Limits of successive middle and late Pleistocene ice sheets in Alberta-western Montana

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Introduction

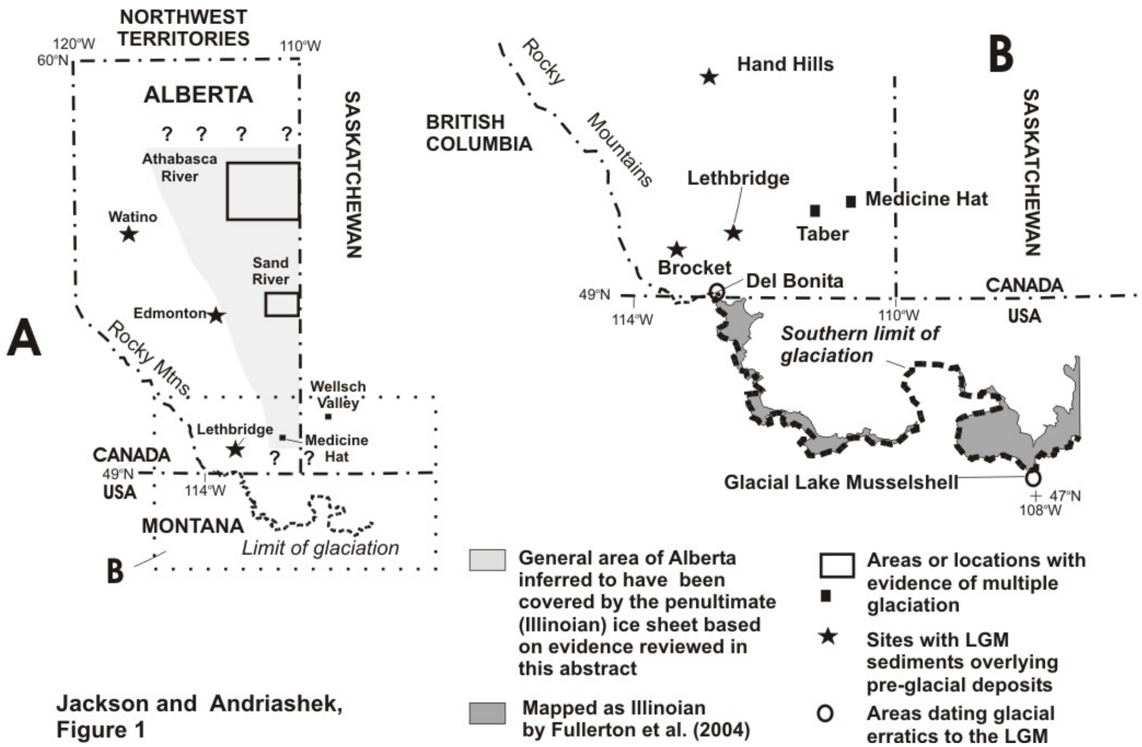
Cosmogenic exposure dating of glacial erratics has shown that the limit of glaciation by continental ice sheets in Alberta and western Montana dates to the climax of the Late Wisconsinan Glaciation (last glacial maximum (LGM)) (Davis et al. 2006; Jackson and Phillips, 2003; Jackson and Andriashek in preparation). This glacial limit includes belts of ground moraine and the basins of glacially dammed lakes formerly referred to the Illinoian Glaciation (Fig.1) (Fullerton et al., 2004). This abstract presents evidence indicating that the lithostratigraphy and chronologic control of glacial sediments preserved in the buried valley systems of Alberta are in accord with this revised surficial geology.

Advance-retreat lithofacies preserved in buried valley systems

Ice sheets advancing into Alberta from the north, northeast or east must ascend the regional slope in opposition to easterly- or northeasterly-trending drainage systems. Conversely, glacial thinning and retreat progressively descend down the regional slope leaving flights of ice-dammed lakes, drainage channels and their sediments. This pattern of advance and retreat up and down the regional slope results in the deposition of a characteristic vertical succession of lithofacies (Proudfoot 1985; Jackson et al. 2008): slackwater sediments succeed and disconformably overlie fluvial sand and gravel or older glacial sediments as drainages are dammed by the advancing ice sheet margin during glacial advance. These are overlain by glaciogenic diamictons that are formed through lodgement and shearing of underlying soft rock and sediments along the base of the ice sheet (till, *sensu stricto*). These are followed by stratified diamictons deposited by meltout and sediment-gravity flow of englacial and supraglacial sediments during glacial stillstand or recession (till, *sensu lato*). These are finally succeeded by proximal and distal glaciolacustrine sediments, then fluvial sand and gravel. These advance-retreat lithofacies assemblages may repeat and accumulate vertically during successive advances and retreats within a glaciation and from one glaciation to the next. These successions are often complicated by glacial tectonism resulting in deformation of individual units or imbricate stacking of allochthons of glacial sediment and weak stratified bedrock blocks or sheets (Christiansen and Whitaker, 1976).

