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The Geomorphology
of the
Strawberry Creek Basin, Central Alberta

by

ⓒ James E. Welch

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF Master of Science

Geography

EDMONTON, ALBERTA
Spring 1983

April 22, 1983

NOTE:

Figure 6.5, page 165, is in part modified and adapted from Schumm (1977) to explain a conceptual development of the Strawberry Creek Basin. Figure 6.5 has been originally drafted for this purpose and is not a direct copy.

James E. Wall
M.Sc. Thesis
GEOMORPHOLOGY OF THE
STRAWBERRY CREEK BASIN
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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled THE GEOMORPHOLOGY OF THE STRAWBERRY CREEK BASIN, CENTRAL ALBERTA submitted by James E. Welch in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

R B Rains
....
Supervisor

....

....

Date 25 March, 1983

ABSTRACT

Although pre-Holocene characteristics of the study basin are briefly reviewed the major focus of this study is on the Holocene development of the Strawberry Creek valley. Thus, strongest emphasis is placed on the alluvial terrace morphology, alluvial stratigraphy and chronology. The morphologic aspect of this study verifies the existence of four, paired, alluvial terraces intermittently displayed along the valley. These reflect at least four main stages of morphologic development, in close agreement with stages previously defined for the Whitemud and Weed Creek valleys. The alluvial stratigraphies of the terrace sections logged in the Strawberry Creek valley imply persistent depositional environments of sinuous or meandering channel systems. An alluvial chronologic sequence has been developed on the basis of nine related radiocarbon dates, and the presence of Mazama Ash in one terrace exposure, from the Strawberry Creek valley. In addition, eight radiocarbon dates are available for the Whitemud Creek valley and two dates from the Weed Creek system. From these dates it was determined that the geomorphic development of the Strawberry, Weed and Whitemud Creeks, defined by the radiometric ages of the related sets of alluvial terraces, was probably time-synchronous. Valley development stages are represented by four net incision phases, each followed by stages of relative channel stability. The chronology now established indicates that two of the major phases of net incision

occurred approximately between the time of deglaciation and 9000 years B.P. and circa 6000 years B.P. Within at least the past 4000 years the tributaries have experienced two additional net incision phases culminating in the contemporary floodplain and channel.

By the integration of previous studies, and additional refinement from recent work, an interpretation of the Holocene development of the North Saskatchewan River valley in the local area is presented. From this review it is concluded that the valley evolution of the North Saskatchewan River has involved four major stages, reflected by remnant river terraces. Thirteen related radiocarbon dates, and occurrences of Mazama Ash, suggest that the local river valley achieved much of its present form early in Holocene time, by approximately 8000 years B.P. Thus, the sequential phases of morphological development of the North Saskatchewan River and the local tributary creeks have <u>not</u> been time-synchronous.

ACKNOWLEDGEMENTS

First, I would like to gratefully acknowledge Dr. R.B. Rains, thesis supervisor, who initially suggested the research topic and provided invaluable guidance and field assistance during all stages of the research. Particularly important were his time and patience extended in the evaluation and editing of the text.

The sections of this thesis that relate to the North Saskatchewan River valley and the Whitemud Creek valley, in particular the inclusion of presently unpublished radiocarbon dates, are from an ongoing research project of Dr. R.B. Rains. Recent field work, supervised by Dr. R.B. Rains, was completed in the above valleys by Deb Pike Glover, Don Jennings, Frank McKenzie and Dan Smith. The photos presented for the North Saskatchewan River valley are courtesy of Dan Smith. The North Saskatchewan River and Whitemud Creek valleys comprise a critical aspect of this study and the author was extremely fortunate to have had this pertinent information available for integration with the Strawberry Creek valley research.

Appreciation is extended to Dr. H.J. McPherson and Dr. W. Pettapiece for their contributions as members of the committee; Dr. J.F. Lerbekmo for review of the bedrock geology chapter; Pam Waters for identification of the Mazama Ash; Don Jennings, Pam Kruse, Olaf Niemann, Dan Smith and Tom Stewart for their assistance in the altimetric surveying; Dr. P. Currie, Provincial Museum and Archives of

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Finally, a special thanks to the many people associated with the Department of Geography, including academic staff, administrative staff and many fellow graduate students, whose significant contributions made the completion of this thesis possible.

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1. INTRODUCTION

1.1 Thesis Objective and Background

The broad objective of this thesis is to present an integrated geomorphic analysis of the Strawberry Creek basin, central Alberta (Figure 1.1). In particular, the emphasis of this research is to outline the Holocene evolution of the Strawberry Creek valley within the framework of the basin's pre-Holocene surficial sediments and local bedrock. An outline of the creek valley evolution is attempted from a detailed investigation of the morphologic and stratigraphic attributes of alluvial terrace remnants which are indicative of former valley development stages.

Rains (1969a) and Shelford (1975) described, among other things, the Holocene valley development of the Whitemud and Weed Creeks respectively. The Whitemud, Weed and Strawberry Creek basins are of similar size, in close proximity, and all are southern tributaries of the North Saskatchewan River (Figure 1.1). The foundation and impetus for the present thesis were thus provided by the earlier studies of Rains (1969a) and Shelford (1975). The major component of this thesis shows that these three central Alberta tributaries of the North Saskatchewan River reflect closely similar morphologic and stratigraphic Holocene development histories.

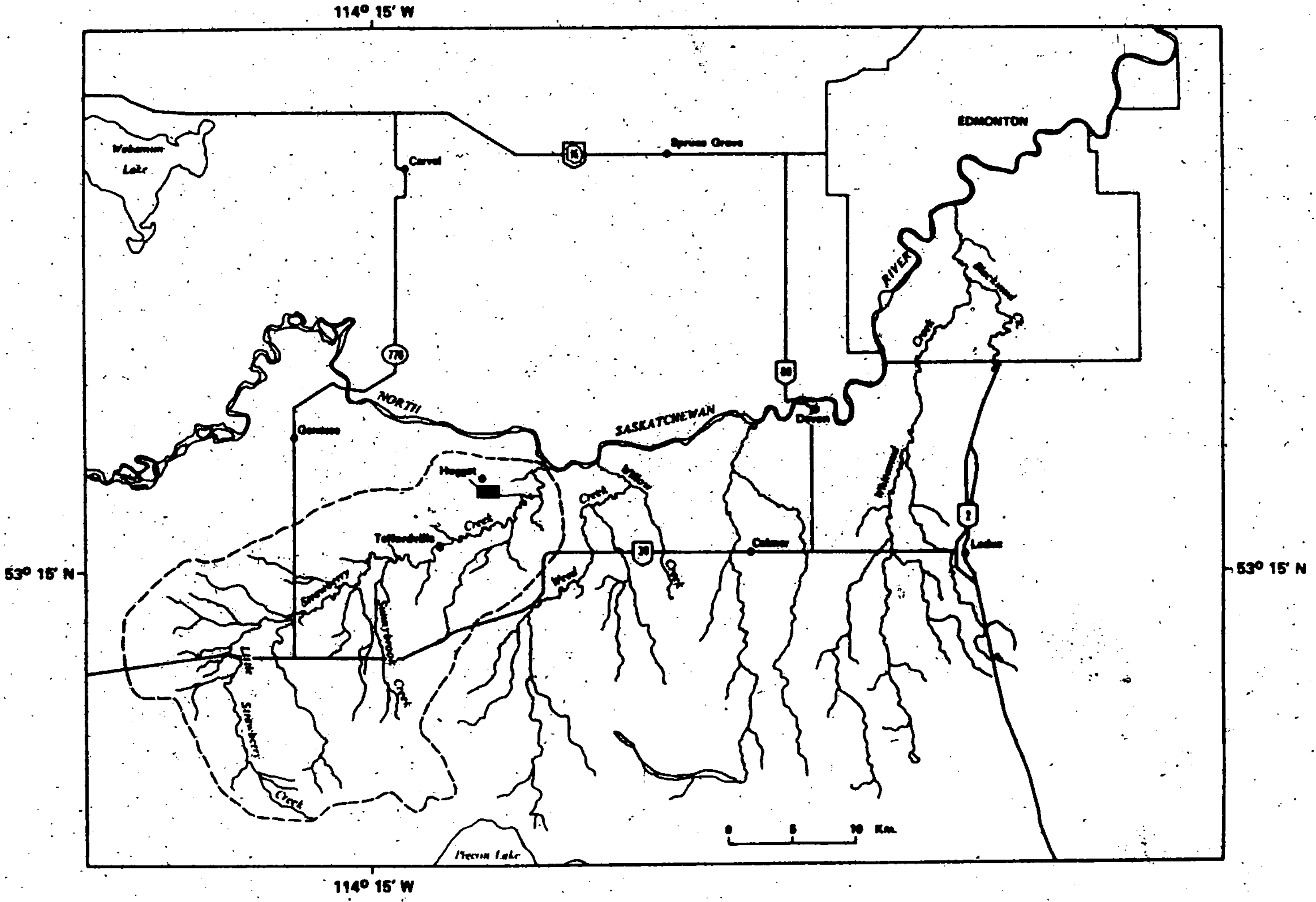


Figure 1.1. Location of study area.

A basic concern in studies of creek or river valley evolution is to interpret the role of local base-level throughout tributary valley development. For this study-basin the North Saskatchewan River acts as the local base-level. Therefore, it is necessary to have a basic understanding of the post glacial development of the North Saskatchewan River valley in the local area. The groundwork for this aspect of the study was largely provided by Bayrock and Hughes (1962), Bayrock and Berg (1966), Westgate (1969), Kathol and McPherson (1975) and Westgate et al., (1976), all of which in part deal with the Quaternary geology of the city of Edmonton. More recent work on the same valley sector allows the refinement of earlier chronological interpretations.

1.2 Introduction to the Field Area

The Strawberry Creek basin (Figure 1.1), of approximately 320 square kilometers, is located in the Eastern Alberta Plains and drains into the North Saskatchewan River which flows east-northeast into Hudson Bay. The basin has small relative relief and is fairly typical of the central Alberta physical and cultural environment. The bedrock underlying this basin is of late Cretaceous and Tertiary origin, partly eroded during denudation cycles that continued into the Pleistocene (Taylor et al., 1964). A prominent aspect of this denudation, evident in the basin's bedrock topography, is the preglacial Warburg valley (Carlson, 1970). Exposures of unconsolidated, probably preglacial, Warburg valley alluvium are occasionally found where Strawberry Creek has intersected the preglacial valley. Stratigraphic relations of glacigenic sediments in the Edmonton area suggest that during the Pleistocene Epoch the preglacial landscape was, at least, twice overridden by continental ice sheets (Rains, 1969b; Westgate, 1969; Westgate et al., 1976 and Shaw, 1982). In the Strawberry Creek valley exposures of glacigenic sediments exhibit stratigraphic evidence of two glacial "pulses". During recession of the late Wisconsinan ice extensive proglacial lakes were formed. A portion of the local proglacial lake system inundated most of the Strawberry Creek basin. The final drainage of this local proglacial lake (St-Onge, 1972) was immediately followed by stream incision into the lacustrine and underlying sediments. Thus began the Holocene development of the Strawberry Creek drainage system.

1.3 Methods of Study

This investigation began with a thorough literature review plus a study of relevant topographic maps and aerial photographs. Particular emphasis was focused on the remnant creek terraces, and planimetric maps were constructed depicting these on aerial photograph overlays for field checking.

Fieldwork was mainly conducted throughout the spring and summer of 1979, and additional shorter periods of subsequent summers. The valley was traversed from its junction with the North Saskatchewan River upstream to the junction of the Strawberry and Little Strawberry Creeks, where the valley depth becomes comparatively minor. Field observations encompassed the following:

(1) The superficial examination of bedrock characteristics from outcrops along the valley walls.

(2) General descriptions of preglacial sediments and glacigenic deposits, with more detailed logging of "exceptional" exposures.

(3) The location and description of alluvial terrace remnants within the main valley.

(4) Altimetric surveys of pre-selected valley cross-sections to typify the terrace relationships.

1.4 Organization of Thesis

The contents of the study are presented in a geo-chronological progression after Chapter 2, which reviews relevant published studies and outlines more recent, presently unpublished, work on the North Saskatchewan River terraces, Edmonton. Chapter 3 examines general characteristics of the Strawberry Creek basin bedrock geology and thus deals with the foundation upon which the catchment has recently evolved. Pre-Holocene surficial deposits observed in the study basin are discussed in Chapter 4, emphasizing contemporary interpretations regarding their genesis. The Strawberry Creek Holocene valley evolution, physical and chronological, is outlined in Chapter 5 with the presentation of field data and radiocarbon dates. Chapter 5 also compares the physical attributes of the Strawberry Creek valley with those previously reported for the Whitemud (Rains, 1969a) and Weed (Shelford, 1975) Creek systems. In conclusion, Chapter 6 considers the probable roles of paleo-environmental and complex-response factors in the Holocene evolution of the Strawberry Creek valley.

2. PREVIOUS STUDIES; NORTH SASKATCHEWAN RIVER VALLEY AND SELECTED TRIBUTARIES

2.1 Introduction

An interpretation of Holocene developmental stages of the North Saskatchewan River valley in the Edmonton area is a prerequisite to an understanding of interrelationships between the North Saskatchewan River and its local tributaries. Thus, a range of previous studies related to the geomorphology of the North Saskatchewan River valley in the Edmonton area is reviewed, along with an outline of recent work completed in the same valley sector. From the available data a chronological interpretation of the valley evolution is presented.

The North Saskatchewan River valley development is linked to that of tributary valleys mainly through the former's role as a local base-level. Three, major, local tributaries are Whitemud, Weed and Strawberry Creeks. An evaluation of the Holocene development of these three tributaries, with particular emphasis on Strawberry Creek, is the primary objective of this thesis. Earlier, related studies are those of Rains (1969a), on the Whitemud Creek valley, and Shelford (1975), on the Weed Creek valley. Their main conclusions are also briefly reviewed later in this chapter.

2.2 North Saskatchewan River Valley

2.2.1 Previous Work

The local North Saskatchewan River valley development began with the late Pleistocene deglaciation of the area. At the regional scale, St-Onge (1972) proposed a sequence of proglacial lakes and related Laurentide deglaciation stages for north-central Alberta. More recently Christiansen (1979) synthesized a large number of previous studies, and related radiocarbon dates, to provide a nine-phase model of deglaciation for southern Saskatchewan and part of easternmost Alberta. St-Onge (1980) also pointed out that a combination of his earlier interpretations and Christiansen's (1979) model provides a well-documented sequence of deglaciation for much of Alberta and Saskatchewan. Thus, a combination of their interpretations will be used as a base (see section 2.2.3). This combination incorporates their major phases relative to the Edmonton area, and the progressive opening-up of new North Saskatchewan River valley sectors northeast and east of Edmonton.

Studies which have focused more specifically on the local river valley and alluvial terraces include Bayrock and Hughes (1962), Westgate (1969), Kathol and McPherson (1975) and Westgate et al., (1976). Westgate (1969) recognized four distinct, terrace tread relative elevations in the Edmonton sector of the North Saskatchewan River valley (Table 2.1).

TABLE 2.1. NORTH SASKATCHEWAN TERRACE NOMENCLATURE

Terrace Designations Used in This Study	Approximate Terrace Tread Elevations Above Present Low Water Surface (Modified after Westgate, 1969)
T-1	45 m (Approx. 150 ft.)
T-2	30 m (Approx. 110 ft.)
T-3	19 m (Approx. 60-70 ft.)
T-4	[illegible] m (Approx. 20-[illegible] ft.)

Figure 2.1a shows examples of the relevant terrace treads based on a generalized interpretation of Westgate's (1969) terrace descriptions. Figure 2.1b is a generalized cross-section, modified from Westgate (1969), representing examples of tread heights (T-1, T-2 and T-4) above the river. The location of this profile is shown on Figure 2.1a as line X-Y.

The alluvial stratigraphy was described by Westgate (1969) for a T-3 site, at Emily Murphy Park, which yielded bone material (location W-3, Figure 2.1a). The alluvium of this terrace section consisted of 5m (about 15 ft.) of basal gravels succeeded by 1.5m (about 5 ft.) of sands. The sand unit displayed two paleosols and was capped by 0.5m (about 2 ft.) of contemporary loam soil. A paleosol between the alluvium and present soil was dated at 2090 ± 110 yrs. B.P. (I 2931), but this appears to markedly post-date the main deposition-phase of T-3 alluvium. The sequence of alluvium probably reflects a formerly stable channel system with lateral accretion as the primary mode of alluvial deposition.

An exposure of T-4 alluvium, also described by Westgate (1969), contained Mazama Ash, a useful marker-bed stratigraphically dated elsewhere at approximately 6600 yrs. B.P. Additional radiocarbon-dated bones, wood, charcoal, paleosols and marl have been reported for numerous North Saskatchewan River T-4 sites in the vicinity of Edmonton. These provide a reasonably detailed alluvial chronology for

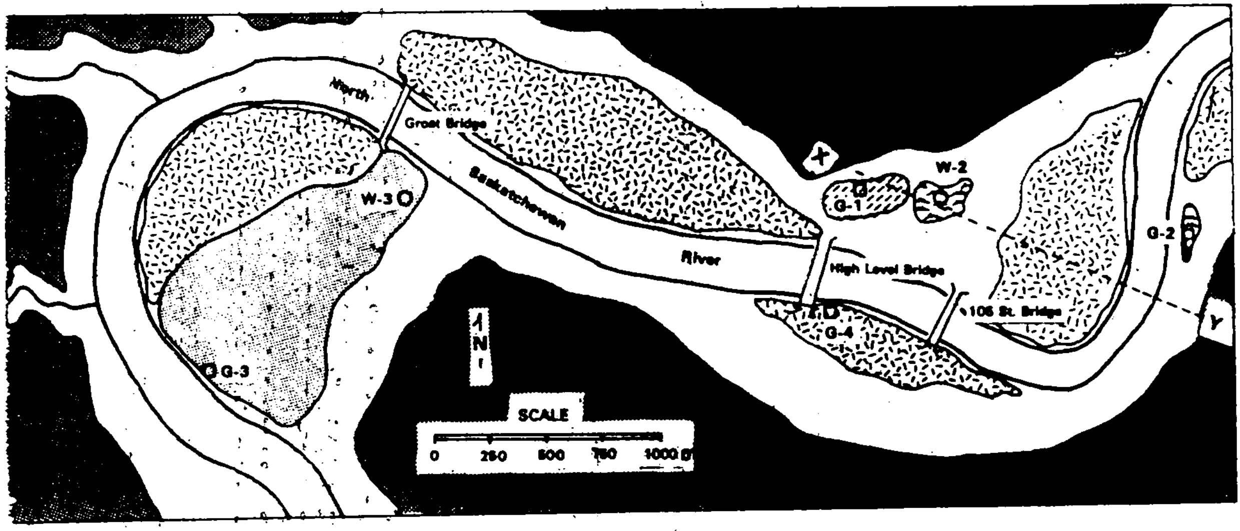


Figure 2.1a. Planimetric distribution of North Saskatchewan River terraces.

