as water drained through the Portage channel, and at slightly lower elevations during drainage though the Brule channel. A radiocarbon date on plant material from Brule channel fill has a 2-sigma range of about 9170-8930

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yr B.P. (Engseth, 1998), providing a minimum age for its drainage. An older age is available for fill in the Blackhoof diversion channel; the measurement has a large standard deviation with a 2-sigma range of about 11,600-9600 yr B.P. (Wright and Watts, 1969). The Marquette advance filled much of the Superior basin with ice, but perhaps not on the extreme southwest margin or the Minnesota section of the north shore. Lake elevations in these areas were at Lake Duluth levels or higher.

Melting of the Marquette phase ice enlarged the area of the lake in the Superior basin and began to lower water to the Minong level again (Phillips and Hill, 2001, 2004). The earliest of these recessional shoreline features is at about 307 masl in the Duluth area. This shoreline extends along the entire Minnesota north shore. It reaches (due to tilt caused by postglacial rebound) a present elevation of 386 masl at Grand Portage, near the Canadian border. Three less developed shorelines, designated Highbridge, Moquah, and Washburn, are between the Duluth level and the well-developed Beaver Bay shoreline. Several other lake margins have also been recognized between the Beaver Bay and Minong levels (Phillips and Hill, 1993, 1994a). By about 9500 yr B.P., Lake Minong shorelines formed around the entire margin of the Superior basin. Lake levels continued to drop from 9500 to 8000 yr B.P. The extreme low around 8000 yr B.P. is designated the Houghton level (Phillips and Hill, 2001, 2004).

Interior Lakes and Rivers

The Cloquet River drainage provides an example of the interior settings formed after the melting of St. Croix phase ice (Hill, 1995a). Melt waters from the Automba phase Superior Lobe, Highland moraine) and the Rainy Lobe-deposited outwash over St. Croix phase deposits along the Cloquet River valley and then into Lake Aitkin–Upham basins (pre-Alborn phase Aitkin-Upham). This area was unglaciated throughout the Late Glacial period, although glacial advances occurred to the east of the Superior basin. Also, to the west glaciers were associated with the St. Louis sublobe. Radiocarbon ages indicate that the depositions of peat had begun by about 9800-8900 yr B.P. (Bog 2), although the landscape was presumably inhabitable after the melting of St. Croix phase ice.

Two lake episodes in the Upham basin are separated by the Alborn phase advance of the St. Louis sublobe. The extent and age of the lakes is constrained by the retreat of the Rainy Lobe (the end of the St. Croix phase) and the advance of the St. Louis sublobe (Alborn phase). Melting of the St. Louis sublobe began in the area south of the Giants Range, creating a lake in the Upham basin (Glacial Lake Upham). As more ice meted, the Lake Aitkin basin was filled with water (Upham, 1899; Winchell, 1899, 1901; Hobbs, 1983; Mooers, Marlow and Phillips, 2005). Remnants of these lakes may have existed to about 9000 yr B.P. (Hobbs, 1983), although the age on marl.

A series of lakes formed to the north and west of the Aitkin and Upham plains, eventually leading to the development of glacial Lake Agassiz. As the Koochiching Lobe melted to the west, Lakes Norwood and Koochiching formed. Further melting led to the expansion of Lake Koochiching (early Cass Agassiz; Fenton et al., 1982) dating to around 11,600 yr B.P. At this time, the Rainy Lobe may have been in the vicinity of the Steep Rock moraine in Canada (Antevs, 1951; Nielsen et al., 1982; Teller and Thorleifson, 1983; Fisher et al., 2005; Lowell et al., 2005). When the Rainy Lobe was between the Eagle-Finlayson-Brule and Hartman-Dog Lake moraines, Lakes Koochiching and Climax coalesced to form the Lockhart stage of the glacial Lake Agassiz, around 11,000 yr B.P. Retreat of ice form the Superior basin opened the previously blocked eastern outlets for Lake Agassiz around 10,800 yr B.P., lowering the water level to the Moorhead stage of Lake Agassiz (Ashworth et al., 1972). Wood and charcoal radiocarbon ages associated with the Moorhead regression have a combined 2-sigma range of 10,720-9700 yr B.P. (Bajc et al., 2000; Fisher and Lowell, 2006).

