« Two Middle Holocene Marker Beds in Vertically Accreted Floodplain Deposits, Lower Fraser River, British Columbia »

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TWO MIDDLE HOLOCENE MARKER BEDS IN VERTICALLY ACCRETED FLOODPLAIN DEPOSITS, LOWER FRASER RIVER, BRITISH COLUMBIA

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ABSTRACT Drill cores obtained from the eastern Fraser Delta and adjoining Fraser River floodplain reveal two middle Holocene marker beds—a peat with an age of about 6000 ^{14}C yr BP and a tephra bed, identified as Mazama (6800 yr BP). These marker beds, in conjunction with ^{14}C dates from the floodplain sediments, indicate that the Fraser River floodplain aggraded in response to a rise in sea-level, between about 8000 and 2250 yr BP, and that aggradation kept pace with sea-level rise. The aggradational deposits form a sediment wedge consisting mainly of organic-rich silts and fine sands of overbank origin. The wedge extends at least 20 km into the lower Fraser River Valley. Preservation of the marker beds indicates considerable channel stability in the lower reaches of the Fraser River over about the last 7000 years.

RÉSUMÉ *Deux lits repères de l'Holocène moyen dans les dépôts de crue à croissance verticale du Fraser inférieur, Colombie-Britannique.* Des carottes recueillies dans la partie est du delta du Fraser et de la plaine d'inondation adjacente montrent deux lits repères datant du milieu de l'Holocène, un lit de tourbe datant d'à peu près 6000 BP et un lit de tephra, correspondant à l'éruption du mont Mazama (6800 BP). Ces lits repères, ainsi que les datations au radiocarbone obtenues dans les sédiments de crue, montrent que la plaine d'inondation du Fraser a progressé en réponse à une hausse du niveau marin survenue entre environ 8000 et 2250 BP et que l'aggradation suivait la hausse du niveau marin. L'accumulation de sédiments, de forme triangulaire, est composée principalement de limons riches en matière organique et de sables fins d'origine alluviale. Le triangle s'étend jusqu'à au moins 20 km dans la vallée inférieure du Fraser. La conservation des lits repères démontre la grande stabilité des biefs du Fraser inférieur depuis environ 7000 ans.

ZUSAMMENFASSUNG *Zwei Betten, die als Anhaltspunkt dienen, in vertikal angelagerten Hochflutablagerungen aus dem mittleren Holozän, unterer Fraser-Fluss, British Columbia.* Bohrkerne von dem östlichen Fraser-Delta und der angrenzenden Hochflutebene lassen zwei Betten aus dem mittleren Holozän erkennen, die als Anhalt dienen: ein Torfbett das auf etwa 6000 ^{14}C Jahre v.u.Z. datiert wird und ein Tephra-Bett, das aus der Zeit des Ausbruchs des Mazamabergs stammt (6800 Jahre v.u.Z.). Die als Anhaltspunkt dienenden Betten weisen zusammen mit den von den Hochflutsedimenten gewonnenen ^{14}C-Daten darauf hin, dass die Hochflut des Fraser-Flusses als Reaktion auf eine Anhebung des Meeresspiegels zwischen etwa 8000 und 2250 Jahren v.u.Z. zugenommen hat, und dass diese Zunahme der Hebung des Meeresspiegels entsprach. Die Akkumulationssedimente bilden einen Sedimentkeil, der vor allem aus organisch reichem Schlamm und feinem Sand alluvialer Herkunft besteht. Der Keil erstreckt sich mindestens 20 km in das Tal des unteren Fraser. Die Erhaltung der als Anhaltspunkte dienenden Betten beweist eine beachtliche Kanalstabilität in den unteren Stillen des Fraser während ungefähr 7000 Jahren.

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INTRODUCTION

The Fraser River Delta (Fig. 1) has been growing into the Strait of Georgia for about the last 9000 years (Williams, 1988). An investigation of the evolution of the delta has demonstrated that it aggraded in response to a 13 m rise in relative sea-level between about 8000 and 2250 yr BP. Vertical accretion on the delta kept pace with rising sea-level as the delta continued to prograde into the Strait (Williams and Roberts, 1989).