Stratigraphic evidence of two or more glaciations in eastern Alberta

Two cycles of advance-retreat lithofacies are present in the Medicine Hat area in southeastern Alberta. These are separated by non-glacial sediments that have been radiocarbon dated to the (non-glacial) Middle Wisconsinan Substage (Proudfoot 1985; Fig. 1). The Middle Wisconsinan sediments overlie an erosional unconformity that can be traced for kilometres. In east-central Alberta, drilling in the Elk Island area, east of Edmonton, intersected grass in lacustrine sediments that was radiocarbon dated at 26,000+/- 1100 y BP (Jennner, 1984). The lacustrine sediment underlies the uppermost till in the region and overlies an oxidized carbonate-rich till



Jackson and Andriashek, Figure 1

thus making the underlying till older than the Late Wisconsinan. In the Sand River area of east-central Alberta (54-55° N,110-112°W), Andriashek and Fenton (1989) proposed two extended nonglacial intervals between advance-retreat sequences that underlie deposits of the LGM. In total, this stratigraphy may represent three glaciations. The stratigraphy of these deposits is correlated to the well established multiple glaciation stratigraphy of Christiansen (1992) in adjacent Saskatchewan. Deposits of the stratgraphically highest oxidized till are encountered up to an elevation of about 600 m a.s.l. in test wells. A similar stratigraphy with extended breaks in sedimentation marked by oxidized till was recognized by Andriashek (2003) to the north and west of the Sand River area along the Athabasca River (55-57° N, 110-113° W). Glacial sediments underlying the oxidized till horizon (in the Marie Creek Formation) are found as high as 650 m a.s.l. in the subsurface of this area.

Sites spatially constraining deposits from pre-LGM ice sheets

Successions of advance-retreat lithofacies sequences with evidence of intervening non-glacial periods described above are confined to the eastern third of Alberta. Sites limiting their western extents descend in elevation from southeast to northwest over a linear distance of about 800 km. In southeastern Alberta, sediments equivalent to those in the Medicine Hat area cannot be traced farther west than the Taber area (49.9° N, 112.2° W; elevation ca. 750 m a.s.l). There, sandy sediments bearing finite ages underlie advance-retreat lithofacies sequence related to the LGM and overlie a series of older diamictons from a preceeding advance-retreat sequence or sequences (Stalker, 1962). Sites farther west and at higher elevations with successions of advance-retreat lithofacies include Kipp in the Lethbridge area (49.7°N, 112.9° W; elevation ca. 900 m a.s.l.) and the Brocket area in the Rocky Mountain Foothills (49.3° N, 113.8° W; ca. 1050 m a.s.l.). These have been shown to lack evidence for older glacial cycles. At Kipp, the basal advance-retreat lithofacies succession is overlain by sand that has yielded non-finite radiocarbon ages. However, re-examination of the stratigraphy at Kipp (Jackson and Andriashek, in preparation) indicated that this radiocarbon-dated sequence is contained within a glaciotectonic allochthon that overlies the basal glacial-advance lithofacies sequence. The stratigraphy in the Brocket area has multiple advance sequences. These are clearly related to belts of moraine that have been dated to the LGM by cosmogenic exposure dating of erratics (Jackson and Little, 2004; Jackson et al. 2008). In Hand Hills at a similar elevation to the Brocket area, but 260 km north-east (area of 51.6° N, 112.3° W), seven Middle Wisconsinan radiocarbon ages have been determined on a fossil prairie dog colony that underlies a single till (Burns and McGillivary, 1989; Young et al., 1994). In west central Alberta, a single advance lithofacies succession is present across the Edmonton area (ca. 53.5° N, 113.5° W; elevation ca. 670 m a.s.l.). It overlies gravel of the Empress Group (EG). EG in this area contains faunal material that has yielded 29 finite radiocarbon ages that fall within the non-glacial Middle Wisconsinan Substage. Gravel and sand in EG are derived from Interior Plains and Rocky Mountain lithologies. They completely lack any source in the Canadian Shield: EG deposition clearly predates incursion of a continental ice sheet into the Edmonton area (Young et al.,1994) A similar stratigraphy has been documented in cliff-bank exposures in the Watino area 360 km to the northwest (area of 55.5° N, 118° W). Eight finite Middle Wisconsinan radiocarbon ages have been determined on wood from fluvial sediments compositionally equivalent to EG (Liverman et al., 1989). These sediments predate a single till containing clasts from the Canadian Shield. The elevation of the prairie surface in this region is no higher than 560 m a.s.l.

Discussion and Conclusions

The age and distribution of glacial sediments in the buried valley systems of Alberta are in accord with a LGM age for the limits of continental glaciation in the Interior Plains of southern Alberta and adjacent Montana. During the preceding (Illinoian) glaciation of Alberta, continental ice pressed into the eastern third of the province. The progressive growth of successive ice sheets from Illinoian glaciations through the Late Wisconsinan Glaciation fits the model of progressive expansion of the western margins of continental ice sheets through the Pleistocene (Barendregt and Irving, 1998).

The elevational descent of sites spatially limiting former western ice margins is consistent with an older ice sheet(s) centered to the east of Alberta with its accumulation center closer to Medicine Hat than to Edmonton or Watino. Drift deposited in buried valley systems by the first ice sheet in Alberta contains carbonate clasts from Ordovician and Silurian carbonate rocks that crop out along the edge of the Canadian Shield in central and southern Manitoba. This implies east-to-west ice flow in contrast to the north-to-south flow of glacial ice in Alberta from the Keewatin region during the LGM (Dyke and Prest, 1987). Southerly ice flow from a Keewatin ice center was unique to the LGM as was coalescence of montane and continental ice (Jackson et al. 1997). The Keewatin ice center was either absent or of minor extent during prior glaciations: ice from this source never reached as far south as Watino until the Late Wisconsinan Glaciation.

It follows that a broad ice-free corridor existed in Alberta during all glaciations except during the LGM. Plants and animals were free to move north and south at the height of glaciations prior to the LGM. The coalescence of montane and continental ice at the LGM may have been a factor in biogeographic changes including extinctions at the end of the Pleistocene in contrast to the terminations of previous glacial cycles earlier in the Pleistocene.

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