By about 10,000-9500 yr B.P., the Rainy Lobe was near the Hartman-Dog Lake moraine, and the Superior Lobe had reached the Marks-Mackenzie moraine in Ontario and the Gribben forest region south of Lake Superior. The Marquette advance of the Superior Lobe blocked the eastern outlet of Agassiz and led to the start of the Emerson stage transgression of Lake Agassiz (Bajc et al., 2000; Teller, 2001). The Emerson transgression is constrained by radiocarbon dates from Swift (Bjork and Keister, 1983), where wood and peat underlying beach gravels have a combined 2-sigma radiocarbon age range from 10,250-9150 yr B.P., as well as other Rainy River basin-ages on wood (Bajc et al., 2000) from Emerson phase deposits. The Lake Agassiz plain was exposed and presumably available for habitation in northern Minnesota by about 9300 yr B.P. (Heinselman, 1963; Severson et al., 1980; Lerington et al., 2000).

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Biotic and Archaeological Contexts

Paleoindian archaeological sites are associated with both streams that flow directly into the Superior basin and interior lake and river settings. Geomorphic contexts within the Superior basin are summarized by Phillips and Hill (2001) and Phillips et al. (1994). Archaeological sites in the internal drainages have also been documented (Schneider, 1982; Romano and Johnson, 1990; Harrison, 1995; Peters et al., 1995; Ross, 1997; Mulholland et al., 1997; Mulholland and Shafer, 2000).

In terms of site visibility and site-formation processes, some records of Paleoindian presence prior to about 10,000 yr B.P. could have been eroded or buried by the Marquette ice margin advance, if the advance actually reached the north shore of the basin (Phillips and Hill, 2001). Sites on higher shoreline features situated above the level of the ice sheet would not have been affected by this ice advance. Examples of these landscape conditions are present along the south side of the margin (Crane, 1965; Hack, 1965). Oscillating water levels in the Superior basin resulting from discharge events form Lake Agassiz would not have caused redeposition, as has been interpreted at the Cummins site (Julig et al., 1990). Any post-Minong occupations associated with the recessional beaches preceding the Houghton low stand at around 8000 yr B.P. would potentially have been inundated or eroded by the later transgression. The archaeological discontinuity between Plano-type Paleoindian and Archaic sites has been addressed by Phillips (1993). The shoreline features associated with various glacial lake levels have the most potential for containing Paleoindian sites in the area that directly drain into the Superior basin. If the Marquette ice margin was separated from the northwest side of the basin by the glacial lake, it is possible that the shoreline was occupied immediately after melting of the Automba phase ice. Paleoindian sites could also be located on higher shoreline features of Lake Duluth. For example, unfluted lanceolate points similar to Agate Basin forms have been linked to glacial Lake Duluth beach (Mulholland and Dahl, 1988); the range of radiocarbon ages (1-sigma) for Age Basin points on the northern Plains is about 11,400-9500 yr B.P. (Holliday, 2000l; Sellet, 2001).

Based on the availability of older deglaciated landscapes, the region west of the Superior basin (west of the Highland moraine) and south of the Rainy Lobe margin (Vermilion moraine complex area) has the potential for containing early Paleoindian sites. Outwash from melting ice was deposited along the Cloquet River drainage. Mammoth remains found in gravels within the Cloquet River drainage (Stauffer, 1945) may be associated with these settings, although detailed chronologic information is unavailable for these fossils. Unless they reflect pre-Last Glacial Maximum materials that have been incorporated into the St. Croix phase till, the Cloquet mammoth fossils are probably Late Glacial in age (contemporary with the Automba phase or younger).