Extension of subsurface investigations from the delta into the adjoining western Fraser River floodplain has revealed two widespread marker beds within the aggradational deposits. The upper marker bed is a hitherto undiscovered peat layer at a mean depth of about 4.5 m; the lower marker bed is a Mazama tephra layer at a mean depth of about 7.1 m, previously recognized in a number of locations in the area (Blunden, 1973, 1975; Clague *et al.*, 1983). These marker beds provide valuable chronologic control for paleogeomorphic reconstructions in the lower Fraser River Valley. The objectives of this paper are: 1) to describe the nature and presently known extent of the marker beds; and, 2) to assess the significance of the marker beds for paleogeomorphic reconstructions in lower Fraser River Valley.

SETTING

GEOMORPHOLOGY

Lower Fraser River Valley extends from Hope, at the downstream end of Fraser canyon, to the apex of the Fraser Delta at New Westminster, where the river emerges into the lowland of the Strait of Georgia through a narrow gap in the Pleistocene uplands (Fig. 1).

The floodplain of the lower Fraser River occupies a former arm of the sea, which presumably was infilled by Fraser River sediments between about 11 000 to 9000 yr BP, when the river established its present course following deglaciation (Armstrong, 1981; Clague *et al.*, 1983).

The river below Hope is divided according to planform into a straight reach, a wandering gravel-bed reach (Morningstar, 1987), and a meandering reach (Fig. 1). The wandering gravel-bed reach is characterized by multiple channels separated by large vegetated islands, large width to depth ratios and gravelly bed material. The meandering reach has, for the most part, a single sinuous channel containing a few large, well-vegetated islands, smaller width to depth ratios and sandy bed material (McLean and Church, 1986).

LATE QUATERNARY SEA-LEVEL CHANGES

During and immediately following retreat of the Late Wisconsinan Cordilleran Ice Sheet about 13 000 yr BP, the sea occupied the Fraser Lowland up to an elevation of at least 200 m above present sea-level (Armstrong, 1981). Isostatic rebound proceeded rapidly following removal of the ice load (Fig. 2). Raised glacio-deltaic deposits in the Fraser Lowland suggest that relative sea-level fell to about 40 m elevation by around 11 500 yr BP and reached its present level between 11 000 and 10 000 yr BP (Clague, 1981). Emergence of the Fraser Lowland continued, causing the sea to drop about