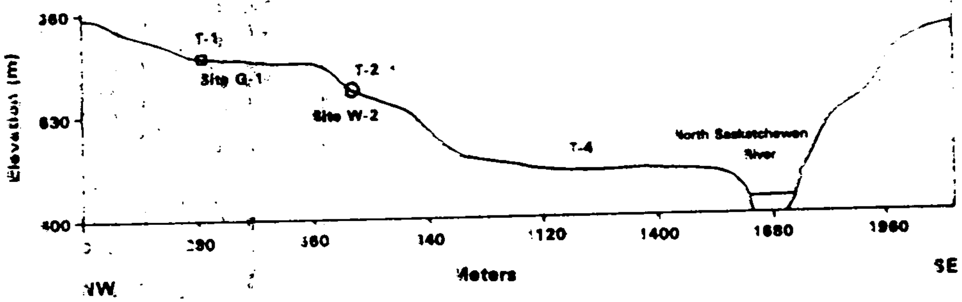


Figure 2.1b. Cross-section X - Y: North Saskatchewan River valley.

the youngest terrace. Dates so far obtained for the alluvium of T-1, T-2 and T-3 remnants are few. Table 2.2 contains information pertinent to the available radiocarbon dates for the local North Saskatchewan River terraces. This information is central to the chronological interpretations which will follow later in the thesis.

Westgate et al.,(1976), revised the earlier work of Westgate (1969) on local river terraces, with two important additions. The first major revision involved the previously distinguished T-1 and T-2 remnants. These were subsequently combined into one terrace that ... "stands well over 100 ft. [30 m] above river level and has been preserved in the neighbourhood of the Parliament Building." (Westgate et al., 1976, p. 25). This revision was based on evidence from a newly excavated sequence of alluvium (location W-2, Figure 2.1a). The elevation of this site , and its associated terrace tread, at approximately 30m above the present river channel may be estimated from Westgate's (1969) cross-section (Figure 2.1b). The alluvial sequence at this site was described as "ten feet of crossbedded sands... covered by 8 feet of coarse, poorly sorted gravels..."(Westgate et al., 1976, p. 25). This sequence of alluvium appears to reflect a relatively high-energy, perhaps braided, channel system with rapid aggradation and lateral shifting of channels depositing sand and gravel bars. However, the amalgamation of T-1 and T-2 terraces appears to be unjustified. Kathol and McPherson (1975)

TABLE 2.2. NORTH SASKATCHEWAN RIVER TERRACE RADIOCARBON DATES.

Terrace	C_{14} Date RCYBP	Lab Number	Reference	Valley Location	Comments
T-1	10,740 ± 470	S-1923	Rains and Welch (in progress)	Edmonton	Bone: from alluvium associated with initial incision of North Saskatchewan River.
T-2	No dates yet available				
T-3	10,700 ± 150*	I-4553	Westgate, et al., (1976)	Edmonton	Bone: from alluvium of 19 m terrace.
T-3	2,090 ± 110	I-2931	Westgate, (1969)	Edmonton	Paleosol: above alluvium and capped with loam
T-4	10,600 ± 300*	S-140	McCallum and Wittenburg (1962)	35 km west of Edmonton	Marl: overlying floodplain sand and silt of lowest terrace.
T-4	9,860 ± 140	I-8483	Westgate, et al., (1976)	Edmonton	Bone: from clean cross-bedded sands of the 9m terrace.
T-4	8,320 ± 140	GSC-767	Lowden and Blake (1968)	35 km west of Edmonton	Wood: from top of river gravels, 3m above channel.
T-4	8,150 ± 100	S-106	McCallum and Wittenburg (1962)	35 km west of Edmonton	Wood: base of Marl.
T-4	7,350 ± 100	S-107	McCallum and Wittenburg (1962)	35 km west	Wood: 3m above base of Marl.
T-4	6,955 ± 80	S-1706	Rains and Welch (in progress)	Fort Saskatchewan	Bone: encasing material, over-bank fines bracketing a tephra, presumably Mazama Ash.
T-4	6,630 ± 200	I-2612	Westgate et al., (1969)	Edmonton	Charcoal: from alluvium directly underlying Mazama Ash.
T-4	6,660	Mazama Ash	Westgate (1969)	Edmonton	Identification by electron - microprobe analysis of the chemical composition of volcanic glass.
T-4	6,290 ± 250	I-2778	Westgate (1969)	Edmonton	Charcoal: from alluvium directly overlying Mazama Ash
T-4	4,920 ± 330	GSC-1132	Lowden et al., (1971)	Edmonton	Paleosol: Ahg horizon of humic gleysol below 50 cm + alluvium, underlain by alluvium with Mazama Ash.
T-4	2,780 ± 85	S-1799	Rains and Welch (in progress)	Edmonton	Bone: bison tibia, from alluvium, positioned in sands above gravels.

* Dates which appear to be anomalous for their stratigraphic positions.

reiterate that four main terrace levels occur in the valley.

The second, important revision made by Westgate et al.,(1976), was the inclusion of a radiocarbon date from the T-3 site W-3 (Figure 2.1a). A date of 10,700 ± 150 yrs. B.P. (I-4553) was obtained from bone of an extinct horse, <u>Equus Asinus</u> <u>cf.</u> <u>conversidens</u> (Table 2.2). The existence of this bone was mentioned by Westgate (1969) but at that time the material had not been dated.

2.2.2 Recent Work

In 1980 a large excavation for a road tunnel being constructed directly north of the Parliament Building, Edmonton, revealed thick deposits of T-1 alluvium (site location G-1, Figure 2.1a and 2.1b). Two fractured bones were retrieved (by the author and R.B. Rains) from this alluvium, and one bone yielded a radiocarbon date of 10,740 ± 470 yrs. B.P., (S-1923). The alluvial sequence revealed by the excavation included vertically and laterally discontinuous gravel beds varying up to 4 m in thickness. These beds were interspersed with thick deposits of plane-bedded and cross-bedded sands . A lowermost gravel unit of of indeterminate thickness (Figure 2.2) was dominated by Cordilleran quartz clasts but contained significant numbers of Canadian Shield igneous and metamorphic clasts. The two bones, noted earlier, were retrieved from a thick sand unit a few centimeters above its contact with the lowermost gravel.

Figure 2.2. T-1 alluvium (site G-1), North Saskatchewan River valley.

An exposure of T-2 alluvium was also recently found on the south bank of the river (site location G-2, Figure 2.1a) directly across the valley from the W-2 excavation site described by Westgate et al., (1976). The elevation of the small remnant tread associated with site G-2 is approximately 30 m above the present river channel, and this is almost identical to the elevation of site W-2 (Westgate et al., 1976). The alluvium exposed at G-2 was dominated by gravel with some elements of imbrication (Figure 2.3). Minor sand lenses were numerous but did not constitute a major proportion of the alluvium. The sedimentary facies of this terrace section, and those of the W-2 section described by Westgate et al., (1976), are apparently indicative of a rapidly aggrading, perhaps braided, river reach.

A terrace section , with a tread at intermediate height between the general T-3 and T-4 relative elevations, was noted at site location G-3 (Figure 2.1a). The alluvium of this section, (Figure 2.4), overlying approximately 1.5 m of exposed bedrock, showed a fining-upwards sequence, with 1.5 m of basal gravels succeeded by 0.5 m of horizontally bedded loose sands, and 1.5 m of well sorted, well compacted overbank fines (sand, silt and clay). These facies reflect activities of a relatively stable, meandering channel system, depositing sediment by vertical and lateral accretion. Westgate (1969) noted similar facies in his T-3 section (site location W-3, Figure 2.1a), with considerable variations in thickness of individual sedimentary units.

Figure 2.3. T-2 alluvium (site G-2), North Saskatchewan River valley.

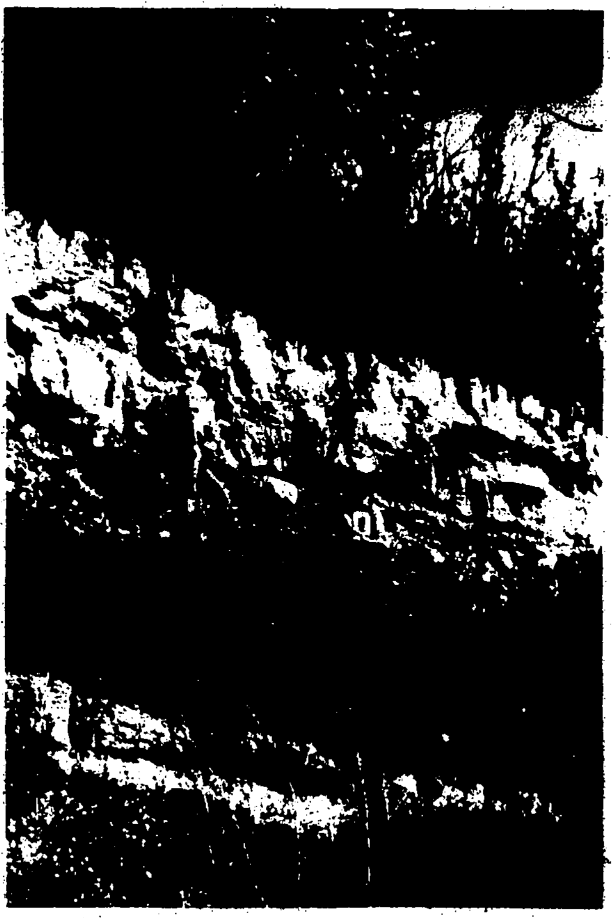


Figure 2.4. Alluvium of site G-3, North Saskatchewan River valley.

Remnants of T-4 are, for obvious reasons, the best preserved and these provide many well-exposed alluvial sections in the area. For example, recent investigation of a T-4 section at site G-4 (Figure 2.1a) yielded bison bones from alluvium approximately 2 m below the terrace tread surface. One bone sample was radiocarbon dated at 2780 ± 85 yrs. B.P., (S-1799). Also of interest in this T-4 section was a buried organic bed overlain by a 1 m bed of poorly compacted, very fine sands and silts which capped the section. This uppermost bed contained a thriving tree, the base of which was associated with the buried organic bed. This, in conjunction with the late Holocene bone date, suggests that at least the upper 1 m of alluvium was deposited quite recently. The T-4 tread surfaces, which occur approximately 9 m above present low-stage water levels, have been susceptible to inundation and deposition during long return-period floods of even recent times. It should be noted, for example, that in 1899 the Hudson's Bay Company steamer "North West" was demolished when the North Saskatchewan River rose nearly 8 m (Folio, University of Alberta, 15 January, 1981). The report by Mustapha et al., (1981) includes photographs of Edmonton T-4 surfaces over-topped by floodwater in 1915.

Another T-4 radiocarbon date of 6955 ± 80 yrs. B.P., (S-1706) was recently obtained for bison bone retrieved from a commercial sand and gravel pit near Fort Saskatchewan. The numerous bison bones found at this site lay above and below a tephra layer which is presumed to be Mazama Ash. The Mazama Ash (ca. 6600 yrs. B.P.) interpretation is supported by the date on bone retrieved from alluvium a few centimeters below the tephra.

2.2.3 Interpretative Update

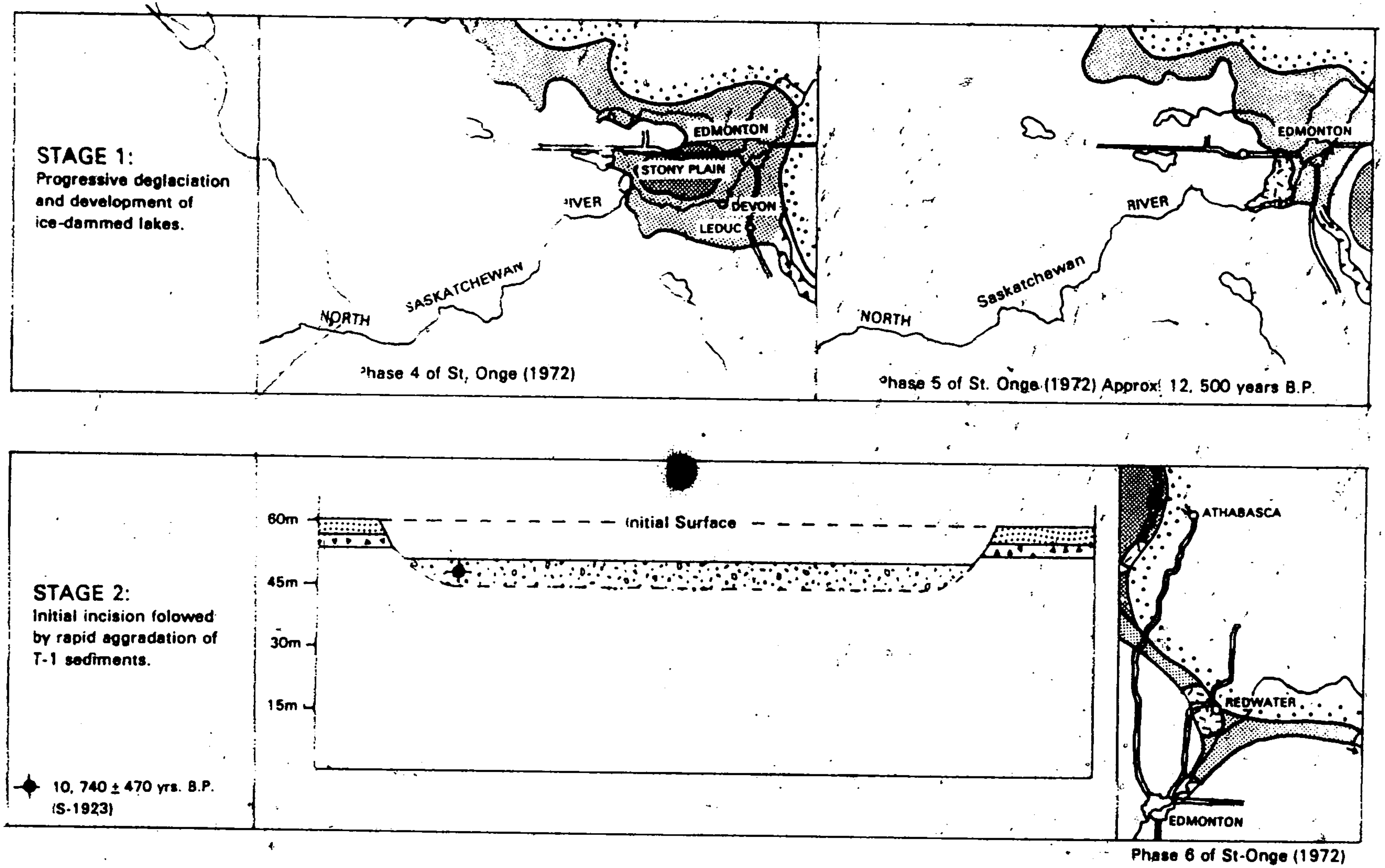
An integration of previous work on local and regional, Holocene, fluvial activity may help to substantiate a proposed post glacial geomorphic chronology of the valley. It is concluded that four, distinct, remnant, terrace tread relative elevations may be identified for the Edmonton sector of the North Saskatchewan River valley. This view is supported by Kathol and McPherson (1975). Hence, the interpreted evolution of the valley will be distinguished in terms of five developmental stages, which began with deglaciation of the area (Stage 1) and led successively to the contemporary river channel and floodplain (Stage 5). Figure 2.5 is a generalized representation of the valley development stages, interpreted mainly from the morphologic, stratigraphic and dating evidence introduced earlier. Figure 2.5 also incorporates combinations of the major, related, deglaciation episodes (phases 4 through 7) suggested by St-Onge (1972) and Christiansen (1979). The following discussion outlines an interpretation of the individual stages shown in Figure 2.5.

<u>Stage 1</u>

⁘	Terrace Alluvium
▒	Glacial Lake Edmonton Sediments
▴	Laurentide Tills
☐	Bedrock:Edmonton Formation
— —	Approximate Depth of Incision
- -? ? -	Unknown Depth of Incision

ELEVATION DATUM IS THE LOW WATER LEVEL OF THE NORTH SASKATCHEWAN RIVER

⁖	Ice Front
░	Glacial Lake
⇝	Outlet, Meltwater Channel
▓	Stagnant Ice
▨	Delta



STAGE 1:
Progressive deglaciation and development of ice-dammed lakes.

Phase 4 of St, Onge (1972)

Phase 5 of St. Onge (1972) Approx. 12, 500 years B.P.

STAGE 2:
Initial incision folowed by rapid aggradation of T-1 sediments.

10, 740 ± 470 yrs. B.P. (S-1923)

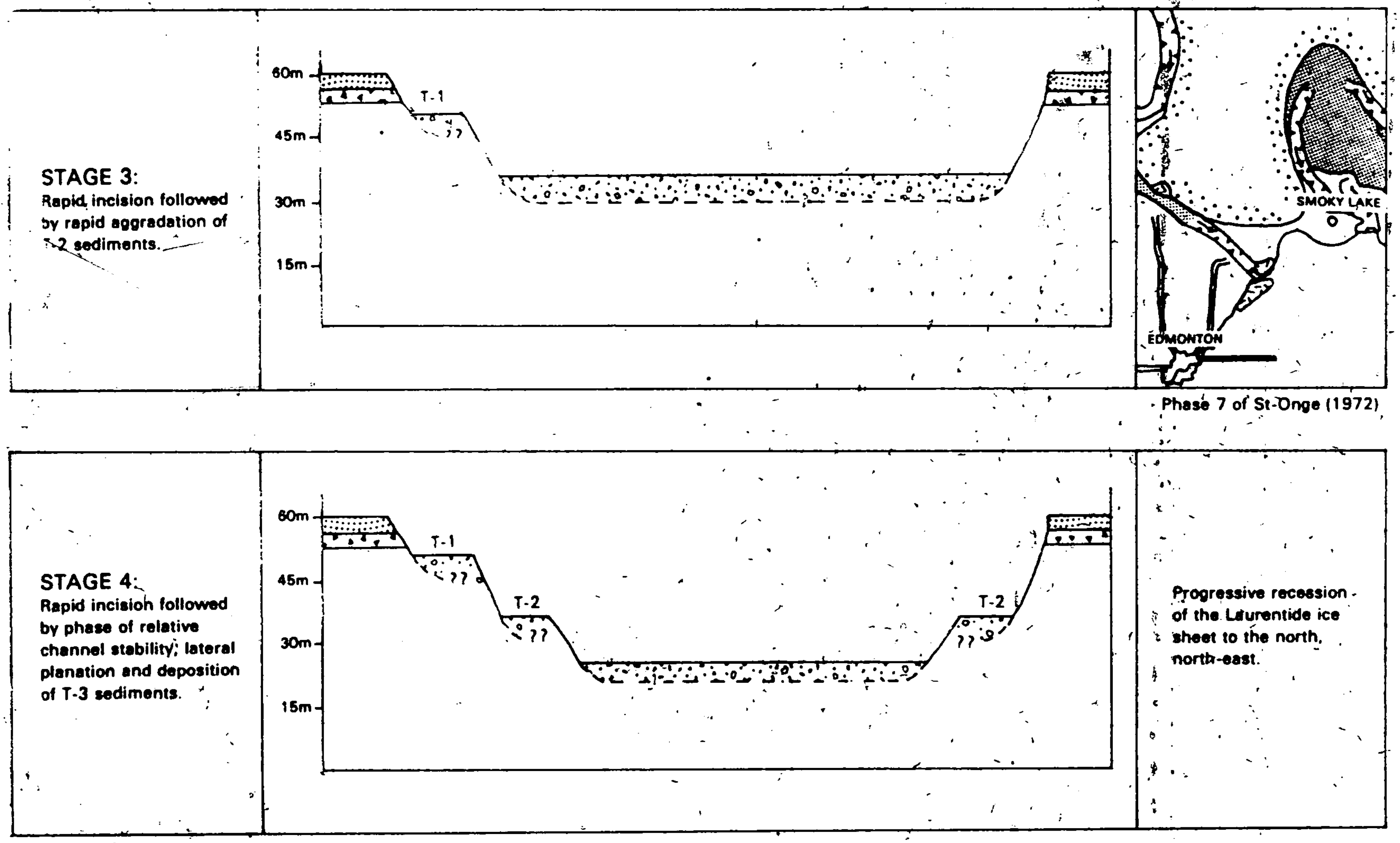
Phase 6 of St-Onge (1972)

Figure 2.5a. Proposed stages of North Saskatchewan River valley evolution, Edmonton.

