Supplementary Information

Figure S1. Highly deformed sand and gravel of Unit 1 is exposed at Section 2. A) ductily deformed sand and pebble gravel with subsequent brittle faulting; B) large fold of laminated silt, sand and bedded sand and gravel; C) folded cobble gravel bed.

Figure S2 A) Lower stratigraphy of Section 9; B) Unit 2 gravel conformably overlain by Unit 3 diamict (Section 9); C) glaciotectonized rafts of sand, gravel and diamict preserved in Unit 3a at the base of Section 10; D) mélange of facetted and striated clasts mixed with shale blocks from the lower contact of Unit 3a (Section 10); E) sandy flame structures that originate at bedrock and terminate as sand filled thrusts from the contact between bedrock and Unit 3a (Section 6); F) massive diamict typical of Unit 3b (Section 6). See Fig. 6 for legend.

Figure S3. A) Sand and gravel lenses in Unit 5 (Section 7); B) non-glacial, imbricated gravel overlain by fining-upward sand to silt and clay of Unit 5 (Section 8); C) upper stratigraphy of Section 9; D) poorly-sorted pebble to cobble gravel of unit 6 (Section 7); E) stratigraphy at the base of Section 10; F) advance-phase glaciolacustrine sediments (Unit 7; glacial Lake Mathews) overlain by intercalated subaqueous debris assigned to Unit 8 (Section 4). See Fig. 6 for legend.

Figure S4. A) Clast and matrix-supported gravel (Unit 8a) interpreted to be an alluvial fan deposits overlain by massive diamict (Unit 9A; Section 5); B) close-up of imbricated to flat-lying gravel (Unit 8a; Section 5); C) flat-lying, clast-supported gravel interpreted to alluvial fan deposit (Unit8a; Section 4); D) silt (Unit 7; glacial Lake Mathews) overlain by normally graded, clast- to matrix-supported diamict interpreted to be a debris flow deposit (Unit 8b; Section 6).

Figure S5. A) Upper stratigraphy of the Section 6; B) massive diamict with minor lenses of massive sand (Unit 9a; Section 6); C) laminated and glaciotectonically folded sand and silt (Unit 9b; Section 6); D) fractured sand clast in bedded diamict interpreted to be waterlain till (Unit 9b; Section 6); E) massive diamict interpreted to be till (Unit 9a; Section 9); F) massive, fissile diamict (Unit 9a; Section 6). Dmm = Matrix-supported, massive diamict.

Figure S6. A) Deltaic forset beds at a gravel pit near the confluence of Pine and Murray rivers (Unit 11a); B) massive to crudely stratified gravel in gravel pit southwest of Section 8 in the paleo-Pine River Valley (see Fig. 2); C) thick overbank sand (and possibly loess) over gravel (Unit 11b; Section 4); D) gravel and overbank sand (Unit 11b) overlain by loess (Unit 12; Section 5); E) oxidized silt interpreted to be loess (Unit 12; Section 7); F) parabolic sand dunes (Unit 12) from above Section 10 in the Septimus area (see Fig. 2).

Figure S7. Examples of the optically stimulated luminescence response for each of the samples including: a typical shine down curve (photon counts per stimulation time), associated growth curve (photon counts per laboratory β dose), and a radial plot used to determine the statistical equivalent dose (D_e) used to calculate the optical age. The open circle on the growth curve plot is a duplicate dose point used to determine the recycling ratio. Since it is close to unity in all these samples, the test dose procedure used has successfully corrected for sensitivity change. The grey region on the radial plots represents the weighted-mean equivalent dose value of all the data. A)

CS02 from Section 7; B) CS03 from Section 7; C) PR01 from Section 10; and D) PR02 from Section 8. OD = Overdispersion. Luminescence intensity was measured using a Risø TL/OSL DA-20 reader. Aliquots were stimulated using light-emitting diodes that delivered 45 mW/cm2 of blue (470 ± 20 nm) light to the sample. Ultraviolet emissions (~350 nm) were detected by an Electron Tubes Ltd. 9235QB photomultiplier tube placed behind a 7.5 mm-thick Hoya U-340 optical filter. Laboratory irradiation was done using a calibrated $^{90}Sr/^{90}Y$ β-source mounted on the reader that delivered 6.03 ± 0.11 Gy/min, 5.89 ± 0.11 Gy/min, 6.04 ± 0.11 Gy/min, and 5.78 ± 0.11 Gy/min for samples CS02, CS03, PR01, and PR02, respectively.

Optical Dating Methodology

Detailed accounts of the method can be found in Lian and Roberts (2006), Wintle (2008), or Lian (2013). For this research, quartz grains in the 180-250 μm diameter size range were prepared using standard laboratory methods (e.g., see Hanson et al. 2012) from bulk samples collected from key lithofacies. Aliquots holding 50-100 individual grains were measured using the single-aliquot regenerative dose (SAR) method, as described by Murray and Wintle (2003) and Wintle and Murray (2006) (Fig. S7). It is likely that the luminescence measured from each aliquot came from that emitted from less than 10 grains (cf. Duller et al. 2000). Most aliquots provided adequate luminescence and typical luminescence intensity vs. stimulation time (shine-down) curves show a significant 'fast component' which is the desired thermally-stable component of luminescence signal preferred for dating (Fig. S7).

The suitability of the SAR protocol for dating quartz from the study area was tested through dose recovery experiments on all four samples (Roberts et al. 1999; Wintle and Murray

2006). In each case the laboratory dose was sufficiently recovered, which implies that the laboratory protocol used (Fig. S7) is sufficient for dating the quartz grains at the sample sites.

References

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