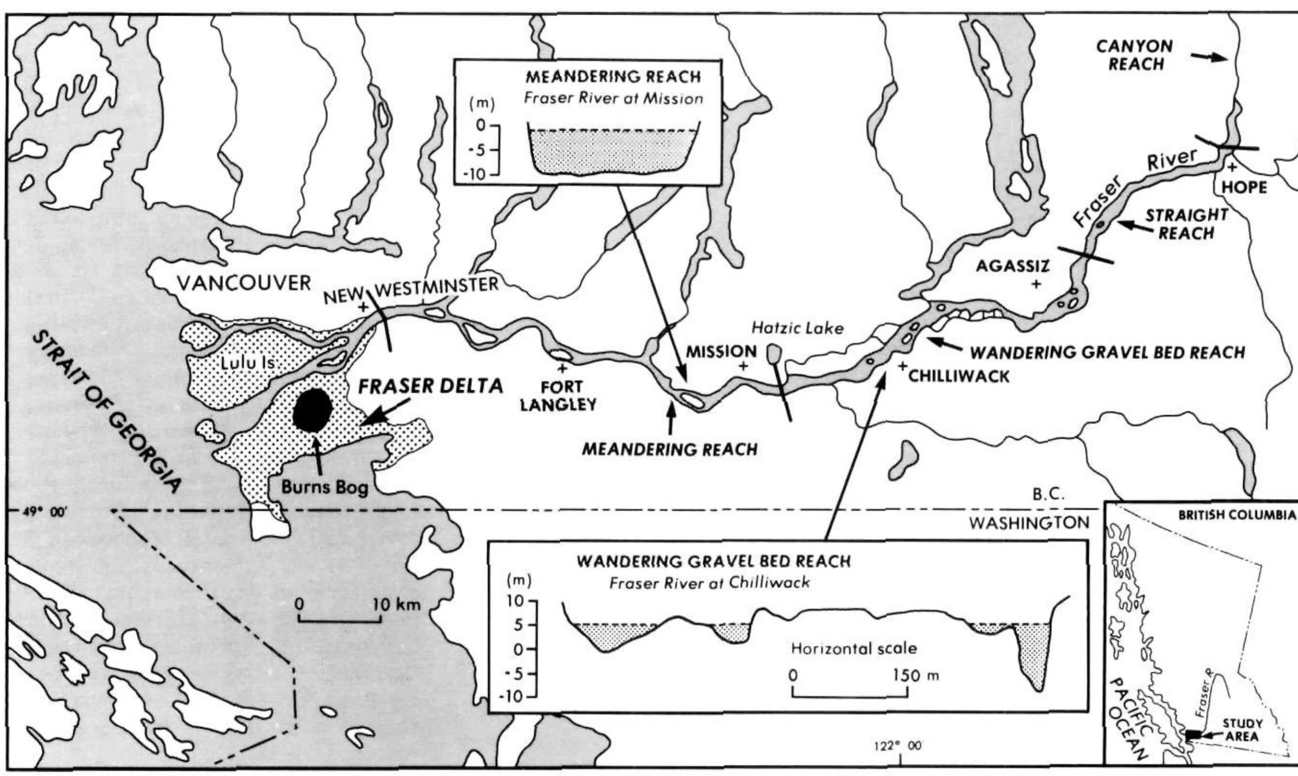

FIGURE 1. Location map of Fraser Delta and lower Fraser River Valley, showing characteristic channel cross-sections in the wandering gravel-bed and meandering reaches.

Localisation du delta du Fraser et de la vallée inférieure du Fraser et coupes caractéristiques dans les biefs à méandres et à lits de gravier divagants.

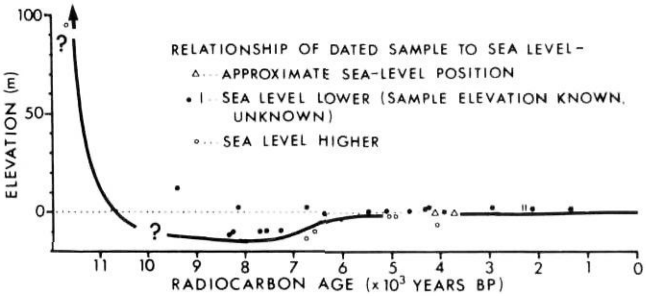

FIGURE 2. Postglacial sea-level curve for Fraser Lowland (from Clague *et al.*, 1982).

Courbe du niveau marin postglaciaire des basses terres du Fraser (de Clague et al., *1982)*

13 m below its present level (Clague *et al.*, 1982; Williams and Roberts, 1989).

The early Holocene low stand of sea-level, resulting from isostatic rebound and possible forebulge migration (Clague, 1983), was followed by a rise in relative sea-level until about 2250 yr BP when it attained its present level (Williams and Roberts, 1989).

METHODS

DRILLING

A drilling programme was initiated on the Fraser Delta in the summer of 1984 and was extended upstream into the Fraser River floodplain during 1986. Core was retrieved using a Concore C-68 drill rig (split tube samples) and a vibracorer (Smith, 1984). Field logging of cores included a visual assessment of particle size and sorting, sedimentary structures and organic matter contents. The two marker beds were identified in core. Samples were obtained from cores for the laboratory determination of texture, radiocarbon dating, and micropaleontological studies (Williams, 1988).

NATURE AND STRATIGRAPHY OF THE MARKER BEDS

STRATIGRAPHY

A stratigraphic section was constructed on the basis of lithofacies sequences encountered in cores drilled along a transect from eastern Fraser Delta to western Fraser River floodplain (Fig. 3). On eastern Fraser Delta, the generalized sequence of lithofacies comprises a basal layer of clean, well sorted, fine to medium sand, deposited in the lower tidal sandflat environment; interbedded silts and fine sands of mid-tidal origin; organic-rich tidal marsh silt; organic-rich floodplain silt; and supratidal delta-top peat (Williams and Roberts, 1989). The complete lithofacies sequence is illustrated by core D23 (Fig. 3).