- ▨ Terrace Alluvium
- ▦ Glacial Lake Edmonton Sediments
- ▨ Laurentide Tills
- □ Bedrock:Edmonton Formation
- — + — Approximate Depth of Incision
- - - ? ? - Unknown Depth of Incision

ELEVATION DATUM IS THE LOW
WATER LEVEL OF THE NORTH
SASKATCHEWAN RIVER

- ⁄ Ice Front
- ▨ Glacial Lake
- ⤳ Outlet, Meltwater Channel
- ■ Stagnant Ice
- ▨ Delta



STAGE 3:
Rapid incision followed by rapid aggradation of T-2 sediments.

Phase 7 of St-Onge (1972)

STAGE 4:
Rapid incision followed by phase of relative channel stability; lateral planation and deposition of T-3 sediments.

Progressive recession of the Laurentide ice sheet to the north, north-east.

Figure 2.5b. Proposed stages of North Saskatchewan River valley evolution, Edmonton.

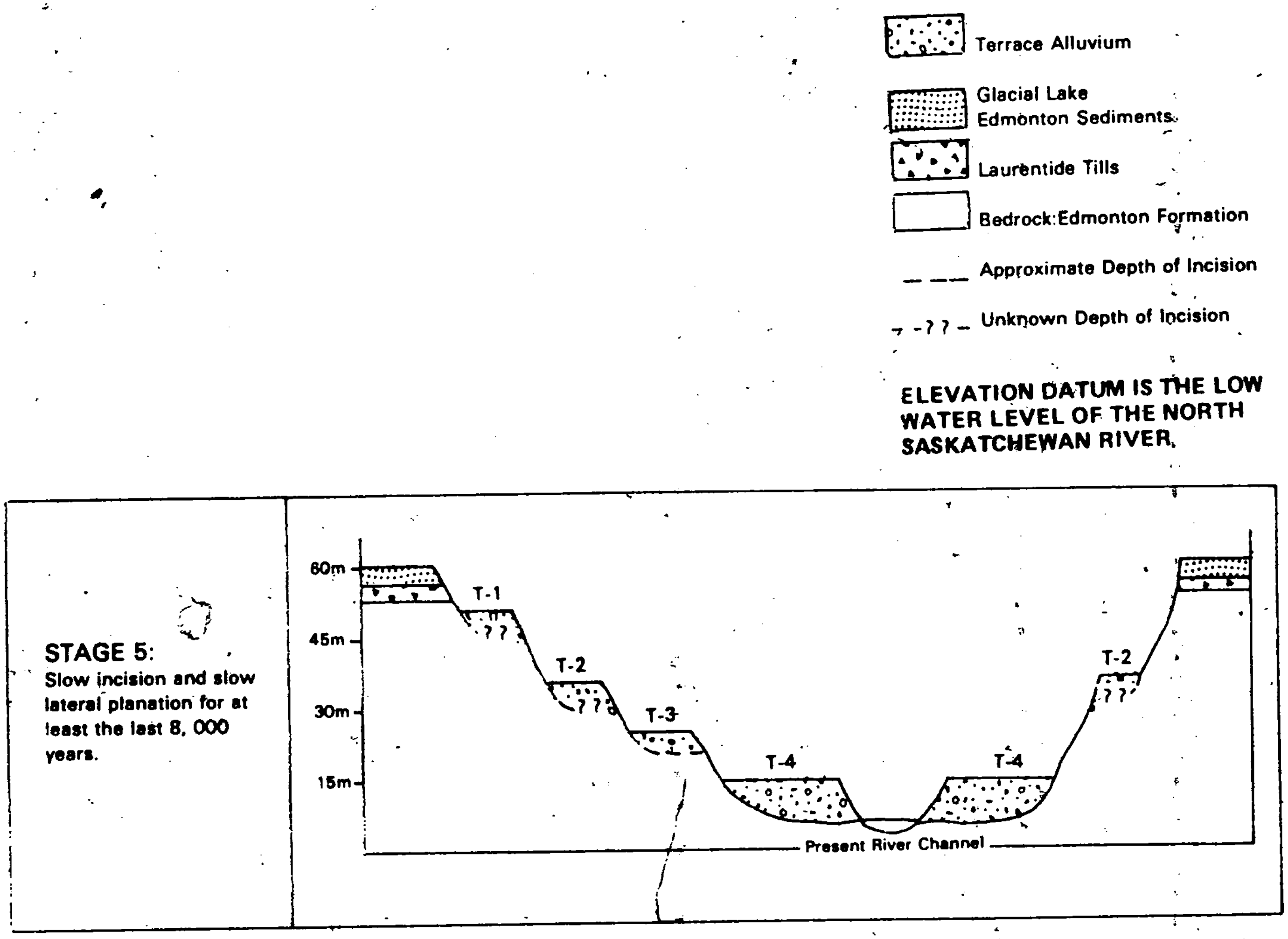


Figure 2.5c. Proposed stages of North Saskatchewan River valley evolution, Edmonton.

Figure 2.5a, Stage 1, illustrates St-Onge's (1972) proposed sequence of deglaciation and proglacial lake development for the Edmonton area. The approximate date of 12,500 years B.P., (Phase 5) was not suggested by St-Onge (1972) but is extrapolated from the study of Christiansen (1979). That study includes a relatively comprehensive deglaciation chronology for successive, late Quaternary, ice frontal positions in Saskatchewan. In combined Phase 4 the Laurentide ice front lay directly east of the Edmonton city area. A large, ice-dammed, proglacial lake, termed Glacial Lake Edmonton by Bayrock and Hughes (1962), extended westward from the ice sheet margin inundating the Edmonton and surrounding areas. During combined phase 5 the ice front lay approximately 50 km northeast of Edmonton, and the Edmonton area was still inundated by a proglacial lake. Discharges through the Gywnne spillway (Bayrock and Hughes, 1962) and the Battle River system, were conducted to Glacial Lake Saskatchewan forming in central Saskatchewan at approximately 12,500 years B.P., (Christiansen, 1979).

Stage 2

Stage 2 (Figure 2.5a) relates combined deglaciation phase 6 with an earliest approximate date of 12,000 years B.P., (Christiansen, 1979). This stage entails the progressive exposure of the initial surface of the Edmonton area as the level of Glacial Lake Edmonton dropped, and drainage through the Gwynne outlet to the southeast ceased.

The Laurentide ice front still lay about 50 km to the northeast, with the smaller, proglacial Lake Bruderheim (St-Onge, 1972) extending west to about the eastern outskirts of the present Edmonton city area. At some time during this stage the early post glacial development of the North Saskatchewan River valley began in the Edmonton area.

It should be mentioned that the initial post glacial valley incision did not utilize a major topographic "low" in the area, the preglacial Beverly valley depression (Carlson, 1967), which lay directly to the north. It has been suggested by Thomson and Townsend (1978) that the original channel incision began its development as an ice marginal stream. If this is correct the ice marginal stream would have been subsequently indundated by the Glacial Lake Edmonton transgression. Following drainage of the lake the channel must have reinhabited the suggested, earlier, ice marginal route.

Alternatively, it may be proposed that the preglacial valley depression to the north was effective in maintaining a mass of stagnant ice during this phase of glacial retreat. The stagnant ice would have required a protective veneer of till, and associated debris, to have survived dissolution throughout the life of the proglacial lake. Observations on the character of glacigenic sediments at Villeneuve (Shaw, 1982) support this idea. The stagnant ice, with such a debris veneer, may well have temporarily existed as a topographic "high" immediately following the lake drainage, thus forcing the developing North Saskatchewan River to cut its established route.

The early incision of the North Saskatchewan River was in the order of 6-9 m below the plains surface. This degradation probably would have have taken place quite quickly in the weak, poorly consolidated surficial deposits of glaciolacustrine sediments and tills. The relatively small depth of incision, and nature of the T-1 alluvium revealed at the Parliament Building site, suggest that the oldest terrace deposits were formed by braided river processes, perhaps linked with deltaic sedimentation further eastward into the reduced glacial lake. Bayrock and Hughes (1962) and St-Onge (1972) identified deltaic sediments associated with late stages of Glacial Lake Edmonton. This type of deltaic sedimentation would have been complex because of large but variable sediment loads, marked seasonal fluctuations of discharge, and the probability of rapidly fluctuating proglacial lake levels. The deposition of the dated bone material in T-1 alluvium about this time suggests that the initial valley incision, and deltaic sedimentation, probably occurred in the range of 10,200 to 11,200 years B.P., or slightly earlier.

Stage 3

Stage 3 (Figure 2.5b) appears to have been initiated with the final drainage of proglacial Lake Bruderheim (Bayrock and Hughes, 1962; St-Onge, 1972) through the newly opened-up depression north of Bruderheim. This was followed by river channel incision and subsequent alluvial aggradation forming the T-2 floodplain. The combined phase 7 of St-Onge (1972) and Christiansen (1979) saw the North Saskatchewan River establish a new route from Edmonton to proglacial Lake Saskatchewan in central Saskatchewan. In the Edmonton area the initial reaction of the North Saskatchewan River, to the drop in base-level accompanying the dissolution of the proglacial lake, would have been rapid incision. It is estimated that the depth of incision was approximately 15 m below the tread surface of T-1. The development of T-2 is marked by only a small number of terrace remnants so far identified in the valley of the Edmonton area (Figure 2.1a). The related exposures of T-2 alluvium, discussed earlier, show characteristics which suggest that, following the second main episode of incision, the river temporarily attained a rapidly aggrading, high-energy, possibly braided regime. If incision to the base of T-2 alluvium came partly in response to the new base-level of Glacial Lake Saskatchewan (perhaps combined with the effects of isostatic uplift) the estimate of 15 m of incision is not unrealistic. No dates are yet available for T-2 alluvium, but the approximate age of this terrace is estimated between 9,000 and 10,000 years B.P..

<u>Stage 4</u>

The subsequent river incision into the T-2 surface (Figure 2.5b), and then aggradation of T-3 alluvium, cannot be confidently related to specific causal factors. Speculations will thus be avoided until such time as further radiocarbon dates are obtained from the T-3 deposits. The date of 10,700 ± 150 yrs. B.P., (I-4553) reported for the alluvium of T-3 by Westgate et al., (1976) is anomalous. The recently obtained date of 10,740 ± 470 yrs. B.P., (S-1923) for T-1 alluvium (Table 2.2) indicates that the T-3 bone material dated by Westgate et al., (1976) was almost certainly re-deposited and is unlikely to be contemporaneous with T-3 alluvial deposition.

The nature of T-3 alluvium suggests that by this stage of valley development the river behavior differed appreciably from that prevailing during T-1 and T-2 alluvial sedimentation. The sequence of T-3 alluvium, consisting of basal gravels, then point bar sands capped with overbank fines, reflects a sinuous or meandering channel undergoing lateral accretion, with the predominant accumulation of point bar and overbank sediments. The older alluvial sediments of T-1 and T-2 appear to have been deposited under circumstances of more pronounced bed-load sedimentation, typical of braided or quasi-braided rivers.

Stage 5

The latest stage of valley evolution began with incision below the floodplain level associated with T-3 aggradation (Figure 2.5c). The radiocarbon dates from organic materials in T-4 alluvium (Table 2.2) suggest that this incision must have been completed before about 8,000 years B.P.. This latest incision episode corresponds chronologically with the near-final stages of Laurentide deglaciation far to the north-east, although direct causal links cannot be proven. For example, it has been suggested that Glacial Lake Agassiz, in its northerly late stages, existed until approximately 8,000 years B.P., (Teller, 1976). Whether the factor of related base-level depressions, for increasingly remote downstream zones, was important for local valley development is quite debatable.

The stage 5 time-span embraces much of the Holocene epoch and thus it is clear that the greater proportion of North Saskatchewan River valley incision in the Edmonton area occurred during early Holocene time. Comparatively slow lateral migration has been the predominant acitivity of the river during the past 8,000 years. Insignificant incision (at most up to three meters) has taken place below the bedrock/alluvial gravel contact of T-1 during that time-span.

The following major points summarize this section on the North Saskatchewan River valley;

(1) Remnants of four terraces exist in the Edmonton area.

(2) The alluvial sediment characteristics appear to show that the river has evolved from an earlier bed-load

dominated type towards a suspended-load dominated form. (3) The T-1 date of 10,740 ± 470 yrs. B.P., (S-1923), and the broad span of dates from exposures of T-4 alluvium, show that much of the total valley incision took place in early Holocene time.

2.3 Whitemud and Weed Creek Valleys

2.3.1 Relationship to the Strawberry Creek Valley

The Whitemud, Weed and Strawberry Creeks are southern tributaries of the North Saskatchewan River in the vicinity, or to the west, of Edmonton (Figure 1.1). The three basins are located in close proximity to each other, are of similar size and exhibit comparable basin relief. These superficial factors contribute to the proposed similarity of their Holocene geomorphic development. They have presumably adjusted to common bio-climatic changes effecting long-term stream discharges and sediment supplies. Also, the three basins have largely developed on Upper Cretaceous bedrock with a variable but comparable veneer of Quaternary sediments. In short, it is suggested that the major, post glacial, geomorphic phases (especially channel aggradation and degradation) were probably time-synchronous for the three tributary basins.

Shelford (1975) proposed that the evolution of the Weed Creek basin closely paralleled that of Whitemud Creek basin

(Rains, 1969a). Chapter 5 of the present study will show conclusively that the Strawberry, Whitemud, and Weed Creek basins exhibit strong morphological similarities, and that they have probably evolved in a time-synchronous manner. Because the terrace terminology employed in the studies of Rains (1969a) and Shelford (1975) is not entirely consistent Table 2.3 should be referred to for clarification.

2.3.2 Whitemud Creek Valley

Rains (1969a) studied the morphometric, interfluve, valley and channel characteristics of the Whitemud Creek basin. As part of that study he mapped the remnant alluvial terraces, described the alluvial terrace stratigraphies and plotted terrace heights above the present channel profile of the creek. He concluded that since deglaciation there have been at least three, and probably four, phases of incision/aggradation resulting in three remnant, cut and fill, paired alluvial terrace suites. Two older remnants of an unpaired,("high level") T-1 were found preserved in the downstream reaches of the valley. These were thought to probably represent the first incision/aggradation phase following the initial drainage basin development. Numerous paired terrace remnants of T-2, T-3 and T-4 were identified. Towards the lower end of the basin, to about the Blackmud Creek confluence, the terrace treads have approximate elevations of 16 m (T-1), 12 m (T-2), 6 m (T-3) and 3 m (T-4) above the contemporary channel. Rains (1969a)

TABLE 2.3. COMPARISON OF THE STRAWBERRY, WHITEMUD, AND WEED CREEKS TERRACE TERMINOLOGY AND HEIGHTS[1].

Strawberry Creek Basin (this study)		Whitemud Creek Basin (Rains, 1969a)		Weed Creek Basin (Shelford, 1975)	
Terrace	Height	Terrace	Height	Terrace	Height
T-1	20-22 m	High-level Terrace	15 m	Highest Terrace	20-22 m
T-2	12-14.5 m	Upper Terrace	12 m	Upper Terrace	13-16 m
T-3	6- 8 m	Middle Terrace	4.5 m	Middle Terrace	9-11 m
T-4	3- 4.5 m	Lowest Terrace	3 m	Lowest Terrace	3- 6 m

[1] Height range above present low water surface.

correlated the Whitemud Creek terraces with the four-fold, North Saskatchewan River valley suite identified by Westgate (1969). This extrapolation was considered by Rains (1969a, p.213) to be tentative because "a more definitive assessment of the local geomorphic history awaits detailed geochronological work on the higher terraces". Related evidence, in Chapter 6 of the present study, will show that this tentative extrapolation now must be abandoned.

2.3.3 Weed Creek Valley

Shelford (1975) identified four, paired, cut and fill terraces preserved in the Weed Creek valley. His study confirmed the paired existence of T-1, which was only represented by two remnants in the Whitemud Creek valley. Shelford (1975) identified relative tread heights above the present channel as 20-22 m (T-1), 13-16 m (T-2), 9-11 m (T-3) and 3-6 m (T-4), and stressed the very close similarity to Whitemud Creek terrace heights.

2.4 Summary

The objectives of this chapter have been three-fold. First was the necessary review of prior studies regarding the Holocene development of the North Saskatchewan River valley in the Edmonton area. Second, an outline of recent work in the same valley sector has led to a revision of morphological and chronological interpretations of the valley development. This is of importance for analyses of its local tributaries, which include Strawberry Creek. Finally, previous works on the Whitemud (Rains, 1969a) and Weed (Shelford, 1975) Creeks were outlined in terms of their relationship to the Strawberry Creek. All of the above has been presented as an introduction to the regional Holocene valley development relevant to the Strawberry Creek. The remaining chapters focus particularly on the Strawberry Creek basin, beginning with the bedrock foundation upon which the basin has evolved.

3 STRAWBERRY CREEK BASIN: BEDROCK GEOLOGY

3.1 Introduction

The main aims of this chapter are to review the recently revised stratigraphic nomenclature of the late Cretaceous and Tertiary rocks, and their general characteristics, which outcrop in the study basin. The Strawberry Creek basin is geologically interesting in that it includes exposures of the Kneehills Tuff stratigraphic marker, economically important coal seams and units which span the Cretaceous Tertiary stratigraphic boundary. The underlying bedrock was also of some importance in the Quaternary geomorphic development of the study area because the preglacial topography partly influenced the types and accumulation of preglacial, Pleistocene and Holocene surficial sediments. The bedrock units are of varied lithologies, contrasted induration and differ in their resistance to erosion. Thus the present morphology of the drainage basin, and particularly the form of the main valleys are partly influenced by bedrock characteristics.

3.2 Previous Studies, Central Alberta

The central plains of Alberta are underlain by a gently westward dipping succession of sedimentary strata of Cretaceous and Tertiary ages. The boundaries and nomenclature of these strata have been subdivided and revised by a number of researchers. Allan and Sanderson (1945) established the first significant nomenclature and stratigraphic boundaries for the central Alberta Plains (Table 3.1). They proposed a three-fold division of Upper Cretaceous strata of the Edmonton Formation (a term first used by Selwyn, 1874). The Bearpaw Formation, consisting largely of dark marine shales and sandstones, was defined as the base of the Edmonton Formation. The Drumheller marine tongue and the Kneehills Tuff zone were used as stratigraphic markers separating the lower, middle and upper members of the Edmonton Formation. The base of the Tertiary Paskapoo Formation (a term first used by Tyrrell, 1887) was demarcated above the coal-bearing strata of the upper Edmonton Member and at the base of a coarse grained, massive sandstone. Allan and Sanderson (1945) postulated an erosional, unconformable, contact between the Edmonton and Paskapoo Formations, and suggested this as the Cretaceous-Tertiary boundary.