In the internal drainages removed from the Superior basin, archaeological visibility has been both helped and hindered by the 20th century creation of reservoir lakes on some of the major tributaries (Harrison et al., 1995). These reservoirs have inundated portions of major rivers along which sites are situated (Hill, 1995a). Oscillating water levels have made artifact occurrences more visible (Harrison et al., 1995), but they have also produced lag accumulations. In some cases the effect of post occupational erosion and redistribution on the spatial patterning and composition of the cultural assemblages would be high. Also, aggradation and peat formation have buried available terrains after the initial deglaciation (Hill, 1995a).

If the Clovis point recovered from the Island Lake area (Mulholland et al., 1997; Romano and Johnson, 1990) can be used as a time-marker, it implies human presence between 11,700 and 9600 yr B.P. (Holliday, 2000). The geomorphic association of Agate Basin and Hell Gap (Plano-type artifacts, such as those found in the Cloquet River drainage (Harrison, 1995; Hill, 1995a), appear to indicate a human presence between about 11,400 and 9500 yr B.P. (Holliday, 2000; Sellet, 2001). Paleoindian sites in the vicinity of Island Lake (Hill, 1995a) were situated along streams and lakes within Automba phase outwash (overlying St. Croix phase till). The upper reaches of the Cloquet River drainage also contain a site with a Paleoindian component (at Cloquet Lake; Mulholland et al., 1997); the site is in an area composed of Automba phase till of the Superior Lobe. The site is situated in a geomorphic terrain similar to the Paleoindian localities in the Island Lake area. West of the Cloquet River, a series of Plano-type Paleoindian sites are located in the Whiteface River drainage (Mulholland et al., 1997; Mulholland Shafer, 2000). In this region, deposits of the Rainy Lobe are overlain by outwash deposits and till from the St. Louis sublobe (Alborn phase). Thus, while the area to the east may have been a deglaciated landscape, the area to the west was directly associated with the Albron phase ice margin.

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Melting of the St. Louis sublobe and Rainey Lobe resulted in the creation of proglacial and postglacial shorelines and drainages. Rancholabrean mammal communities, including human populations, could have inhabited the region between the melting St. Louis sublobe and the ice within the inhabited the region between the melting St. Louis sublobe and the ice within the inhabited the region between the melting St. Louis sublobe and the ice within the Superior basin. Biotic communities could have been established by taxa migrating up the Cloquet River drainage, and then northward toward the ice margin. Melting of Alborn phase ice would have led to the creation of shorelines within the Lake Upham basin; these would have been available to Paleoindian populations. Paleosols under radiocarbon-dated wood at Aitkin would have been available for habitation sometime before 10,800 yr B.P. (based on the earliest date of the 2-sigma range). Later deglaciation provided accessible landscapes associated with the Agassiz basin.

Melting of the St. Louis sublobe resulted in an expansion of Lake Aitkin (see paleogeographic reconstructions in Hobbs, 1983), and these new shorelines may be associated with late Clovis and early Folsom artifacts (based on the Aitkin wood date). By about 10,000 yr B.P., Lake Upham drained though the St. Louis River and into a lake in the Superior basin that discharged southward into the St. Croix River via the Portage and Kettle channels. At about the same time, Lake Aitkin first drained through the Snake River channel and eventually the Mississippi River (Hobbs, 1983). The remnants of these lakes were probably gone by the time human populations associated with later Plano artifacts were present in the region (~9000-8000 yr B.P.). Studies of the buried soils, lake deposits, and recessional lake margin features might help to clarify the lake chronology and provide information on Paleoindian groups in the region.

The Agassiz basin, including the Rainy River drainage, also contains Paleoindian artifacts (Steinbring, 1974; Schneider, 1982; Pettipas and Buchner, 1983; Buchner and Pettipas, 1990). Finds are also situated along lakes and rivers in the vicinity of the Vermilion moraine complex and near the border with Canada (Petters et al., 1995; Phillips and Hill, 2001). Several Paleoindian sites are associated with the Vermilion moraine complex (Peters et al., 1995; Mulholland et al., 1997). These include a site near Big Rice Lake that is situated in an area of proglacial lake sediments. The location could have been part of Glacial Lake Norwood-Koochiching until about 12,500 yr B.P. (Leher and Hobbs, 1992). Big Rice Lake contains basal organic sediments with a 1-sigma age range of about 12,600-11,500 (Huber, 1988), thus indicating that the glacial margin was north of this region prior to this time interval.