The floodplain deposits on the delta grade laterally into similar sediments underlying the Fraser River floodplain (compare, for example, core D29 and core TH85-14, Fig. 3). These sediments, consisting predominantly of horizontally bedded organic-rich silt and interbedded silts and fine sands (see core TH85-14, Fig. 3), are interpreted as representing overbank sedimentation in a relatively low-energy, vegetated, floodplain environment on the basis of their fine grain size and abundant incorporated organic matter. These deposits contain freshwater pollen and spores, including arrowhead (*Sagittaria* sp.), horsetail (*Equisetum* sp.), skunk cabbage (*Lysichiton americanum*) and buckbean (*Menyanthes trifoliata*) (Williams and Roberts, 1989). The peat and tephra marker beds are found within these floodplain deposits, and are clearly traceable from the delta into the adjoining floodplain of the lower Fraser River (Fig. 3).

PEAT BED

The peat bed, averaging 250-300 mm thick, in almost all cases grades into the enclosing floodplain deposits; the one exception is site D68 (Fig. 3), where the top of the peat is marked by a sharp contact overlain by a 10 cm thick bed of fine sand presumably of flood origin. Palynological analysis of the peat bed from the delta has shown that it represents the initial stages of a raised peat bog. The pollen spectrum is dominated by shrubs of the Rosaceae family and has relatively low arboreal and herbaceous pollen components. These findings suggest that the site became sufficiently elevated above high tide level to permit shrub vegetation (probably *Spiraea douglasii* [hardhack]) to dominate, and to reduce the input of flood-derived arboreal pollen (Hebda, 1977; Williams, 1988).

Radiocarbon age determinations on samples of the peat bed from three widely spaced locations (sites D52, D69 and D71—Fig. 3) were obtained in order to confirm that the peat bed does represent organic accumulations on a continuous, coeval paleosurface. The resulting radiocarbon ages are remarkably close: 6025 ± 105 (S-2872), 5840 ± 145 (S-2866) and 5990 ± 155 (S-2867) yr BP, from sites up to 20 km apart (Table I). These dates suggest that a hitherto unknown stillstand of sea-level at approximately 6000 yr BP was of sufficient duration (presumably several hundred years) to allow extensive peat deposits to develop on the surface of the Fraser Delta and adjoining Fraser River floodplain. An average rate of peat accumulation of about 0.7 mm/yr has been reported from Burns Bog on the Fraser Delta (Fig. 1) (Hebda, 1977); thus the buried peat layer is estimated to have formed in about 400 years. This implies a stillstand in sea-level rise between approximately 6200 and 5800 yr BP.

The areal extent of this stillstand is presently unknown, but evidence of a stillstand at *ca.* 6000 yr BP has been found in a core from Puget Lowland, Washington (Eronen *et al.*, 1987), approximately 160 km south of the Fraser Lowland, suggesting that it may have been at least regional in extent.

TEPHRA BED

The tephra bed, 10-20 mm thick, is bounded by sharp contacts with both the underlying and overlying sediments (Fig. 4). The tephra has a gritty texture and is clearly distinguishable in core by its white/pale yellow colour, which contrasts sharply with the greyish brown colour of the enclosing organic-rich silts.

The radiocarbon dates obtained in this study provide evidence that the tephra layer encountered in many drill cores