Ower (1960) subdivided the Edmonton Formation of central Alberta into five members on the basis of lithology (Table 3.1). He elevated to member status the Kneehills Tuff, and its associated bentonitic shale and bentonitic white sandstone at the base (Member D). He also subdivided Allan and Sanderson's (1945) lower and middle Edmonton Formation into three members, with Member B including the Drumheller marine tongue. Members A, B and C were distinguished by the presence or absence of coal seams and

TABLE 3.1. MAJOR BEDROCK FORMATIONS.

ALLAN & SANDERSON (1945)	OWER (1960)	IRISH (1970)	GIBSON (1977)	
PASKAPOO	PASKAPOO	PASKAPOO FORMATION	PASKAPOO FORMATION	TERTIARY
EDMONTON FORMATION	EDMONTON FORMATION	EDMONTON GROUP	EDMONTON GROUP	UPPER CRETACEOUS
UPPER EDMONTON	MEMBER E	SCOLLARD MEMBER	SCOLLARD FORMATION	
Knh tuff	MEMBER D	BATTLE FORMATION WHITEMUD FORMATION	BATTLE FORMATION WHITEMUD FORMATION	
MIDDLE EDMONTON MEMBER	MEMBER C	HORSESHOE CANYON FORMATION	HORSESHOE CANYON FORMATION	
	MEMBER B			
Drumheller Marine Tongue				
LOWER EDMONTON MEMBER	MEMBER A			
BEARPAW FORMATION				

carbonaceous material. Ower (1960) arbitrarily placed the Edmonton-Paskapoo contact at the base of a coal-free sandstone above the Ardley coal seam of Member E. This contact is similar to that proposed by Allan and Sanderson (1945). However, Ower (1960) disagreed with Allan and Sanderson's (1945) interpretation of an erosional unconformity between the Edmonton and Paskapoo formations. He suggested that continual sedimentation characterized Edmonton-Paskapoo time, with only local erosion occurring as the result of stream channel processes.

Irish (1970) substantially revised the previous subdivisions and nomenclature of Upper Cretaceous and Tertiary strata and stated that earlier work had been based on lithologic differences of beds which lacked widespread marker zones. Therefore, he considered these useful only for local correlations. Irish (1970) employed the stratigraphically continuous, lithologically homogeneous, and time-synchronous Kneehills Tuff, and its associated deposits, as a reliable and widespread marker throughout the central plains of Alberta. He identified the Paskapoo-Edmonton contact as directly overlying these deposits.

Furthermore, Irish (1970) re-defined the Edmonton Formation as the Edmonton Group and subdivided the Edmonton Group into three formations (Table 3.1). His Horseshoe Canyon Formation included Ower's (1960) Members A, B and C. Irish (1970) subdivided Ower's (1960) Member D into the

Whitemud Formation and the Battle Formation. Strata above the Battle Formation were assigned to the Paskapoo Formation, with a Scollard Member including all strata between the top of the Battle Formation and the stratigraphically highest coal seam (this included most of Ower's, 1960, Member E).

Gibson (1977) incorporated the subdivisions and nomenclature proposed by Irish (1970) but re-defined the Paskapoo-Edmonton boundary as the top of the former Scollard Member. He raised the Scollard Member to formational rank within the Edmonton Group. Gibson (1977) agreed with Irish (1970) that the Paskapoo-Edmonton boundary is difficult to delimit because of similarities of sandstones and inconsistencies of coal seams in field sections. He stated, however, that "this does not warrant lowering the long established lithologic and biostratigraphic contact between the Paskapoo and Edmonton Formation to the top of the Battle Formation..."(Gibson, 1977, p.3). The lithostratigraphic subdivision and nomenclature proposed by Gibson (1977) is used here to define the bedrock geology of the Strawberry Creek basin. Additional information on Upper Cretaceous and Tertiary strata of the central Alberta plains may be found in Elliott (1960), Campbell (1962), Campbell and Almadi (1964), Taylor et al., (1964), Williams and Burk (1964), Srivastava (1965, 1970), Irish and Havard (1968), Carrigy (1970, 1971) and Douglas et al., (1976).

3.3 Bedrock Geology, Strawberry Creek Basin

The general bedrock geology outcrop pattern (Figure 3.1) and a diagrammatic cross-section (Figure 3.2) have been constructed using data from Ritchie (1957), Pearson (1959, 1960), Ower (1960), Carrigy (1971), Ozaray (1972), Steiner et al., (1972) and Holter et al., (1975). The following are brief descriptions of the formations (from oldest to youngest) and interpretations of their significance, following the work of Irish (1970) and Gibson (1977).

3.3.1 Horseshoe Canyon Formation

The upper part of the Horseshoe Canyon Formation outcrops along the Strawberry Creek valley walls in the extreme northeastern part of the basin. The formation consists of an interbedded sequence of sandstone, siltstone, shale and clay ironstone, with several coal seams. Sandstone, the most common rock type of the formation, is poorly indurated when associated with a high montmorillonite content and is well indurated where crystalline calcite forms the predominant cement. The sandstones represent fluvial and deltaic deposits of interbedded and lenticular facies.

Underlying the Horseshoe Canyon Formation but not outcropping in the Strawberry Creek basin, is the Bearpaw Formation, consisting of marine bentonitic shale. At Lethbridge, Alberta, the Bearpaw bentonite No. 1 has yielded a K-Ar date of 75 m.y. and the top of the formation is about

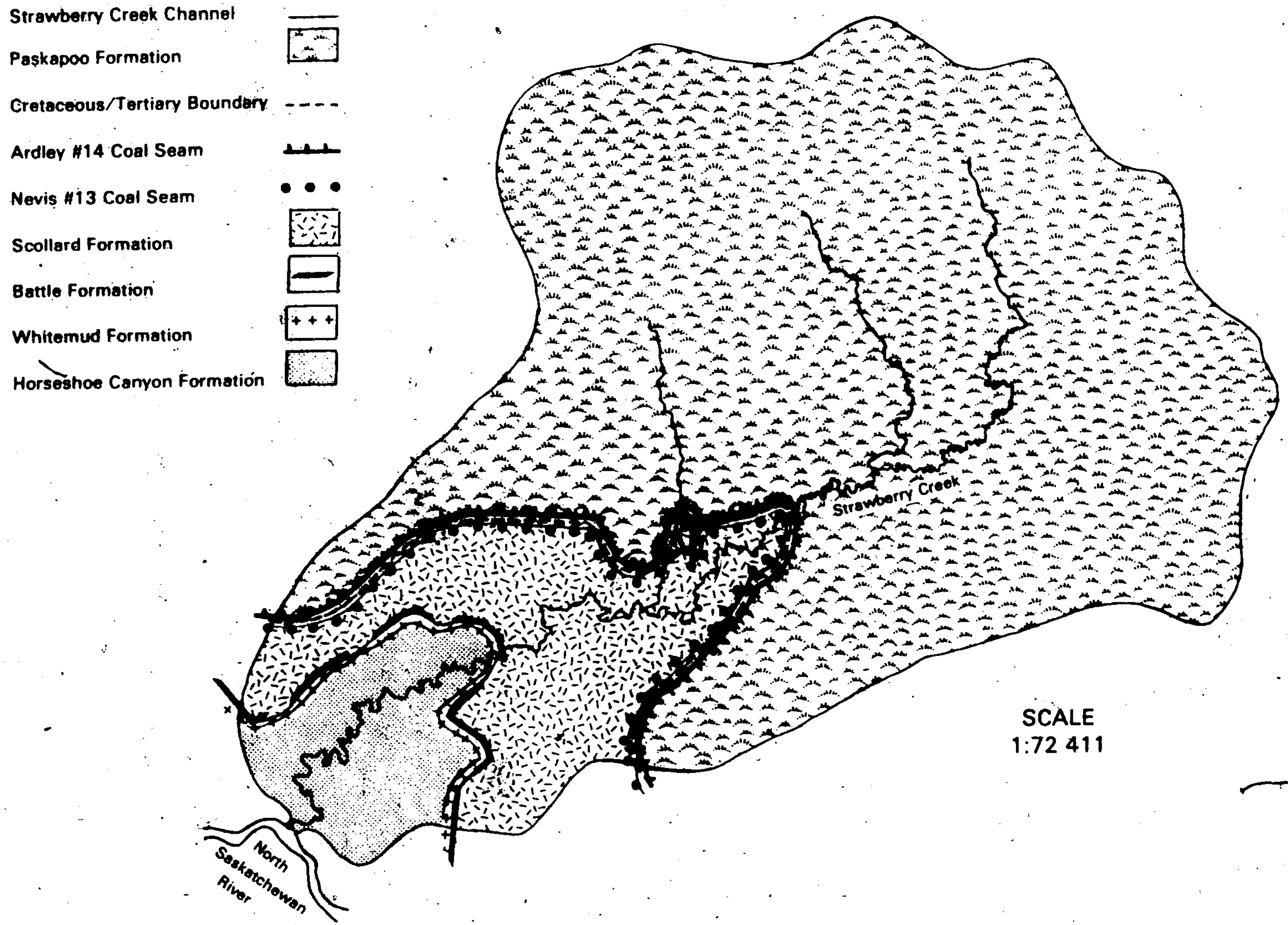


Figure 3.1. Bedrock geology of the Strawberry Creek basin.

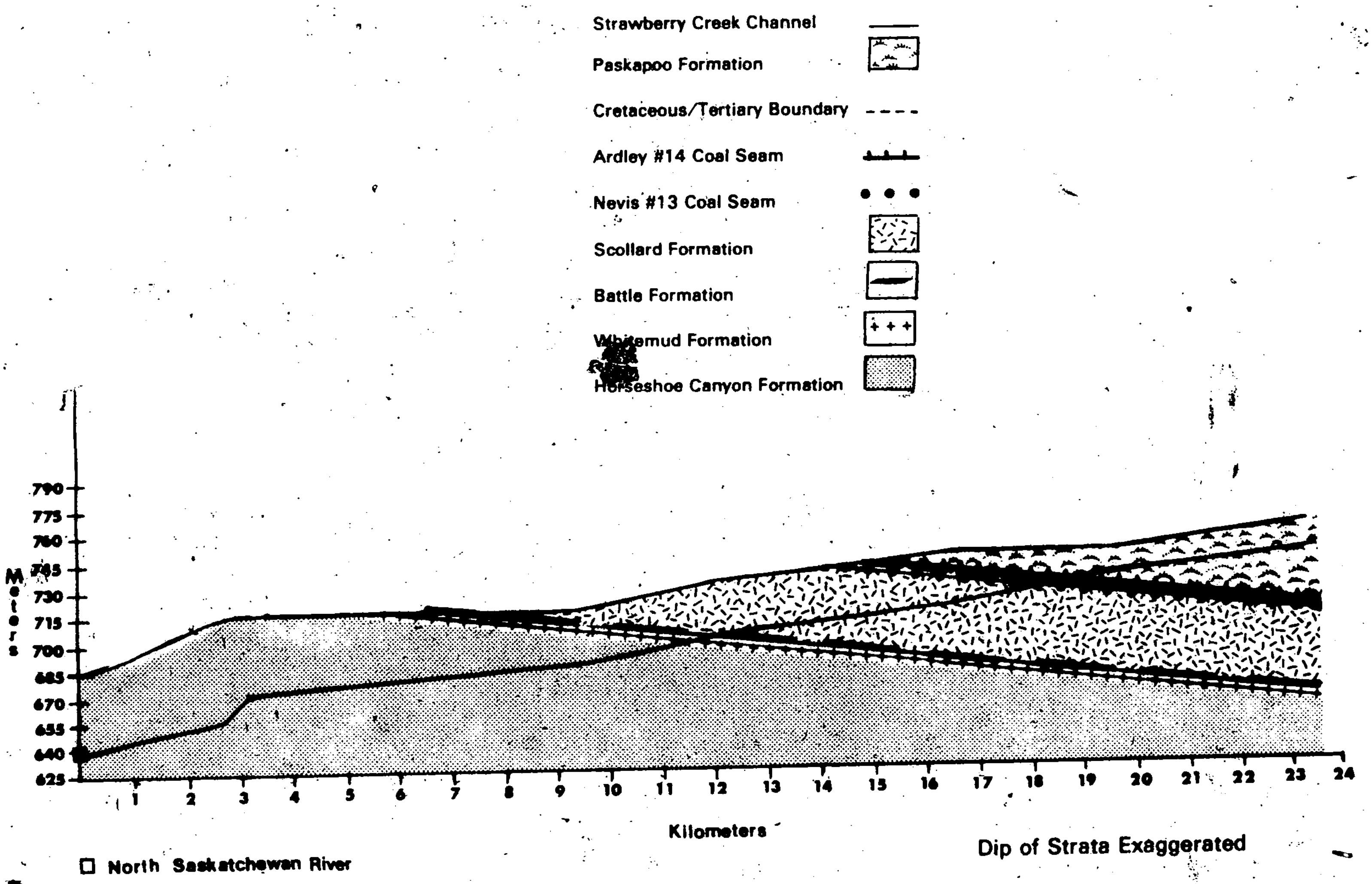


Figure 3.2. Diagrammatic geologic cross-section, Strawberry Creek basin.

68 m.y. old (Folinsbee et al., 1961).

3.3.2 Whitemud Formation

The Whitemud Formation is a relatively thin (2-6 m), white weathering, light grey and light greenish grey, clayey siltstone and sandstone. Extremely argillaceous sandstone predominates. This may be visually distinguished from the underlying Horseshoe Canyon sandstones by its lighter color and its consistent stratigraphic occurrence directly beneath the Battle Formation. Binda and Lerbekmo (1973), on the basis of grain size analyses and interpretation of microflora (Binda, 1970), interpreted the depositional environment of the Whitemud Formation as "continental fluviatile". Furthermore, Binda and Lerberkmo (1973) state that the "Whitemud sandstones" are of variable thickness, up to at least 30 m. Binda (1970) identified specific outcrops of the Whitemud Formation in the Strawberry Creek basin at Sec. 5, TWP 50, R2 W5.

3.3.3 Battle Formation

The Battle Formation, and its associated volcanic tuff, are easily recognized in outcrops and on electric logs from drilled wells. The ease of recognition, related to its stratigraphic, lithologic and chronologic continuity, coupled with its widespread occurrence, make the Battle Formation a most important marker-zone for surface and subsurface correlation.

The Battle Formation consists of a relatively thin (3-10 m) sequence of mauve-grey weathering, dark brownish grey to purplish black, bentonitic claystone or mudstone. Srivastava (1968) and Binda and Lerbekmo (1973, p.73) suggested a continental "lacustrine to swampy" depositional environment for the Battle Formation. Previously, Elliott (1960) and Russell and Chamney (1967) suggested that the formation is part of a marine succession. Volcanic tuff occurs within the Battle Formation and was named the Kneehills Tuff by Sanderson (1931). The tuff normally occurs in the upper part of the Battle Formation as a single bed (12-25 cm thick) or may occur as two to four thin beds. The tuff is light grey weathering, well indurated rock containing macroscopic vugs.

Folinsbee et al., (1961) dated, by the K-Ar method, the Kneehills Tuff at 66 m.y.±5% using a bentonite stratigraphically near the tuff, from an outcrop along Strawberry Creek. Shafiquallah (1963) obtained three K-Ar dates for the tuff zone and suggested a mean value of 66 ± 1.4 m.y., thus confirming the tuff's consistent geochronology. Ritchie (1957) and Binda (1969) concluded, on the evidence of heavy-mineral similarities and areal distribution of grain sizes, that the tuff probably originated in association with an Upper Cretaceous extrusive, the Butte Rhyolite, of Montana.

The Kneehills Tuff was observed during the present investigation of the Strawberry Creek valley. Figure 3.3a

Figure 3.3a. Kneehills Tuff of Battle Formation, Strawberry Creek valley.

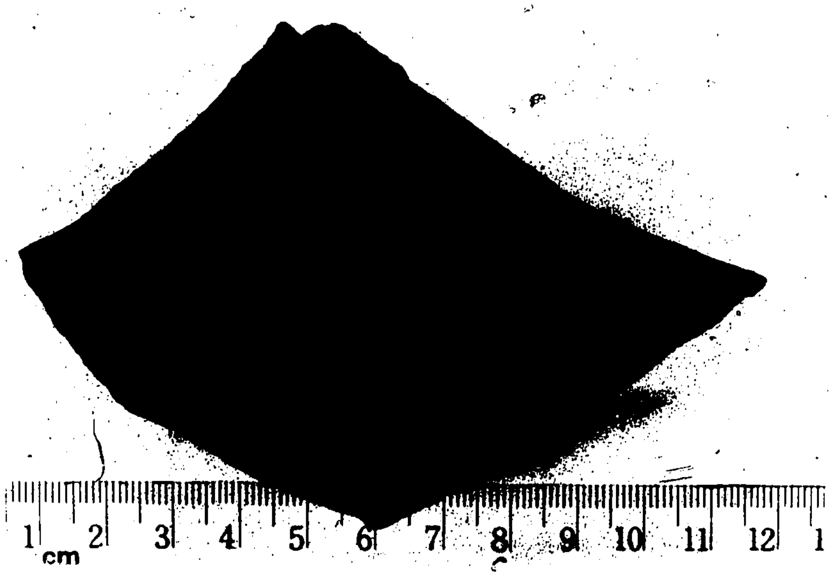


Figure 3.3b Horizontal view of extracted slab of Kneehills Tuff.

shows the tuff bed exposure and a horizontal view of an extracted slab of the tuff is indicated by Figure 3.3b .

The thickness of the Battle Formation at different localities ranges up to 10m and in places even the overlying Cretaceous beds (Scollard Formation) have been removed by erosion (Irish, 1970). Also, at the Strawberry Creek valley section (Figure 3.3) a fossil vertebrate bone fragment was discovered in a relatively large block of horizontally bedded, medium to fine grained, friable sandstone, weathered and eroded presumably from the overlying Scollard Formation. This displaced sandstone block, with the fossil bone, is shown in Figure 3.4. The Strawberry Creek valley location of the south-southeast facing valley wall where the Kneehills Tuff and fossil bone fragment were found is presented on Figure 5.4 (Chapter 5). For further information on the Kneehills Tuff and its associated strata reference may be made to Allan and Sanderson (1945), Byrne (1951), Ritchie (1958, 1960), Elliott (1960), Ower (1960), Campbell (1962) and Binda (1970).

3.3.4 Scollard Formation

The boundaries of the Scollard Formation, as defined by Gibson (1977), include all strata between the top of the Battle Formation and the base of a massive, cliff-forming, sandstone unit (Paskapoo Formation) above the uppermost major coal seam of the Ardley coal zone. Also present are the economically important Nevis (No.13) and Ardley (No.14)

Fig[illegible] [illegible] ne [illegible] lard [illegible] coal seams (as defined by Allan and Sanderson, 1945, and re-adopted by Gibson, 1977). The Ardley seam No. 14, within the Scollard Formation, has been dated by the K-Ar method at 63 m.y. (Shafiqullah et al., 1966). For further references to the coal-bearing strata of the Scollard Formation see Pearson (1959, 1960), Campbell and Almadi (1964), Campbell (1967), Kramer and Mellon (1972), Steiner et al., (1972), Holter et al., (1975), Yurko (1975), and Gibson (1977).