Other Paleoindian sites lie between the Vermilion moraine and the Eagle-Finlayson-Brule moraine, which marks the ice margin at perhaps about 11,000 yr B.P. For example, a Holcombe-like (basally thinned) artifact was recovered from the Bearskin Lake area (Okstad et al., 2000). If the age estimates are reasonable, the entire area was potentially habitable by late Rancholabrean faunal communities and human populations using Clovis artifact forms, as well as later Paleoindian populations. For instance, McLeod (2001) has proposed that artifacts west of Thunder Bay may indicate the presence of human populations in that region prior to the Marquette advance.

The chronology of Lake Agassiz is important in terms of potential early human occupation of the Rainy River system (Buchner and Pettipas, 1990). The Lockhart phase, which may date to before 12,000-11,000 yr B.P., is associated with Herman beach lines, as well as Norcross, Tintah, and Campbell levels (Teller, 2001). Woolly mammoth (*Mammuthus primigenius*) remains have been recovered from deposits forming the Herman strandline (Harington and Ashworth, 1986). The beginning of the Moorhead phase is marked by a low water stand starting at about 11,000 yr B.P. A return to about the high Campbell strandline is associated with the Emerson phase (sometime after 10,000 yr B.P.; Fenton et al., 1983; Leher and Hobbs, 1992; Leverington et al., 2000). This transgression flooded the previously exposed landscape that had been available for habitation during the Moorhead phase. The lake abandoned the Campbell beach line and withdrew into Canada between 9500 and 7000 yr B.P. (Johnston, 1946; Klassen, 1989). Based on this chronology, any Paleoindian presence dating to 11,000 yr B.P. would be associated with features associated with the final part of the Lockhart phase. Artifacts linked to Paleoindian groups inhabiting the area exposed during the Moorhead-phase regression would have been eroded or buried by the flooding associated with the Emerson phase transgression. Potential Paleoindian habitation between the 10,000 and 9500 yr B.P. could be associated with Emerson-phase Lake Winnibigoshish near Round Lake (Peterson in Ross, 1997) is in a region containing Lake Agassiz sediments and Koochiching Lobe till (Meyer, 1993; Richmond and Fullerton, 1983).

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Archaeological sites are situated close to major tributaries of the Rainy River or in contexts related to glacial Lake Agassiz. There are two sites where Plano-type Paleoindian artifacts have been found: the Pelland site and the Plummer site (Stoltman, 1971). Stratigraphic sequences situated north of the Pelland site suggest that the low-water Moorhead stage of Lake Agassiz started around 11,000 yr B.P. and ended with a rise to at least Campbell levels around 10,000 yr B.P. (Emerson phase transgression; Bajc et al., 2000; Nielsen et al., 1982). The Plummer site may be associated with outwash deposits on the Lake Agassiz plain. It seems to be situated on a terrace of a previous channel of the Rainy or Black Rivers. Further to the west, the Greenbush site contains Plano-type (Scottsbluff variant) artifacts and it's situated on the Campbell shoreline of Lake Agassiz (Nystuen and Peterson, 1972; Peterson, 1972).