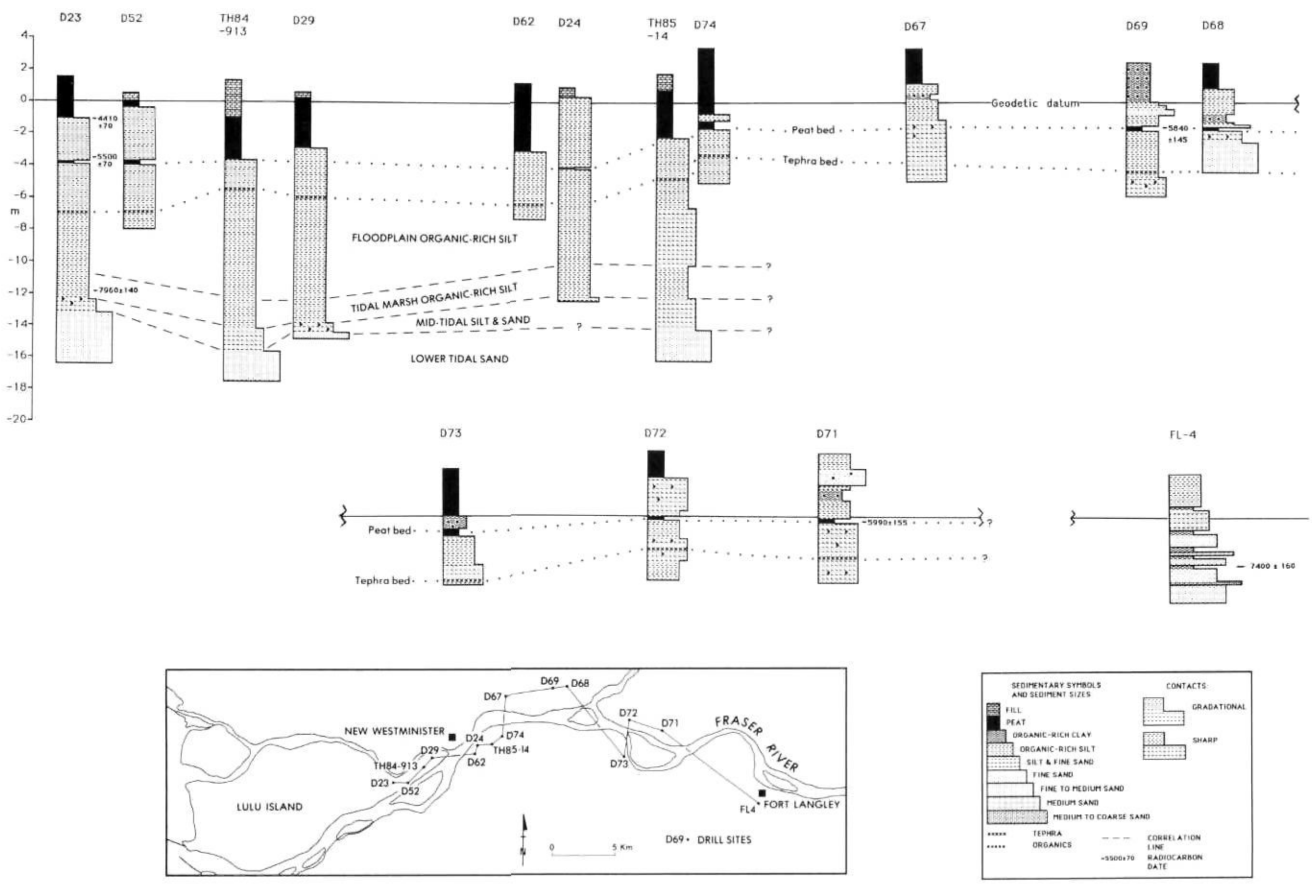

FIGURE 3. Lithostratigraphic section, from eastern Fraser Delta to western Fraser River floodplain, showing peat and tephra marker beds enclosed by floodplain deposits.

Coupes lithostratigraphiques, de la partie est du delta du Fraser jusqu'à la partie ouest de la plaine d'inondation du Fraser, qui montrent les lits repères de tourbe et de tephra contenus entre les dépôts de crue.

TABLE I

Radiocarbon Dates

Laboratory No.	Age (^{14}C years BP)	Core No.	Location Lat. N	Long. W.	Material	Elev. (m) bmsl*
GSC-4194	4410 ± 70	D23	49°10.5′	122°58.4′	Peat	1.19
GSC-4238	5500 ± 70	D23	49°10.5′	122°58.4′	Organic detritus	3.55
S-2866	5840 ± 145	D69	49°14.3′	122°48.6′	Peat	1.8
S-2867	5990 ± 155	D71	49°12.7′	122°41.3′	Peat	0.3
S-2872	6025 ± 105	D52	49°10.5′	122°57.7′	Peat	3.77
SFU-308	7400 ± 160	FL4	49°09.30′	122°35.15′	Wood	3.1
GSC-4255	7960 ± 140	D23	49°10.5′	122°58.4′	Organic detritus	11.71

* Below mean sea level.

is Mazama (*ca.* 6800 yr BP, Bacon, 1983), confirming previous identifications (Blunden, 1973, 1975; Clague *et al.*, 1983). In seven drill cores (D23, D52, D69, D71, D72, D73 and D74), the tephra bed is found stratigraphically below the buried peat marker horizon dated at *ca.* 6000 yr BP. The identification of the tephra bed as Mazama was also made independently on the basis of its trace element composition, using x-ray energy spectroscopy (Cormie *et al.*, 1981). It was found that Mazama could be distinguished from other Holocene tephras in southern British Columbia on the basis of its zirconium concentration (Williams and D'Auria, in prep.).