The controversial Cretaceous-Tertiary stratigraphic boundary occurs within the Scollard Formation. A recent study by Russell and Singh (1978), in south-central Alberta placed the Cretaceous-Tertiary boundary at the base of the Ardley (No. 14) coal seam. Their boundary definition was on the basis of dinosaur remains thought to be stratigraphically above the Nevis (No. 13) coal seam. Lerbekmo et al. (1979a) noted that the stratigraphic position of the dinosaur remains reported by Russell and Singh (1978) was incorrectly reported. The more recent investigation concluded that "all in situ dinosaur remains reported so far from Alberta have been found below the Nevi coal seam" (Lerbekmo et al., 1979a, p. 1866). Thus, Lerbekmo et al. (1979a) place the Cretaceous-Tertiary boundary, in south-central Alberta, at the top of the Nevis (No. 13) coal seam. In addition, Lerbekmo et al., (1979b) further define the Cretaceous-Tertiary boundary at the top of the Nevis seam on magneto-stratigraphic evidence. On the basis of eleven K-Ar dates on bentonite near this boundary Lerbekmo et al., (1979b) provide a mean age of 63.1 ± 0.5 m.y. for the Cretaceous-Tertiary boundary. Thus, the boundary has been strongly defined in the northwestern interior of the United States, and southern Alberta, on the basis of many studies recording synchronous changes in the microfloral record (Srivastava, 1968, 1970; Snead, 1969), the palynofloral record (Leffingwell, 1971), the dinosaur record (Lerbekmo et al., 1979a) and magnetostratigraphy (Lerbekmo et al., 1979b).

In Figures 3.1 and 3.2 the Cretaceous-Tertiary boundary, for the Strawberry Creek basin rock sequence, has been stratigraphically designated at the top of the Nevis No. 13 coal seam. The specific occurrence of the Nevis No. 13 coal seam in the Strawberry Creek basin cannot be verified without further detailed investigation. Within the central Alberta, Ardley coal zone, the Nevis No. 13 coal seam is erratically developed and preserved. In places it is distinct and stratigraphically separated from the Ardley No. 14 seam, but in other places it is absent. At some localities it may be combined with the Ardley No. 14 coal seam (Holter et al., 1975). The explanation for this is that the paleoenvironmental conditions reflected by the sedimentary deposits of the Scollard Formation suggest a "complex of broad, swampy flood plains across which easterly and northeasterly flowing drainage systems traversed and at times coalesced" (Holter et al., 1975, p. 23). The Ardley coal zone is being mined in the Strawberry Creek basin, the

Wabamun Lake area (directly northwest), and Wizard Lake area (directly southeast).

3.3.5 Paskapoo Formation

Rocks of the Paskapoo Formation are occasionally exposed at the surface within the Strawberry Creek basin. Locker (1973) described the Paskapoo Formation strata as lenticular beds of sandstone, siltstone and claystone, with massive cliff forming sandstones predominating. The Paskapoo Formation sandstones are generally coarser grained, less bentonitic, more strongly cemented and usually of a darker color than the underlying sandstones of the Edmonton Group. The Paskapoo Formation is considered to be non-coal-bearing in this area, although some poorly developed lignite does occur.

3.4 Bedrock Topography

3.4.1 Bedrock Topography: Central Alberta

The bedrock surface of the central plains of Alberta underwent a denudation cycle (cycles?) probably in the late Oligocene, and generally intense erosion continued through the Miocene and Pliocene into the Pleistocene (Taylor et al., 1964). The bedrock surface was stripped of a large, indeterminate mass (approximately 610 m; Scott and Brooker, 1968) of Tertiary sediments. The amount of modification of the preglacial topography by the Pleistocene glacial stages is not known, but would have been comparatively minor in relation to the cumulative effect of the denudation processes that occurred preglacially. In Alberta, the end product of those denudation processes was a contemporary bedrock surface that exhibits a relatively minor element of Tertiary strata. Consistent outcrops of Tertiary sedimentary rocks occur in Alberta along a northwest - southeast trending line that traverses part of the Strawberry Creek basin (Figure 3.1).

Preglacial valleys and channels deeply incised into bedrock are characteristic of the bedrock surface topography. The preglacial valleys are topographically quite distinctive, and have been mapped in central and southern Alberta by Stalker (1961), Farvolden (1963) and Carlson (1967, 1970), among others. Farvolden (1963) suggested that the main divides and stream channels of the preglacial topography began developing in the mid-Tertiary, Oligocene epoch. The regional drainage pattern depicted by the preglacial valleys suggests that the main drainage systems flowed to the northeast. Residual, unconsolidated, preglacial materials are intermittently preserved, occasionally on southern Alberta uplands and predominantly in preglacially developed valleys, as alluvial fill or terrace deposits. From the discovery of representative mammalian fauna in the preglacial sands and gravels, these deposits are known to partially span the Tertiary period (deposits capping upland areas; Storer, 1979) and Pleistocene epoch (valley fill and terrace deposits; Reimchen, 1968). The distinctive lithologic character, dominated by quartzites, of the preglacial sands and gravels suggests an original provenance to the west, in the Rocky Mountain region.

3.4.2 Bedrock Topography: Strawberry Creek Basin

The bedrock topography of the Wabamun Lake area, including the Strawberry Creek basin, has been mapped by Carlson (1971). This map shows clearly that the basic morphology of the present Strawberry Creek basin has been strongly regulated by the underlying bedrock topography. Bedrock "highs", corresponding with the surface outcrops of the more resistant, Tertiary, Paskapoo Formation sandstones near the southern, western and northern perimeters of the basin, coincide with parts of the contemporary drainage divide. Thus, the topographic "highs" of the post glacial landscape roughly correspond with the underlying preglacial bedrock "highs".

The dominant feature of the basin's bedrock topography is a preglacial valley, called the Warburg valley by Carlson (1970). The preglacial Warburg valley constituted a topographic "low" which the post glacial Strawberry Creek reinhabited, and the contemporary channel exists within the confines of the preglacial valley. The depth of valley incision for the preglacial channel has been surpassed by the modern channel in parts of the Strawberry Creek valley. This is evident from Carlson's (1970) map on which are superimposed the contoured depths of the preglacial and post glacial valleys. This premise is further verified by the fact that preglacial, alluvial sand and gravel deposits were observed in the field at various elevations above the present thalweg. The apparent reason for the different depths of preglacial versus post glacial incision is that the present Strawberry Creek meets with its local base-level, the post glacially positioned North Saskatchewan River valley, some distance south of the preglacial base-level junction. Thus the preglacial valley alluvial deposits occasionally exposed in the present valley reflect an upstream segment of the Warburg valley that met with its local base-level, the Beverly valley, further downstream to the northeast.

3.4.3 Preglacial Valley and Pleistocene Deposition

During the Pleistocene glacial advance, the Strawberry Creek preglacial valley was over-ridden and inundated by the Laurentide ice sheet. The preglacial valley topographic "low" consitituted a sediment trap during the advances and subsequent retreats of the Laurentide ice sheet. Consequently, representative Pleistocene glacial deposits are commonly displayed in the Strawberry Creek valley. During this research exposures of glacial tills, inter-till sands (possibly sandur deposits), structures indicating ice flow direction, and proglacial lacustrine sediments were recognized in the valley. The Strawberry Creek valley, and others influenced by preglacial valleys in the Alberta plains area, are ideal locations for the study of many aspects of Pleistocene, Laurentide, glacial deposits. The general characteristics of these sediments, as exposed in the Strawberry Creek valley, are discussed in Chapter 4 and by Shaw (1982).

3.5 Strawberry Creek Basin Bedrock: Erosion Propensity

The Upper Cretaceous bedrock strata are characteristically poorly indurated, relatively weak, with moderate to excellent propensity for fluvial erosion. Indications of volcanism during this geologic time period are evident in the Upper Cretaceous strata as distinct bentonite seams, bentonitic rock, and a high montmorillonite clay content of the strata. The bentonitic and montmorillonite clays of the strata readily react with water and thus greatly increase the erosive potential of the material. Geomorphic examples reflecting the bedrock weakness and instability are the slumping and landslide activities which occur along the North Saskatchewan River valley. In the Edmonton area this presents a major problem for construction and preventative measures are required to stabilize the valley walls (Thomson, 1970; Thomson and Yacyshyn, 1977). In the Strawberry Creek valley bedrock slumping is quite evident. Field work carried out in the spring was hindered by this mass movment activity.

3.6 Summary

In summary, several important points need to be emphasized:

(1) The bedrock strata of the Strawberry Creek basin span parts of the Cretaceous-Tertiary periods.

(2) An important marker-bed, the Kneehills Tuff, is displayed in the valley.

(3) Bedrock topography played an important role in the development of the basin's morphology.

(4) Strawberry Creek has partly reinhabited a preglacial valley.

(5) The creek has incised into sequences of unconsolidated glacial deposits and poorly indurated bedrock.

(6) Bedrock has not been a major obstacle to valley development, insofar as the strata are only weakly resistant to fluvial erosion and mass movement processes.

4. STRAWBERRY CREEK BASIN; PRE-HOLOCENE SURFICIAL DEPOSITS

4.1 Introduction

The aim of this chapter is to present brief descriptions of pre-Holocene surficial deposits observed in the Strawberry Creek valley. Pre-Holocene deposits are displayed intermittently throughout the valley and include an assemblage of preglacial gravels and sands, glacial tills, inter-till sands and glaciolacustrine sediments. Figure 4.1 is a diagrammatic cross-section showing the general stratigraphic relationships of these pre-Holocene deposits. The sediments will be discussed separately in chronological order. Included will be a short review of some earlier, relevant studies, and descriptions of representative exposures observed during field work.

4.2 Preglacial Gravels and Sands

Preglacial valleys of the Canadian prairie provinces often contain remnant channel fill and other alluvial deposits along their courses (see, for example, Farvolden, 1963 and Carlson, 1967). In central and southern Alberta these alluvial sediments were deposited by preglacial, generally eastward-flowing, drainage systems arising in the western Cordillera (Green and Laycock, 1967, p.72). In addition to valley fill deposits sediments of similar provenance may occur preserved as isolated caps on upland

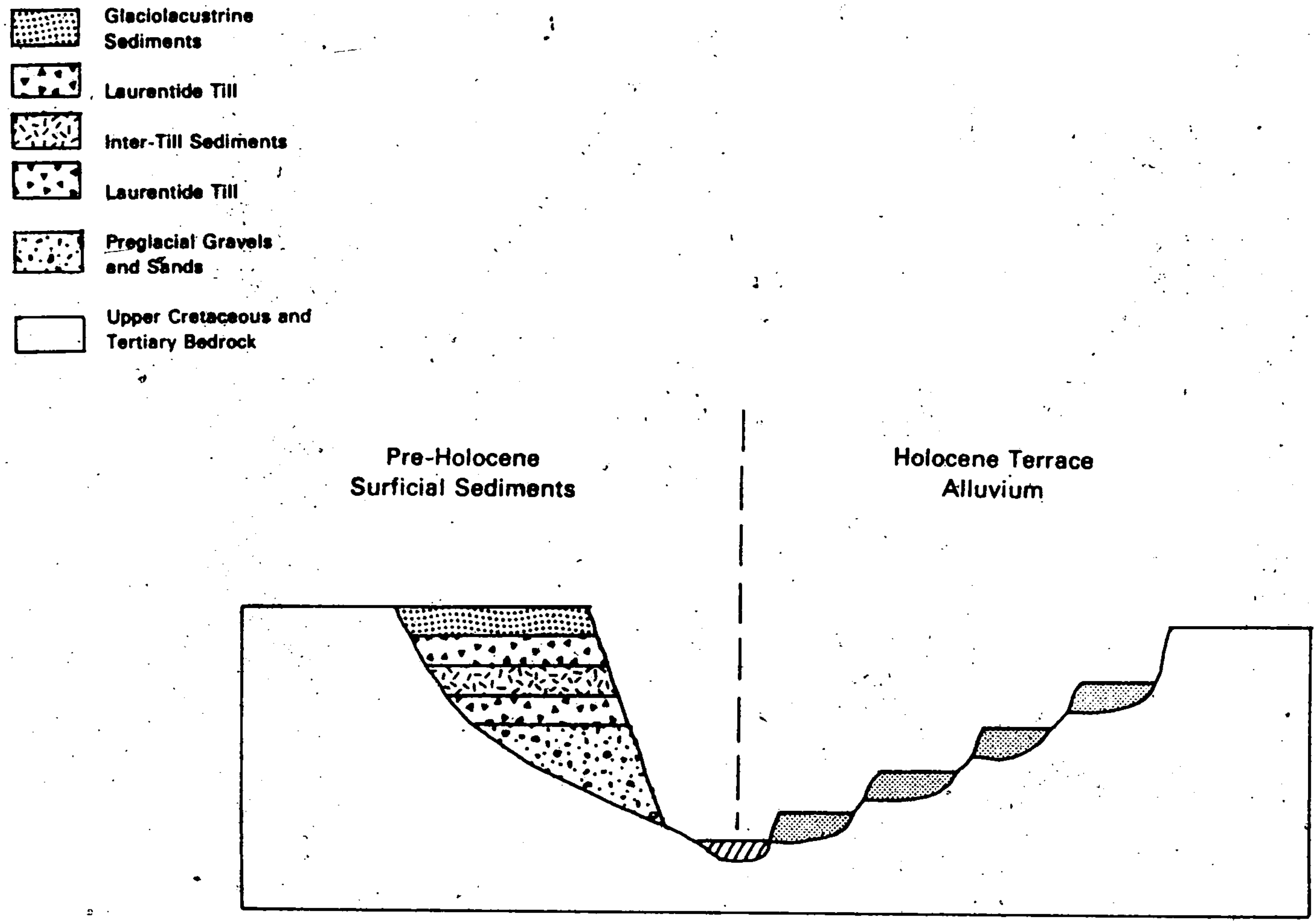


Figure 4.1. Diagrammatic cross-section of pre-Holocene surficial deposits, Strawberry Creek basin.

areas. These upland materials almost certainly predate the alluvial deposition in the preglacial valleys. Preglacial gravels and sands are distinguished lithologically by exhibiting mixtures of Cordilleran and plains materials, but without clasts derived from the Precambrian Canadian Shield rocks. Stratigraphically the alluvial deposits usually occur unconformably atop bedrock and they commonly lie beneath Pleistocene glacial sediments or Holocene alluvial deposits. These preglacial deposits range in age from the late Tertiary until deposition was interrupted by continental glaciation during the Pleistocene.

Preglacial gravels and sands of the western prairies have been described in numerous earth science studies. Early recognition of these sediments was by McConnell (1885), Tyrrell (1887) and Rutherford (1937). The designation of surficial gravels and sands as "preglacial, glacial or post glacial" is essential for accurate interpretations of Quaternary stratigraphy in the central plains. Stalker (1968) advises investigators to be cautious in making classifications of preglacial gravels and sands. Principally, Stalker (1968) refers to a particular sequence of preglacial deposits known as "Saskatchewan Gravels and Sands", a term introduced and qualified by Rutherford (1937). In an attempt to resolve mis-identifications and imprecise classifications Stalker (1968, p.155) recommends that the term "Saskatchewan Gravels and Sands" be restricted ... " solely to the last series of deposits laid down by preglacial rivers before the Quaternary glaciations disrupted the drainage". Furthermore, Stalker (1968) presents eight criteria that should be met before the classification of sediments as "Saskatchewan Gravels and Sands" is certain. These criteria will not be repeated here.

As discussed in Chapter 3, the post glacial Strawberry Creek partially re-inhabited the preglacial Warburg valley depression. A number of exposures in the contemporary valley exhibit masses of preglacial gravels and sands of the former Warburg valley drainage system. The detailed recognition of "Saskatchewan Gravels and Sands" in particular was not undertaken for this study as their precise classifications are peripheral to the emphasis of the thesis. For this reason the sediments are simply referred to as "preglacial gravels and sands". In Chapter 5 generalized sections of Holocene terrace alluvium, logged throughout the Strawberry Creek valley, are presented in Figures 5.19 to 5.22. Several of these sections were found to have preglacial gravels and sands underlying Holocene sediments (sections; 33, 39, 43, 45 and 75).

Figure 4.2, (section 45), exhibits a representative exposure of preglacial gravels and sands in the Strawberry Creek valley. This section consists of approximately 8m of bedrock, approximately 6m of preglacial alluvial deposits, which are commonly capped by up to 3m of post glacial terrace alluvium (T-1). A general view of this section is presented in Figure 4.2a. The base of the Holocene T-1

Figure 4.2a. General view of T-1 section 45 with underlying preglacial deposits.

Figure 4.2b. Contact of T-1 alluvial gravels with underlying preglacial deposits.

Figure 4.2c. Till lens of section 45

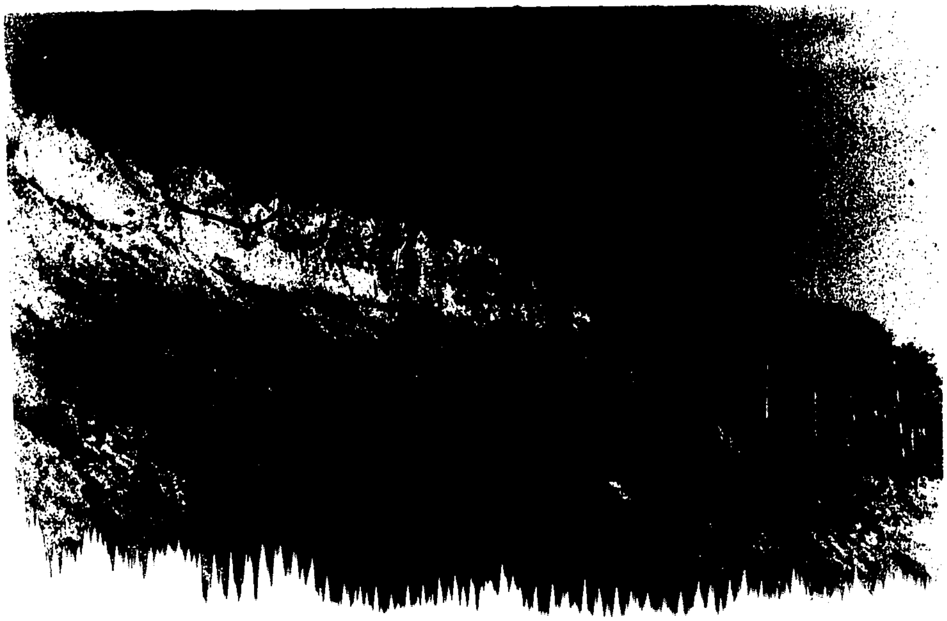
alluvial sequence is outlined by the lateral extensiveness of the associated basal gravels, generally paralleling the well defined terrace tread. Figure 4.2b displays the sharp contact of the T-1 alluvial gravels with the underlying preglacial deposits. The preglacial deposits consist predominantly of well bedded sand occasionally grading to gravel size material. The common planar bedding with an occasional bed truncation, of these preglacial deposits is evident on Figure 4.2b. At one site of this section an irregular shaped lens of Laurentide till, up to 1m thick was found between the preglacial deposits and the Holocene terrace alluvial gravels. Figure 4.2c exhibits this particular site (specific location encircled on Figure 4.2a) which displays the basal gravels of T-1 underlain by glacial till with planar bedded preglacial alluvial deposits evident in the lower right corner. Deposition of the glacial till would have occurred as the advancing Pleistocene ice sheet progressed over the preglacial valley. Subsequent Holocene degradation of the Strawberry Creek to the T-1 level presents an erosional contact between the Holocene alluvial gravels and both the till and preglacial deposits.