Summary

An integrated landscape ecology approach can help to evaluate the chronologic relationship between deglaciation dynamics and time-diagnostic artifacts forms, as well as the habitats available to Late Glacial Rancholabrean fauna and Paleoindian human populations. Geomorphic and stratigraphic relationships of Quaternary deposits can be used to reconstruct the physical settings potentially available to late Rancholabrean-age faunal communities and prehistoric people in the western region of Lake Superior. To the east, in the Superior basin, lakes fluctuated in elevation and extent. Shorelines associated with the Duluth level and higher shorelines could have been occupied by human populations using either fluted or lanceolate artifact forms. Artifacts deposited on Minong levels may have been buried or reworked as a result of a lake transgression associated with the Marquette ice advance, or by the advance of this ice sheet if it reached the north shore of basin. This transgression started around 10,000 yr B.P. and lasted until about 9500 yr B.P. Thus, artifacts associated with occupations prior to or during this interval may be associated with Duluth or higher lake levels. After about 9500 yr B.P., occupations would have been first associated with shoreline features of Lake Minong. Continued lowering of the lake formed recessional beaches that would contain occupations dating to about 8000 yr B.P.

While glacial activity persisted to the east in the Superior basin and to the west in the Agassiz basin, the Rainy Lobe melted away. This left a deglaciated terrain in the central portion of the area. An ice-free region extended north to the Vermilion moraine complex probably by about 12,000 yr B.P. By about 11,000 yr B.P., the ice margin of the Rainy Lobe was in southern Canada. This left the central portion of northeastern Minnesota available for Rancholabrean faunal communities and Paleoindian populations associated with Clovis artifacts, as well as other fluted and unfluted Paleoindian artifact forms. These deglaciated landscapes are partly contemporary with ice margin habitats elsewhere in the Great Lakes that contain radiocarbon-dated Rancholabrean fauna, sometimes in association with artifacts (cf. Overstreet, and Kolb, 2003).

Melting of the St. Louis sublobe starting ~11,000-9000 yr B.P., created landscapes connected with changing configurations of the lake shorelines within the Upham and Aitkin basins. These landforms may contain a suite of fluted and Plano-type artifact forms. To the north and west, in the Agassiz basin, Paleoindian artifacts may be associated with higher shoreline features associated with Lockhart phase (~11,000 yr B.P.). Recessional beaches of the low water Moorhead stage may be associated with later fluted and unfluted artifact forms. Artifacts at these sites would have been buried or possibly eroded and redeposited when Lake Agassiz returned to higher levels during the Emerson stage. Early Plano artifacts can be expected on these higher beaches, as well as later recessional beaches.

The western region of the Lake Superior-Agassiz basin provides a record of landscape evolution connected with deglaciation dynamic from the Last Glacial Maximum through the Preboreal chronozone. This time interval, containing the Pleistocene/Holocene boundary, was associated with the extinction of Rancholabrean megafauna and the presence of time diagnostic fluted and unfluted points. Remains of Late Rancholabrean mammals, including *Mammuthus*, have been reconfirmed from the Agassiz basin (Herman beach), and the upper Mississippi drainage, and parts of the Cloquet River drainage, although they have yet to be found in direct association with artifacts. Clovis, Folsom, Holcombe, Agate Basin, and Hell Gap artifact forms, elsewhere dated to the Late Glacial interval, have been found within the region, and landscapes were available at this time that would contain older nondiagnostic artifact forms associated with Rancholabrean fauna.

Geomorphic and stratigraphic relationships of Quaternary deposits in the western Lake Superior region can be used to construct interpretations of the physical settings potentially available to late Rancholabrean faunal communities and Paleoindian populations. Between about 20,000 and 14,000 yr B.P., the Rainey Lobe melted away from the

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region between the Agassiz and Superior basins. By perhaps 12,400 yr B.P., an ice-free region extended to about the location of the Vermilion moraine, and by 11,000 yr B.P. the ice margin was in southern Canada. This left the area immediately west of the Superior basin available for Rancholabrean fauna communities and Late Glacial human populations using fluted and unfluted points. Isolated ice-margin lakes may have been present within the Superior basin as a result of the Marquette advance, which also resulted in the Emerson transgression of Lake Agassiz. Geoarchaeological models that integrate interpretations of the spatial and temporal landscapes and assessments of the temporal range of the Paleoindian artifacts can help provide a more complete understanding of Late Glacial biotic communities in the western Lake Superior region.