PALEOGEOMORPHIC IMPLICATIONS OF THE MARKER BEDS

The marker beds represent extensive subaerial surfaces of the Fraser River floodplain at two stages of its Holocene evolution; therefore, they play a valuable role in paleogeo-

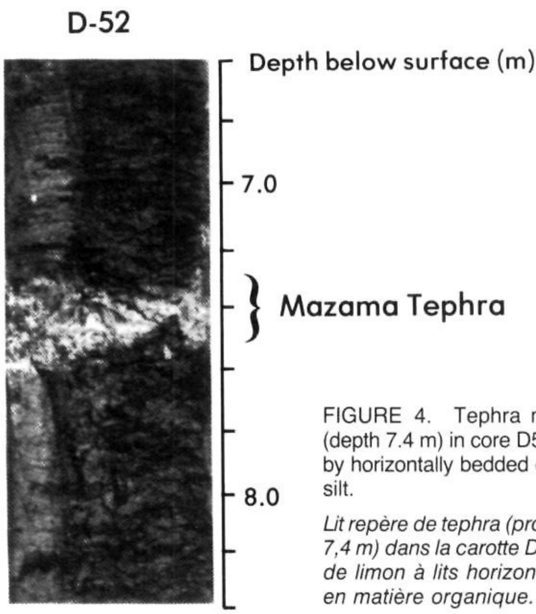

FIGURE 4. Tephra marker bed (depth 7.4 m) in core D52 enclosed by horizontally bedded organic-rich silt.

Lit repère de tephra (profondeur de 7,4 m) dans la carotte D52, entouré de limon à lits horizontaux riches en matière organique.

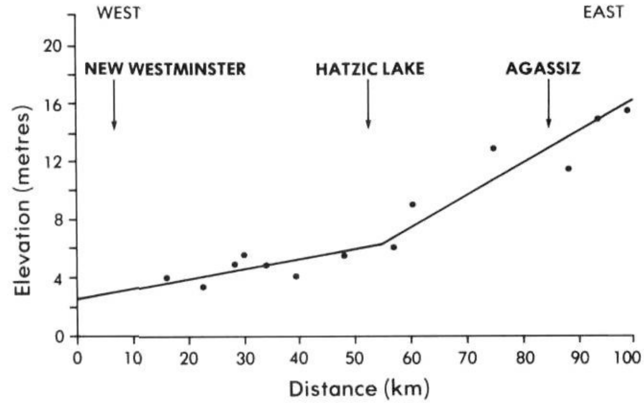

FIGURE 5. Longitudinal profile of the Fraser River floodplain surface, showing the break in slope between meandering and wandering gravel-bed reaches.

Profil longitudinal de la surface de la plaine d'inondation du Fraser, montrant la rupture de pente entre le bief à méandres et le bief à lits graveleux en méandre.

morphic reconstruction of lower Fraser Valley. The marker beds provide insights into: a) floodplain aggradation; b) lateral stability of the river channel; c) grade adjustments of the river in response to base-level changes.

FLOODPLAIN AGGRADATION

The marker beds can be traced from the Fraser Delta eastwards into the floodplain (Fig. 3). The stratigraphic continuity of the marker beds shows that the floodplain and the delta aggraded in concert. Rising base level caused accelerated aggradation of both the delta and the floodplain, such that the rate of sediment accumulation kept pace with the rate of sea-level rise (Williams and Roberts, 1989). Terrestrial conditions were thus perpetuated, giving rise to the thick floodplain unit on both the delta and floodplain (Fig. 3).

On the eastern delta, the base of the aggradational deposits enclosing the marker beds coincides with the base of the thick floodplain unit, radiocarbon dated at 7960 ± 140 yr BP (GSC-4255; core D23—Fig. 3). This floodplain unit extends some 14 m below the delta surface, indicating aggradation of 14 m in approximately the last 7960 years—an average sedimentation rate of about 1.8 mm/yr.