4.3 Laurentide Tills

The glacial stratigraphy of central Alberta has been examined in various studies (for a review see Westgate 1969), with more recent emphasis in the Edmonton area (

prevailing issue has been the accurate distinction of, and correlation between, till units and their representation of discrete Laurentide glacial advances. Contemporary agreement appears to be that two distinctive till units exist in the Edmonton area (for example see [illegible], 1969b; Ramsden and Westgate, 1971; Westgate et al., [illegible]; Shaw, [illegible]). The lower till is usually found overlying bedrock or preglacial gravels and sands. The two till units often [illegible] each other but are occasionally separated by stratified sands. Normally the two till units may be distinguished on the basis of differences in color, texture, structure and a well defined contact between the tills. The lower till grey, relatively clay rich and has fewer coarse clasts the upper till. The latter unit is commonly light brown with a sandier matrix and is generally richer in coarse clasts. The occurrence of three till units in numerous localities complicates this simplistic sequence.

In the Strawberry Creek basin a number of sections of tills were observed, the best exposures occurring along the the valley rim. In many of these exposures two till units could be identified on the basis of the general criteria mentioned earlier for till in the Edmonton area. Figure 4 is a general view of a representative valley rim exposure that demonstrates a generalized distinction of two, distinct, till units defined on the basis of the clear contact between the units plus their different structural and color characteristics. The [illegible]



[illegible]

COLOURED PICTURES
Images en couleur

4.3 slopes sharply to a T-1 remnant (section 12) visible to the right, just downstream. The location of the valley rim exposure and T-1 (section 12) exhibited on Figure 4.3 is presented on Figure 5.3 (Chapter 5).

Till fabric analysis of the preferred orientations of elongated clasts within tills is one procedure for determining their distinctiveness. In many instances till fabric analysis may provide strong indications of associated glacier flow directions. Ramsden and Westgate (1971) present a detailed report on the two till units in the Edmonton area and their interpretations of fabric data. They suggest that the preferred orientations of elongated clasts in the upper till support a northeast to southwest direction of related glacier flow. However, at various sites the lower till exhibits fabrics with both northwest-southeast and northeast southwest trends. Ramsden and Westgate (1971) attribute the contrasting fabrics of the lower till to localized reorientation, with structural alternations of this till by the northeast southwest trending glacial advance that deposited the upper till. To summarize, Ramsden and Westgate (1971) infer that two distinct till units exist, with the upper till demonstrating a northeast-southwest preferred orientation and the lower till an original northwest-southeast preferred orientation.

Till fabric analyses of the upper and lower tills, at an exposure in the Strawberry Creek basin known as the Hugget section, was carried out and reported on by Shaw

(1982). The two till units at this location are separated by 6-8 m of stratified, inter-till sediments. One fabric analysis from the upper till reflects a general northeast-southwest orientation of the clasts, while three fabrics from the lower till show a northwest-southeast preferred orientation (Shaw, 1982). The fabric orientations of the two till units measured by Shaw (1982) tend to agree with those reported by Westgate (1969) and Ramsden and Westgate (1971) for the Edmonton area.

4.4 Inter-till Sediments

As mentioned earlier the lower and upper tills are sometimes found separated by inter-till bedded sands. Warren (1954) introduced the term "Tofield sand" in reference to these deposits and Westgate (1969) uses the term for supposedly correlative deposits. This specific term is not used in the present study because the self-explanatory "inter-till sands" avoids possible correlative connotations.

For the Edmonton area Westgate (1969) reports the occurrence of inter-till deposits and states that "stratified sediments, 40 feet (12 m) thick in places, commonly separate the lower till from an upper, yellowish brown till" (Westgate, 1969, p.144). Collins and Swan (1955) reported the occurrence of inter-till sands in their study area 90 km west of Edmonton (this comprises roughly half of the Wabamun Lake mapsheet, 83G, area). They mentioned an exposure of inter-till sands in the Strawberry Creek valley. During field work for the present study an unsuccessful attempt was made to find the Strawberry Creek valley section mentioned by Collins and Swan (1955). Recent slumping and road construction activities appear to have masked the original exposure.

The sands that occasionally overlie the lower till provided an ideal medium for the formation of "linear sole markings" (Westgate, 1968) at the base of the overlying upper till. The formation of these markings is attributed by Westgate (1968) to protruding clasts at the base of till creating "drag marks" in the underlying sand as the glacier advances. The furrow left by the moving clast is then infilled with basal till material. These features are direct indicators of the localized direction of glacier flow. The occurrence of linear sole markings at the base of the upper till, protruding into inter-till sands, is reported by Westgate (1968) for locations in the Edmonton area and elsewhere in Alberta. The linear sole markings found in Westgate's (1968) Edmonton exposure indicate a northeast-southwest ice flow direction, paralleling that reflected by many fabric analyses of the upper till.

A distinctive exposure of inter-till sands was observed in the Strawberry Creek basin, the site being related to a minor tributary gully of the creek. This site is known as the Hugget section and has been referred to before in relation to till fabric analyses. The location of the Hugget section is noted on Figure 1.1. Figure 4.4 is a general view of the east bank of the Hugget section. Here inter-till sands are overlain by the upper till. In turn, the upper till is capped by glaciolacustrine deposits. This particular site does not reveal the lower till which, if present, is masked by recent debris-fall colluvium. However, at other sites in the Hugget gully area the preglacial fluvial sands, lower till, inter-till sands, upper till and glaciolacustrine deposits are all exposed in sequence.

At one site in the Hugget section linear sole markings are evident on the base of the upper till. These markings protrude into the inter-till sands. Figure 4.5a shows a protruding clast at the distal, southwestern end of one linear sole marking. The upper till unit with which this marking is associated is shown in Figure 4.4. Several parallel linear sole markings were evident at this site (Figure 4.5b), all trending from the northeast to southwest (Shaw, 1982). Representing the local direction of glacier flow, these indicators coincide closely with the preferred orientation of the upper till coarse clasts at this section.

A detailed interpretation of the Hugget section, in part emphasizing the significance of structural deformations within the deposits, is presented by Shaw (1982) in a report on till classification for the Edmonton area. A summary of Shaw's (1982) interpretations is as follows:

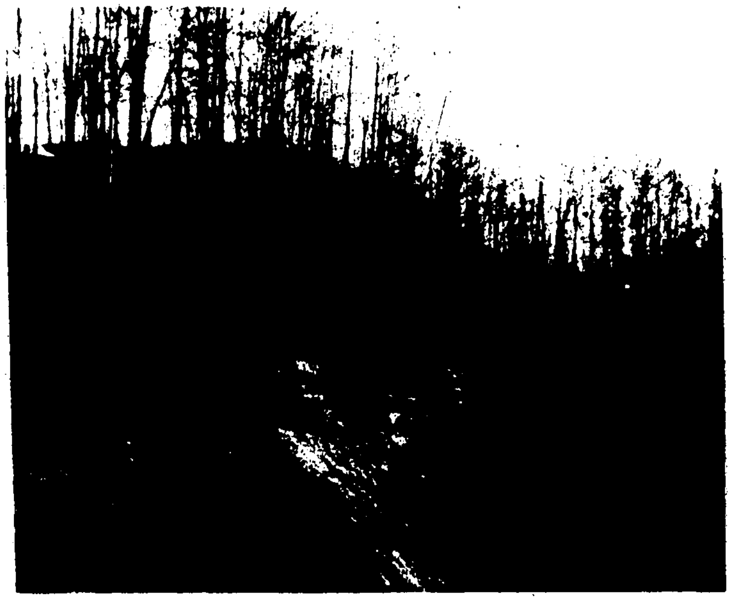


Figure 4.4. General view, east bank of Hugget section. Arrow A indicates lacustrine sediments; arrow B, upper till; and arrow C, inter-till sediments.

Figure 4.5a. Protruding clast of linear sole marking, Hugget section.

Figure 4.5b. Linear sole markings at the base of till, Hugget section.

(1) The two till units represent distinct glacial advances, that were preceded by preglacial fluvial deposition and separated by an interval of fluvial or glaciofluvial sedimentation.

(2) The upper and lower tills are interpreted as passive, melt-out tills.

(3) Stagnant, debris-rich ice, associated with the lower till, persisted throughout the deposition of the inter-till sediments and the deposition of the upper till. The presence of buried ice is inferred from the continuity of faulting evident in the lower till, inter-till sediments and at the base of the upper till. The preglacial sediments, and the superficial glaciolacustrine deposits, are unfaulted.

Indeed, examination of the Hugget section reveals frequent normal faulting of the inter-till sands (Figure 4.6 a and b) and, at certain sites, highly significant truncating faults at the inter-till sand contact with the lower part of the upper till (Figure 4.6a). These also occur across the inter-till sand contact with the upper part of the lower till. The Hugget section sediment faulting, plus other supporting evidence from Hugget and additional local sections, was presented by Shaw (1982) and interpreted to suggest two glacial advances, with the preservation of stagnant buried ice between advances, for the Edmonton area.

Figure 4.6a. Broad view of the faulted nature of inter-till sediments, Hugget section.

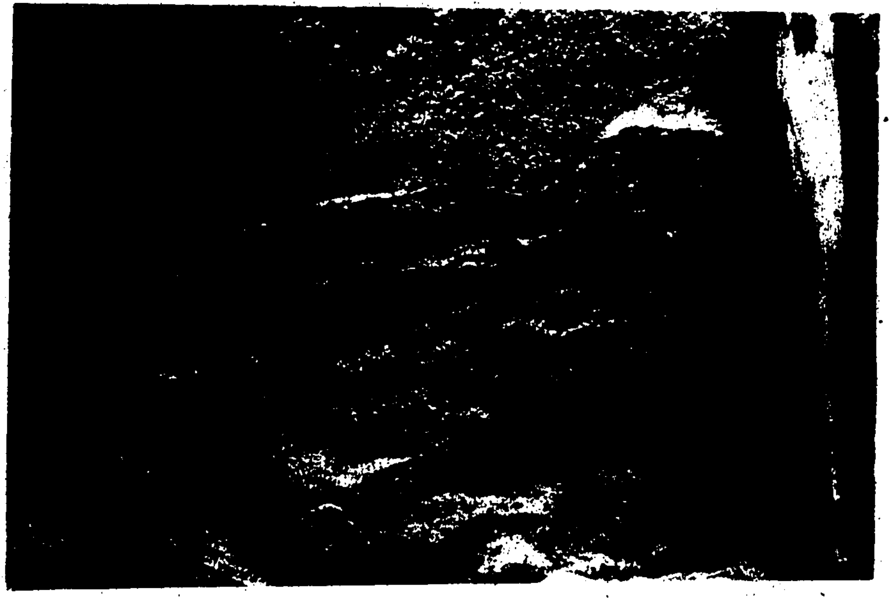


Figure 4.6b. Details of the normal faulting which predominates in the inter-till sediments, Hugget section.

4.5 Glaciolacustrine Sediments

The local retreat of the Laurentide ice sheet, with the associated formation of proglacial lakes, was briefly reviewed in Chapter 2. For additional details on related glaciolacustrine systems of central Alberta reference should be made to St-Onge (1972). Christiansen (1979) describes probably correlative ice margins and time-synchronous glacial lakes of Saskatchewan. Glacial retreat Phases 3 and 4 outlined by St-Onge (1972) saw the Strawberry Creek basin mainly inundated by a proglacial lake. During Phase 3 the Laurentide ice frontal position lay immediately north-east of the basin and by Phase 4 the ice front lay further northeast of the Edmonton area. A recently completed surficial geology map, which includes the present study area (Andriashek et al., 1979), portrays glaciolacustrine deposits as the predominant surficial deposit unit mantling much of the Strawberry Creek basin. Exceptions are a few peripheral areas which have till and "discontinuous till over bedrock" as the major, surficial sediments. Glaciolacustrine sediments overlying till were commonly observed by the author in exposures along the Strawberry Creek valley and are evident on Figures 4.3 and 4.4.

4.6 Conclusions

The pre-Holocene surficial deposits observed in the Strawberry Creek basin have been briefly reviewed in relation to the general stratigraphy reported by others for similar deposits in central Alberta. This review has been presented primarily to outline the general stratigraphic framework of pre-Holocene surficial deposits into which the Strawberry Creek valley has been eroded. In conclusion the following points should be noted:

(1) Preglacial gravels and sands are found intermittently throughout the contemporary valley. From these it is suggested that the Holocene Strawberry Creek re-inhabited part of the preglacial Warburg valley mentioned in Chapter 3.

(2) The two till units, occasionally separated by inter-till sediments, probably represent two glacial advances. The first advance, possibly flowed from the northwest but the second advance flowed from the northeast.

(3) The most areally extensive sediment type at the surface of the Strawberry Creek basin consists of glaciolacustrine silts and clays. These were laid down in a proglacial lake system related to the retreat of the last ice sheet to inhabit this area.

([illegible]) The initial incision of the post glacial Strawberry Creek valley probably began as the proglacial lake system diminished in size from the latest stage(s) of Glacial Lake Edmonton to Glacial Lake Bruderheim (Bayrock and Hughes, 1962; St-Onge, 1972).

This chapter has provided an outline of the pre-Holocene surficial sediments of the Strawberry Creek basin, specifying the type of sediments and reviewing ideas on their origin. In conjunction with Chapter 3, which outlines the bedrock geology, the physical framework of the Strawberry Creek basin in which the development of the valley has evolved is now set. The Holocene evolution of this valley was marked by the development of creek terraces in response to cut-and-fill "epi-cycles". The morphology, stratigraphy and chronological evolution of these terraces constitute the main focus of this thesis, outlined in Chapters 5 and 6, with additional details in Appendices A and B.

5. STRAWBERRY CREEK TERRACES; MORPHOLOGY, STRATIGRAPHY, AND CHRONOLOGY

5.1 Introduction

The focus of this chapter is to outline in detail the Holocene geomorphic evolution of the Strawberry Creek valley. This relies mainly on the field data related to alluvial terrace remnants. Studies of alluvial terrace sequences are numerous in the geomorphic literature, despite many interpretative pitfalls (see for example, Frye and Leonard, 1954; Ritter and Miles, 1973). Indeed, Ritter (1979, p.275) states: " Basically, terraces are terraces are terraces — and we should probably not generalize about features that defy generalization".

Paradoxically, remnant terraces are often the best geomorphic indicators of past stages of valley history and are thus integral to interpretations of valley development. The significance of remnant terraces was obvious to Ritter (1979) who simply emphasized that diligent, painstaking and elaborate investigations are necessary to achieve sound interpretations of valley evolution.

In the present study relevant data are encompassed by a planimetric map of remnant terrace tread distributions, a longitudinal channel profile, terrace heights above the channel profile, diagrams of selected valley cross-sections and generalized alluvial stratigraphies, with associated radiocarbon dates. Four paired terraces dominate the terrace suite preserved along a major portion of the main Strawberry Creek valley. Also, the characteristic alluvial stratigraphy and apparent implications regarding fluvial depositional processes are outlined. Finally, the valley's chronologic development is discussed on the basis of numerous new radiocarbon dates.

5.2 Methodology

A field reconnaissance of the entire valley was completed during the summer of 1979. Terraces were mapped on aerial photograph overlays and pertinent alluvial stratigraphies were logged for exposed terrace sections. A longitudinal channel profile was constructed from NTS topographic maps of 1:50,000 scale, with a 50 ft. (15 m) contour interval. An altimetric survey was carried out at selected locations in the valley to establish terrace height relationships with some accuracy. To achieve this accuracy the surveyors utilized two altimeters and two thermometers. For each traverse a base station was established at the contiguous channel level where fluctuations in base altimeter readings and temperature were recorded. Altimeter height-readings, air temperatures, and times of observations were recorded at selected spots on adjacent terrace treads. The spot-height locations on the individual terrace treads were selected with care in an attempt to obtain representative elevations of specific treads. The valley cross-sections presented in this chapter are based on the altimetric surveys. The locations of the valley cross-sections were pre-selected during the field reconnaissance, and the altimetric surveying was completed at the end of the field season when stable weather conditions prevailed. The individual terrace tread widths, and distances across the valley between the valley rims, for the cross-sections were measured from aerial photographs.

5.3 Distribution and Morphology of Alluvial Terraces

5.3.1 Planimetric Distribution

An entire paired terrace suite is rarely preserved at a single valley location. Rather, the individual terraces of the valley suite are found more or less intermittently as isolated remnants. Therefore, when attempts are made to discern the separated, but chronologically related, members of a valley suite continuity throughout the valley must be verified for each terrace unit.

Figure 5.1 a and b, of the Strawberry Creek valley, show the locations of the planimetric maps, Figures 5.2 to 5.8. The latter figures depict the areal distribution of remnant terrace treads with their terrace designations. The terrace designations, based on the criterion of relative height, are T-1 (oldest), T-2, T-3, and T-4 (youngest).

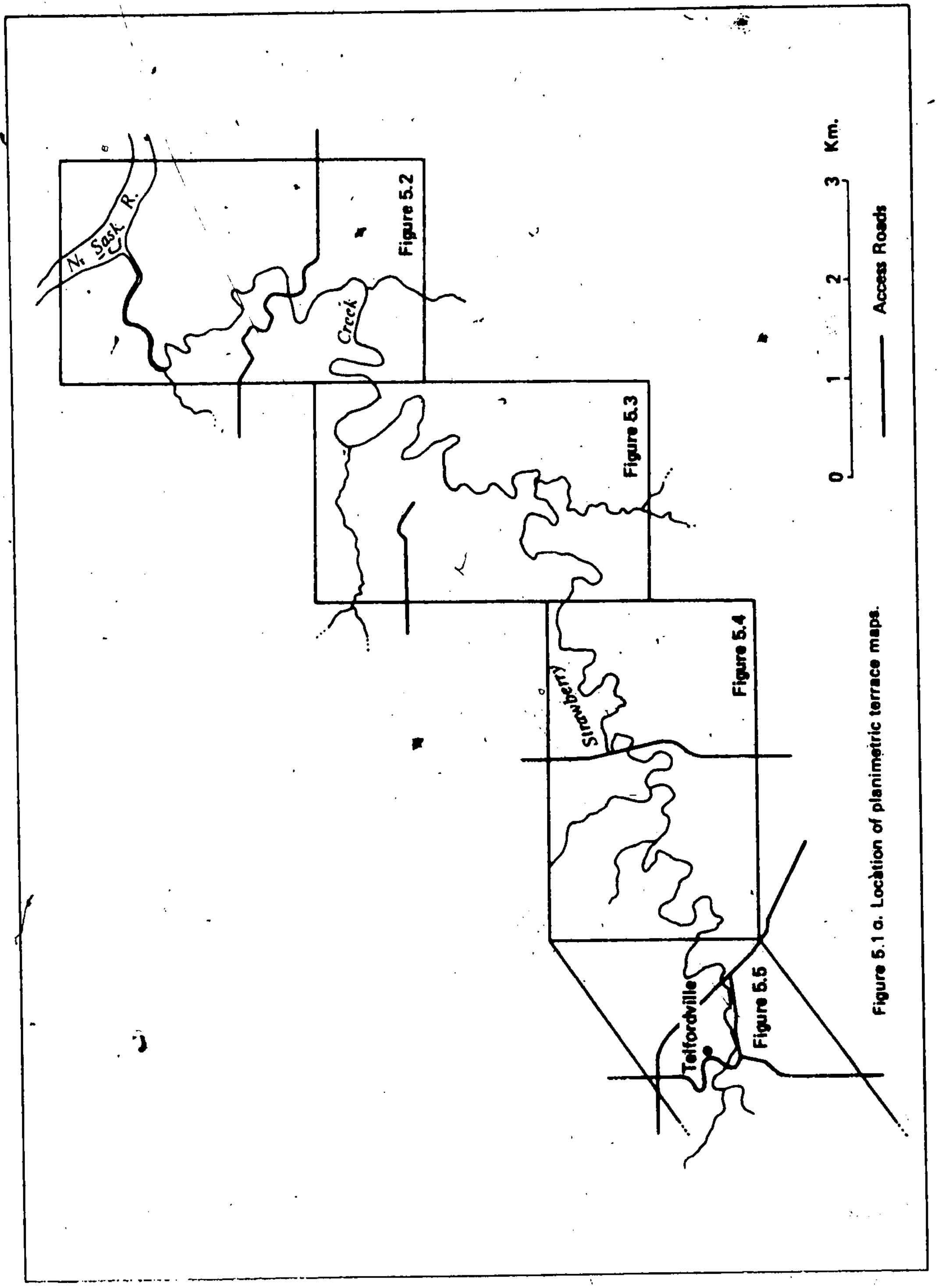


Figure 5.1 a. Location of planimetric terrace maps.