Clague *et al.* (1983) obtained a core from the floodplain some 18 km up-valley from the delta apex (in the vicinity of core D72, Fig. 3). A peat layer in this core, from 11.5 m below the surface, yielded a radiocarbon age of 7710 ± 80 yr BP (GSC-3099), indicating 11.5 m of aggradation and an average sedimentation rate of about 1.5 mm/yr.

A core from the floodplain near Fort Langley (about 38 km up-valley; FL-4, Fig. 3), contained a piece of wood at a depth of about 3.1 m bsl., which was radiocarbon dated at 7400 ± 160 yr BP (SFU-308). The surface of the floodplain here is about 2.6 m asl., indicating a depth of aggradation over the last *ca.* 7400 years of no more than about 5.7 m, and an average sedimentation rate of about 0.8 mm/yr. These findings suggest that there is a progressive up-valley decrease in the thickness of the aggradational deposits.

The deposits enclosing the marker beds form, therefore, a sediment wedge that thins up-valley. The marker beds define two paleosurfaces within this wedge, extending from the Fraser River floodplain onto the surface of the delta.

LATERAL STABILITY OF THE RIVER CHANNEL

Preservation of the peat and tephra marker beds in the lower Fraser River floodplain (Fig. 3) is clear evidence that lateral channel migration has been quite limited over the last *ca.* 7000 years. On the basis of the drill core data (Fig. 3), the floodplain deposits underlying the lower reaches of the river to a depth of at least 8 m consist mainly of overbank deposits, rather than laterally-accreted, in-channel sediments. This is in marked contrast to the wandering gravel-bed reach, where, apart from a shallow veneer of overbank deposits, the floodplain sediments have resulted chiefly from channel migration and island accretion (McLean and Mannerstrom, 1985; Morningstar, 1987).

RIVER GRADIENT AND BASE-LEVEL CHANGES

The growth of the sediment wedge resulted in a considerable reduction in slope of the lower Fraser River. A longitudinal profile of the Fraser Valley floodplain, based on benchmarks on topographic maps (Fig. 5), shows the average gradient of the lower reaches of the river to be 0.00008. The slope of the older floodplain surface, underlying the aggradational deposits (approximated by the estimated position of the *ca.* 7400 yr BP paleosurface in Fig. 3) is 0.0002, indicating a reduction in gradient of over 50%.

A distinct break in slope of the floodplain surface is shown in the vicinity of Hatzic Lake, at the wandering gravel-bed/meandering transition (Fig. 5). This raises the possibility that the up-valley limit of the sediment wedge is marked by this break in slope, as has been found in previous studies of floodplain aggradation (Mackin, 1948; Leopold and Bull, 1979); and, that the transition from wandering gravel-bed to meandering fluvial styles is related to the imposition of a reduced river gradient in the lower reaches of the river. However, in the absence of further data it is not yet possible to distinguish the effects of the downstream base-level rise from upstream controls on floodplain morphology, such as the propagation of the large gravel fan underlying the wandering gravel-bed reach. Such interpretations must therefore remain only speculative.

CONCLUSIONS

This study has shown that the lower Fraser River floodplain aggraded in response to a middle Holocene sea-level rise. Peat and tephra marker beds represent two extensive paleosurfaces within the aggradational deposits. Continuity of the marker beds from the delta into the adjoining floodplain demonstrates that the floodplain aggraded in concert with the delta, and that the rate of sedimentation in both areas kept pace with sea-level rise.

The resulting aggradational deposits form a sediment wedge which extends at least 20 km upvalley. Lithologic and palynologic evidence shows that the deposits consist mainly of organic-rich silt and sand of overbank origin, and that they lack in-channel sediments associated with lateral channel-migration. Preservation of the marker beds, at least in the lower 20 km of the floodplain, demonstrates that the deposits have not been fluvially reworked, and suggests channel stability over this distance during the last 7000 years.

Further drilling of the floodplain is required to establish the extent of the sediment wedge and to explore further the relations between growth of the deposits and the morphologic and depositional response of Fraser River.

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