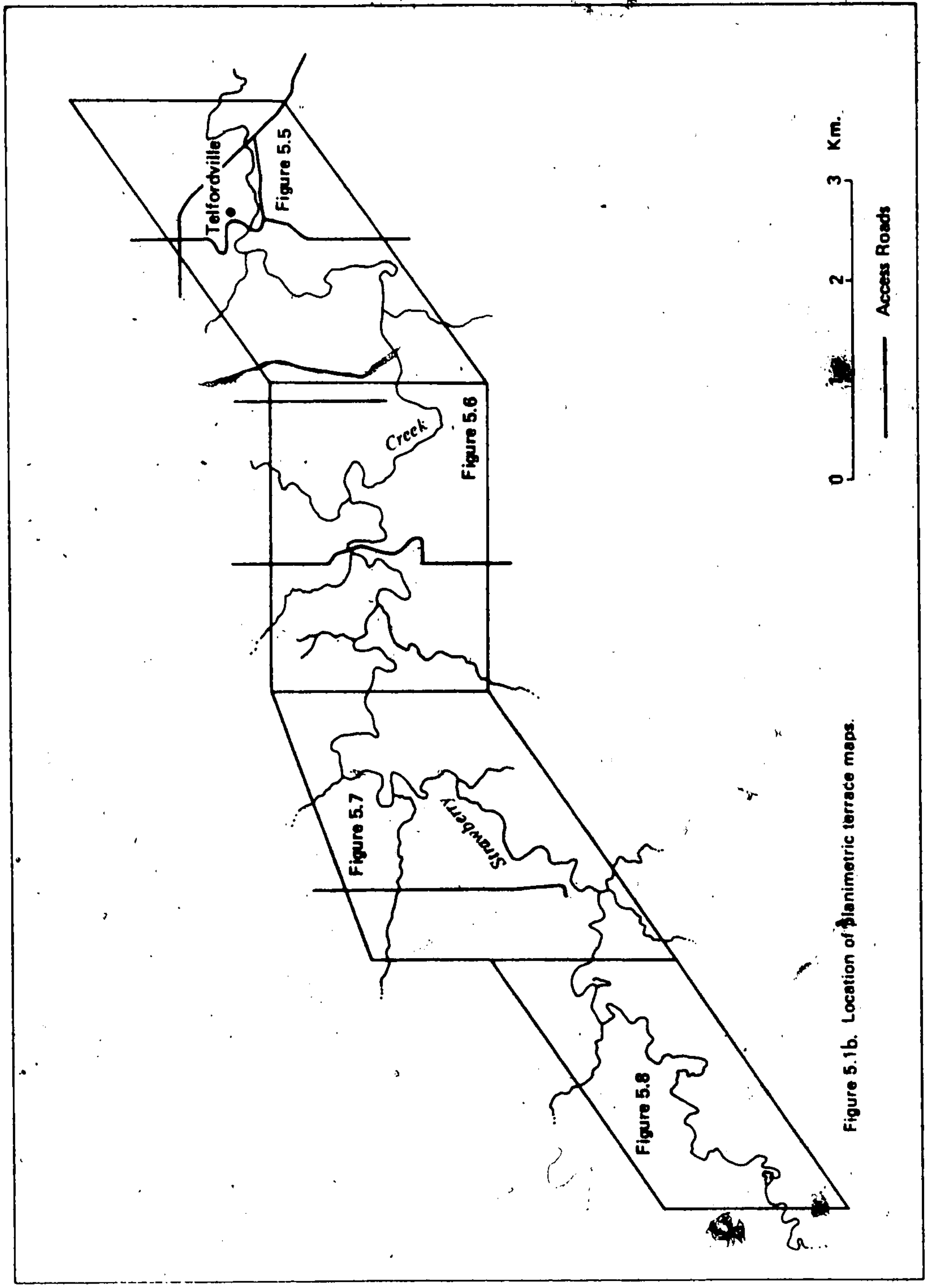


Figure 5.1b. Location of planimetric terrace maps.

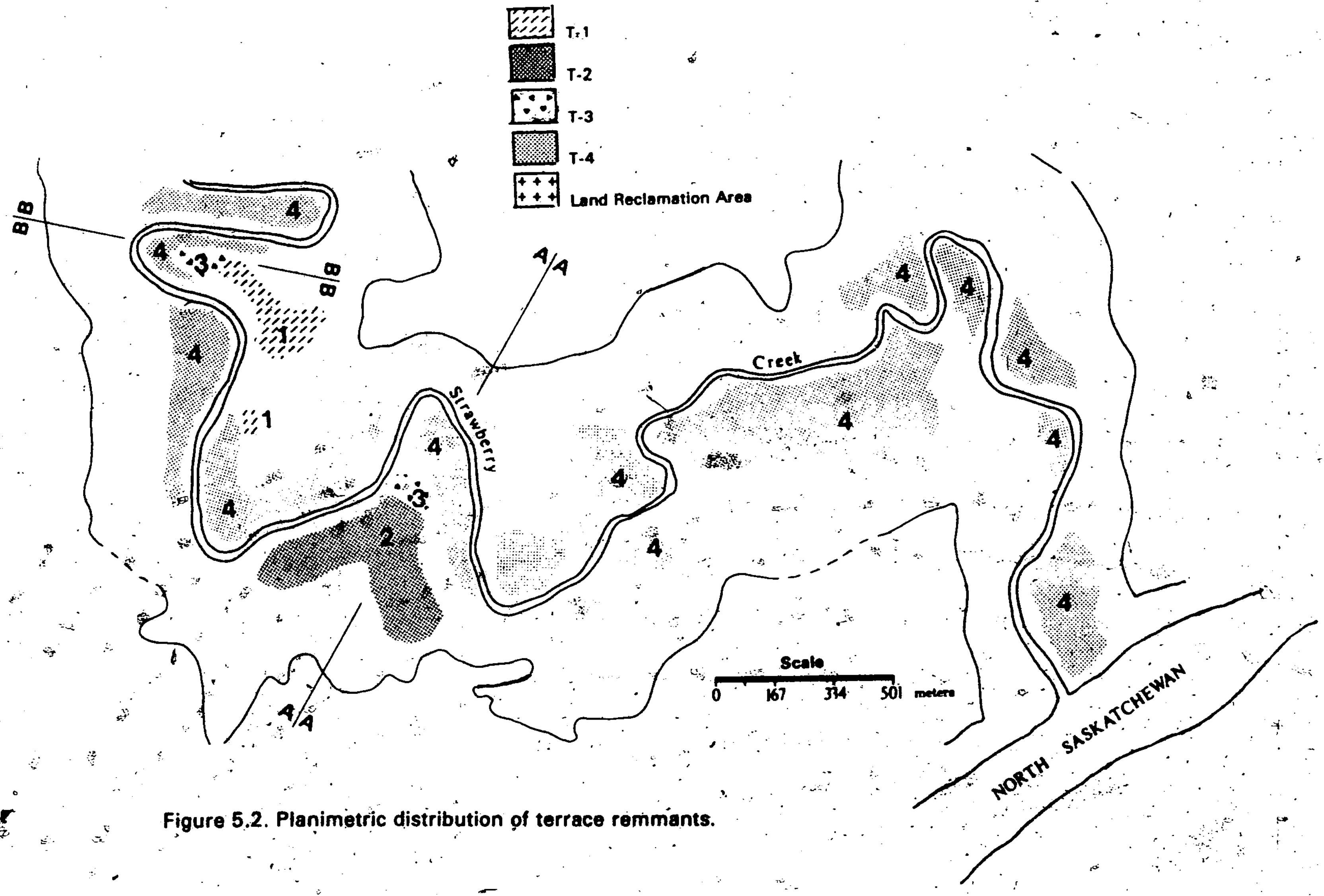


Figure 5.2. Planimetric distribution of terrace remmants.

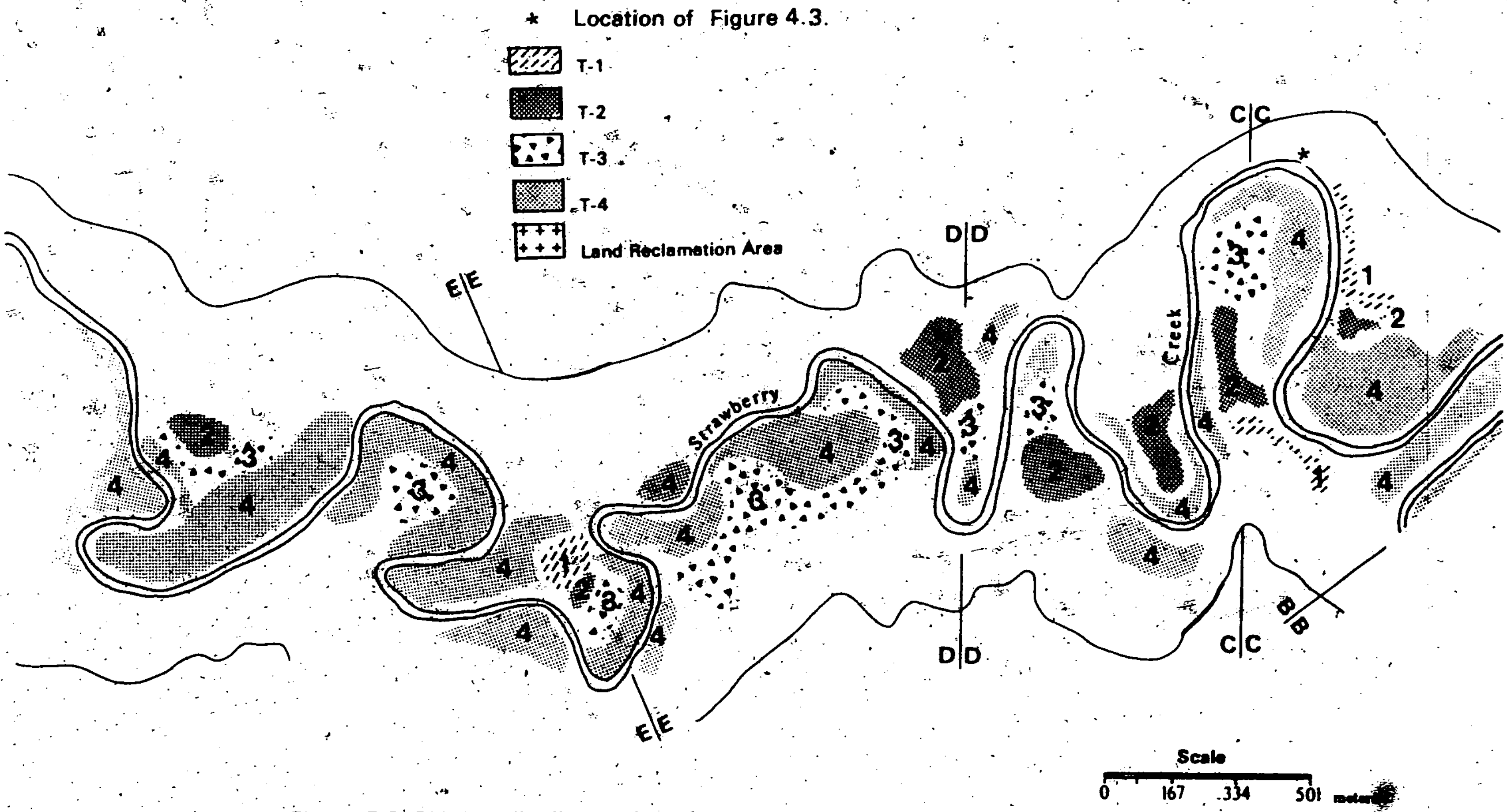


Figure 5.3. Planimetric distribution of terrace remmants.

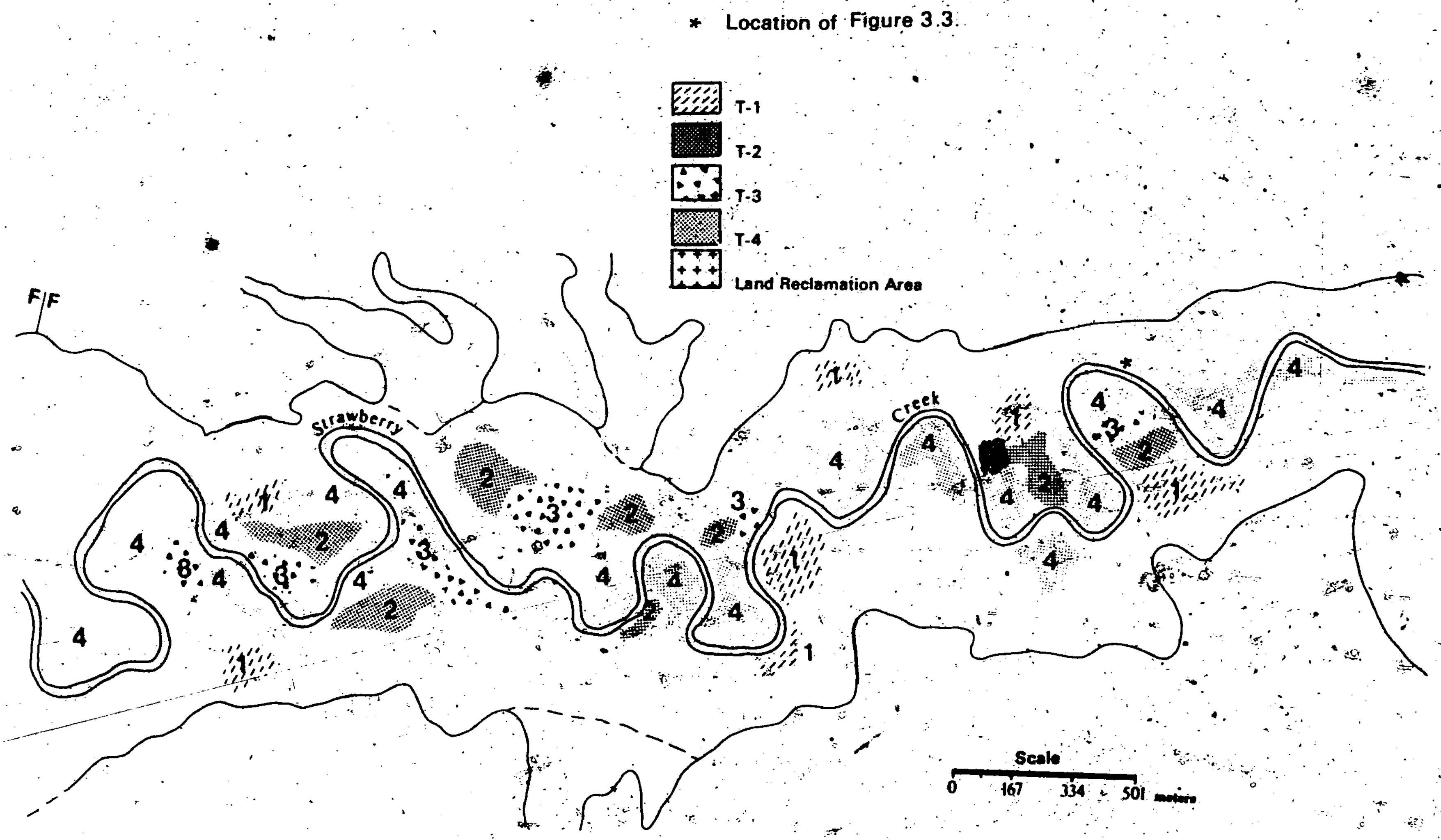


Figure 5.4. Planimetric distribution of terrace remmants.

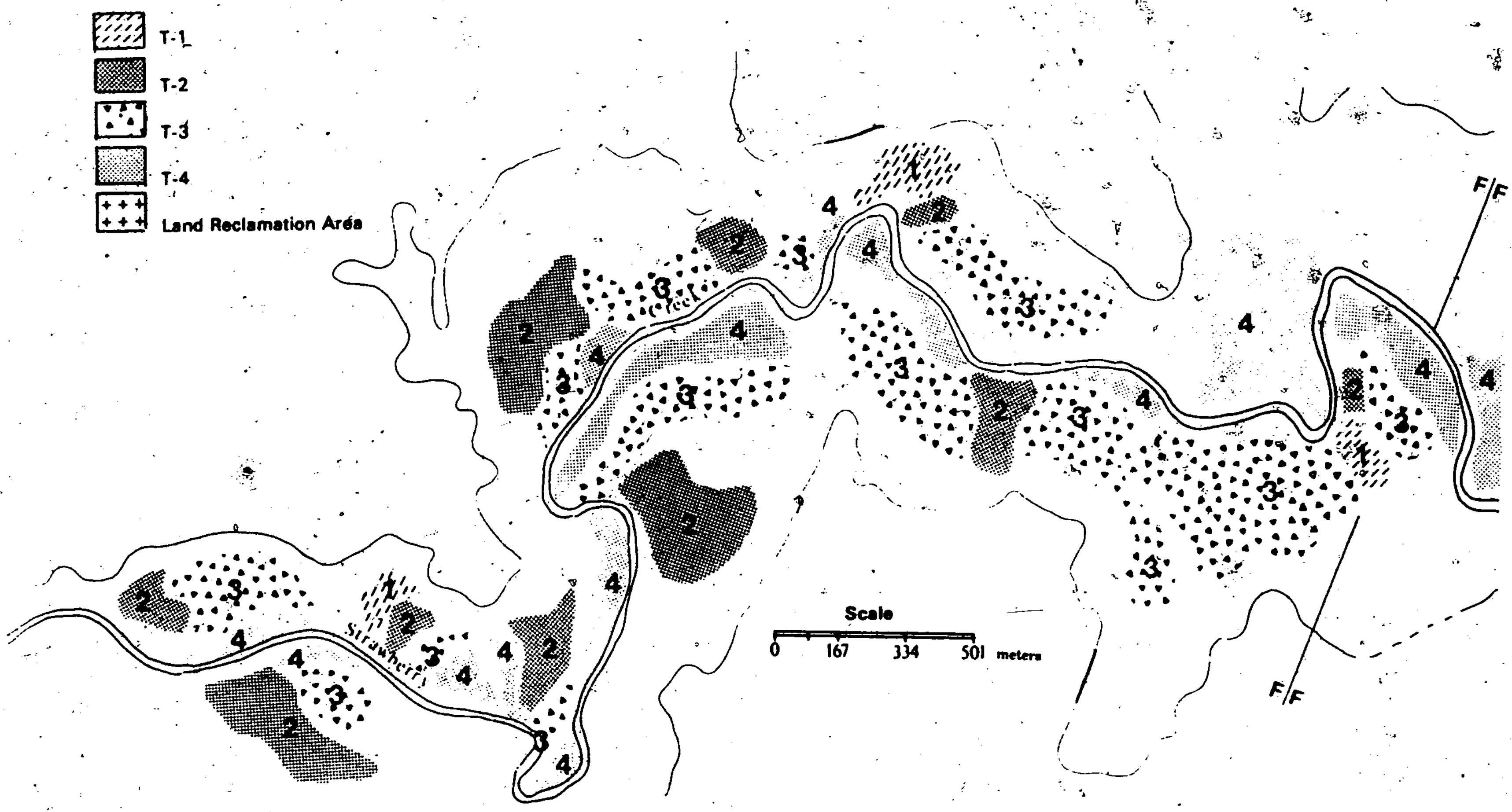


Figure 5.5. Planimetric distribution of terrace remmants.

Figure 5.6. Planimetric distribution of terrace remmants.

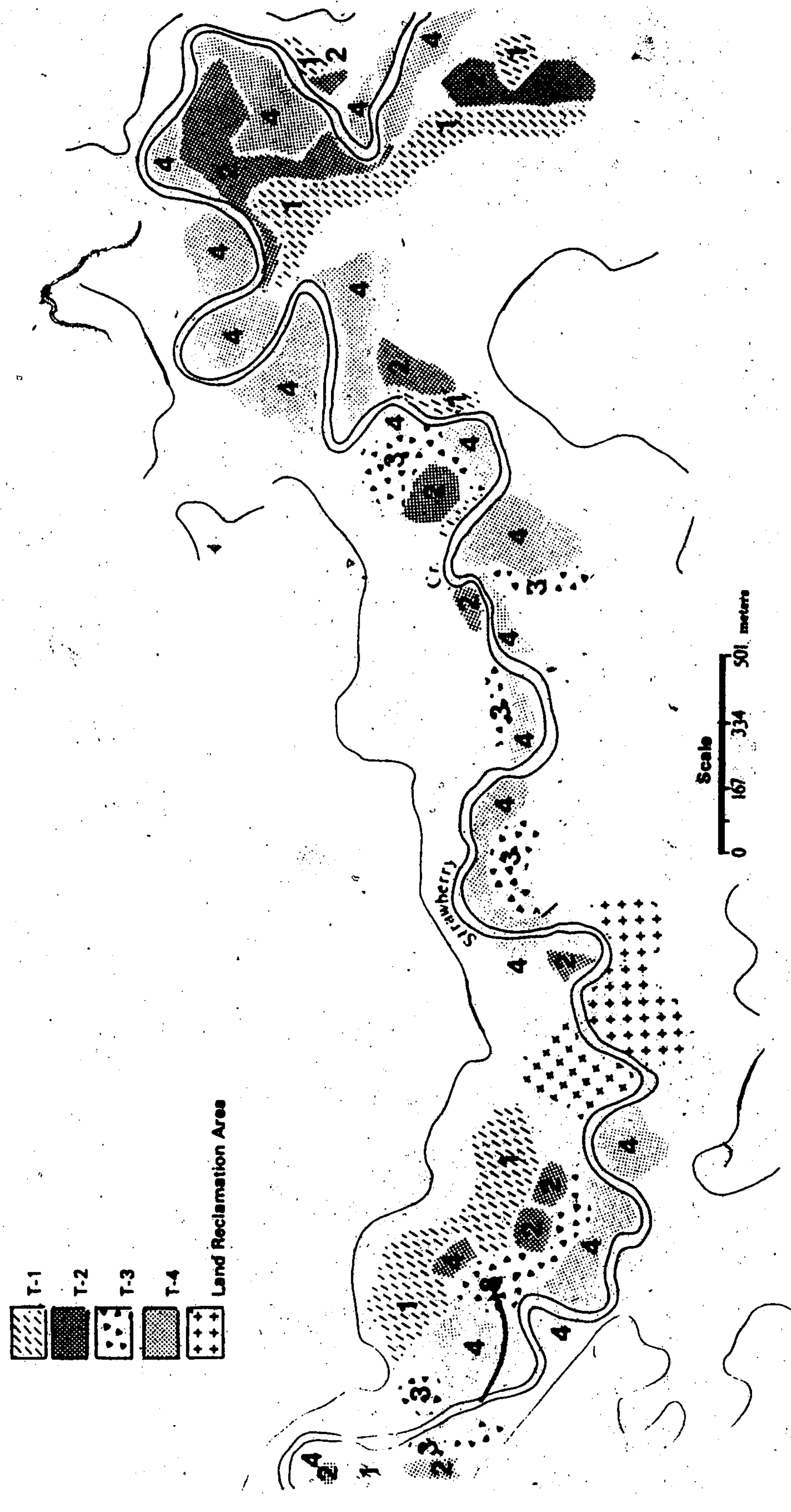


Figure 5.7. Planimetric distribution of terrace remmants.

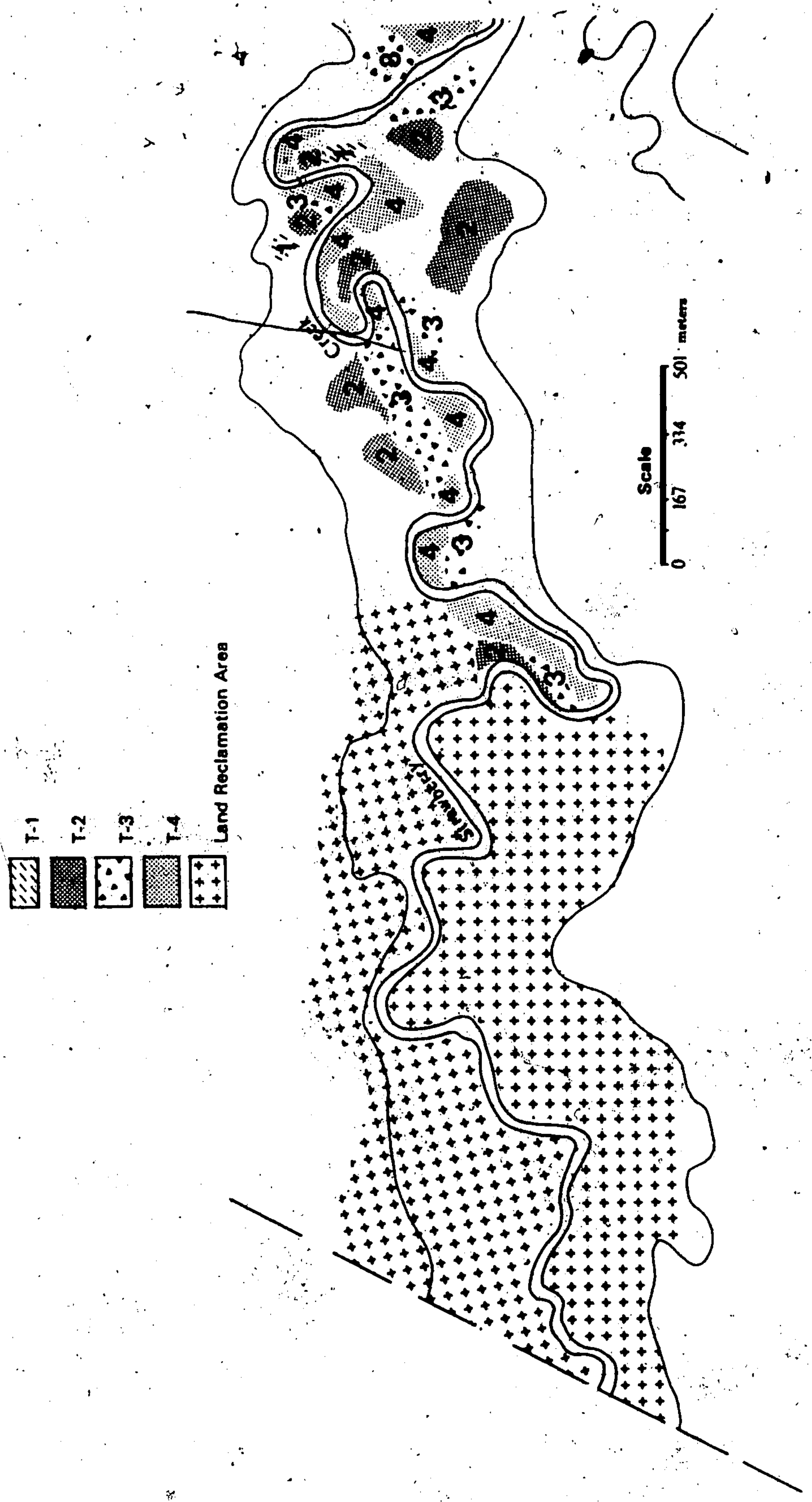


Figure 5.8. Planimetric distribution of terrace remmants.

Generalizations which may be made about the planimetric distribution of terrace remnants in the Strawberry Creek valley are as follows:

(1) Approximately 25 T-1 units are preserved along part of the valley, giving a good representation of the initial phase of incision and aggradation within the valley.

(2) Representation of T-2 is well documented, with over 30 remnant treads dispersed throughout part of the valley.

(3) As is to be expected, the lower, more recently formed, terraces are better preserved because their younger age has permitted less chance for destruction. Hence T-3 units are widely preserved throughout part of the valley , with about 50 identified remnants.

(4) Units of T-4 are exceptionally numerous within the valley and, in part, ~~are~~ still being aggraded at active portions of point bars, and perhaps on their treads by long return-period floods.

(5) The vast majority of the individual tread surfaces display nearly horizontal attitudes, with minor local relief variations imposed by paleochannel scars, colluvium, and small alluvial fans.

(6) In the downstream portion of the valley terrace remnants other than those of the extensive T-4 are rare.

5.3.2 Longitudinal Profile

The longitudinal profiles of streams and rivers are of particular concern to investigators of fluvial systems, partly because their specific shapes reflect dominant developmental controls. Long profile up-concavity is generally accepted as the typical shape towards which streams and rivers evolve. Atypical convex profiles have been attributed to lithologic controls, ephemeral discharge regimes, and other geomorphic variables. Detailed discussions of river longitudinal profiles include the work of Surrel (1841) and Davis (1899), proceeding through time to Wheeler (1979), with innumerable studies and ideas presented by others during intervening years. For example, Leopold et al., (1964) list ten independent, semi-dependent and dependent variables which play a role in the development of river longitudinal profiles.

The longitudinal profile of Strawberry Creek (Figure 5.9) reveals a composite concave-convex form. It is unlikely that this form is a result of lithologic control. The bedrock geology of the Strawberry Creek basin, with the exception of the headward zone, is composed of Upper Cretaceous bentonitic sandstone, occasional clay ironstone inclusions, shale and coal. As outlined in Chapter 3, the Strawberry Creek basin's bedrock has few relatively resistant beds which consistently outcrop over significant distances in the valley. Thus it is unlikely that lithologic controls have been of major importance in the development of

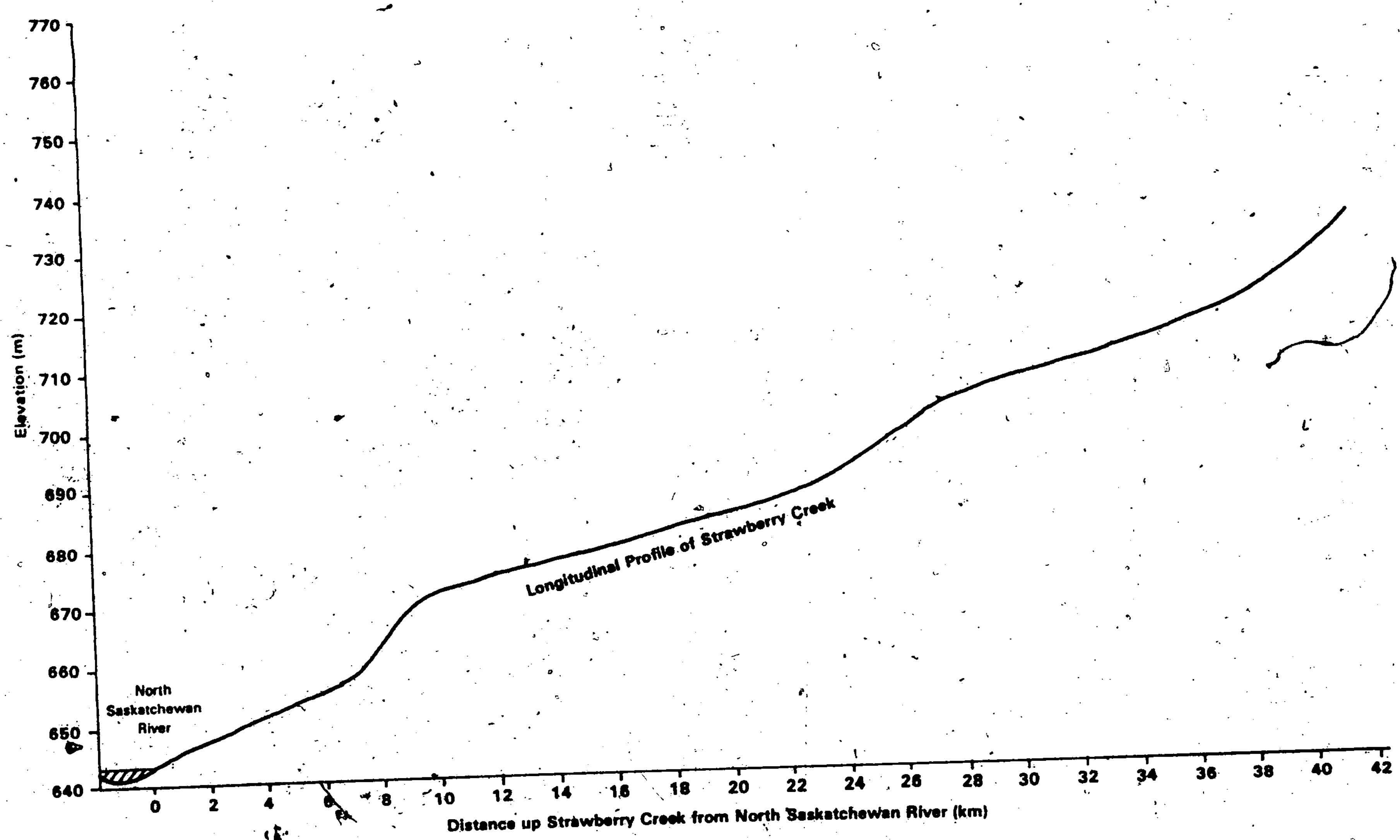


Figure 5.9. Longitudinal channel profile of the Strawberry Creek.

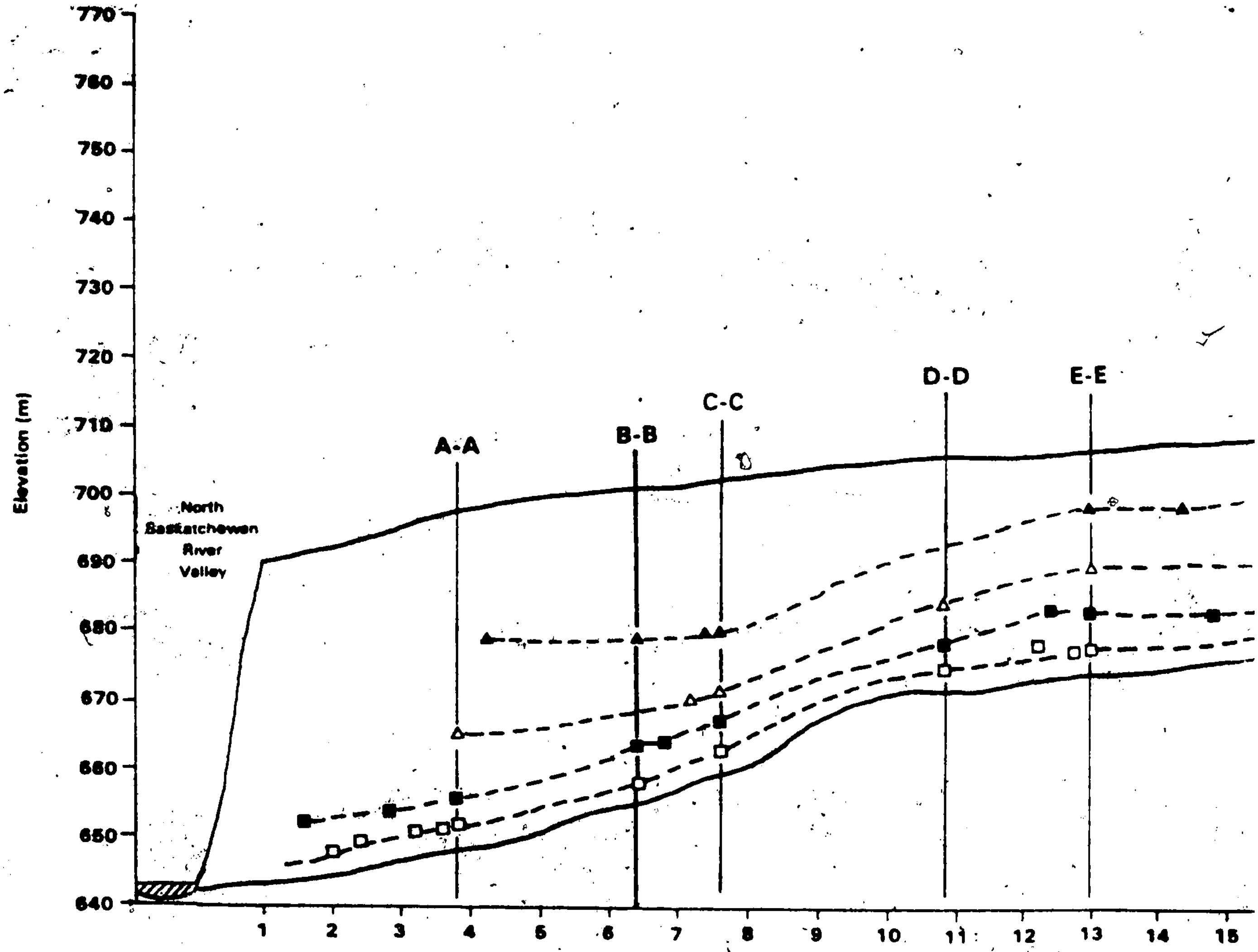
a partially convex longitudinal profile of Strawberry Creek.

The Strawberry Creek longitudinal profile reflects a composite of two channel segments that display distinctive forms. An extensive concave segment encompasses the major length of the valley. This segment by itself represents a longitudinal profile reflecting morphological stability. A convex segment along a short distal portion of the basin completes the composite profile. This convex segment acts as the outlet for the up-valley, predominantly concave reach, and is linked to the North Saskatchewan River base-level at a substantially lower elevation. This convex, channel profile segment presents an unstable morphological element in the composite profile.

5.3.3 Longitudinal Profile with Plotted Terrace Heights

With the present longitudinal profile established the next step is to confirm the paired or unpaired nature of the remnant terraces by plotting their tread heights above the longitudinal profile (Figure 5.10). It is evident from this figure that consistent relative elevations of remnant terraces above the channel may be easily categorized into four distinct levels which display paired characteristics. The occurrence of occasional unpaired remnants is also apparent but this is to be expected for any meandering channel system. In addition, as depth of valley decreases upstream, resulting in the gradual convergence of the four members of the terrace suite, it sometimes becomes difficult

1 OF


Elevation (m)
770
760
750
740
730
720
710
700
690
680
670
660
650
640
North
Saskatchewan
River
Valley
A-A
B-B
C-C
D-D
E-E
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

2OF

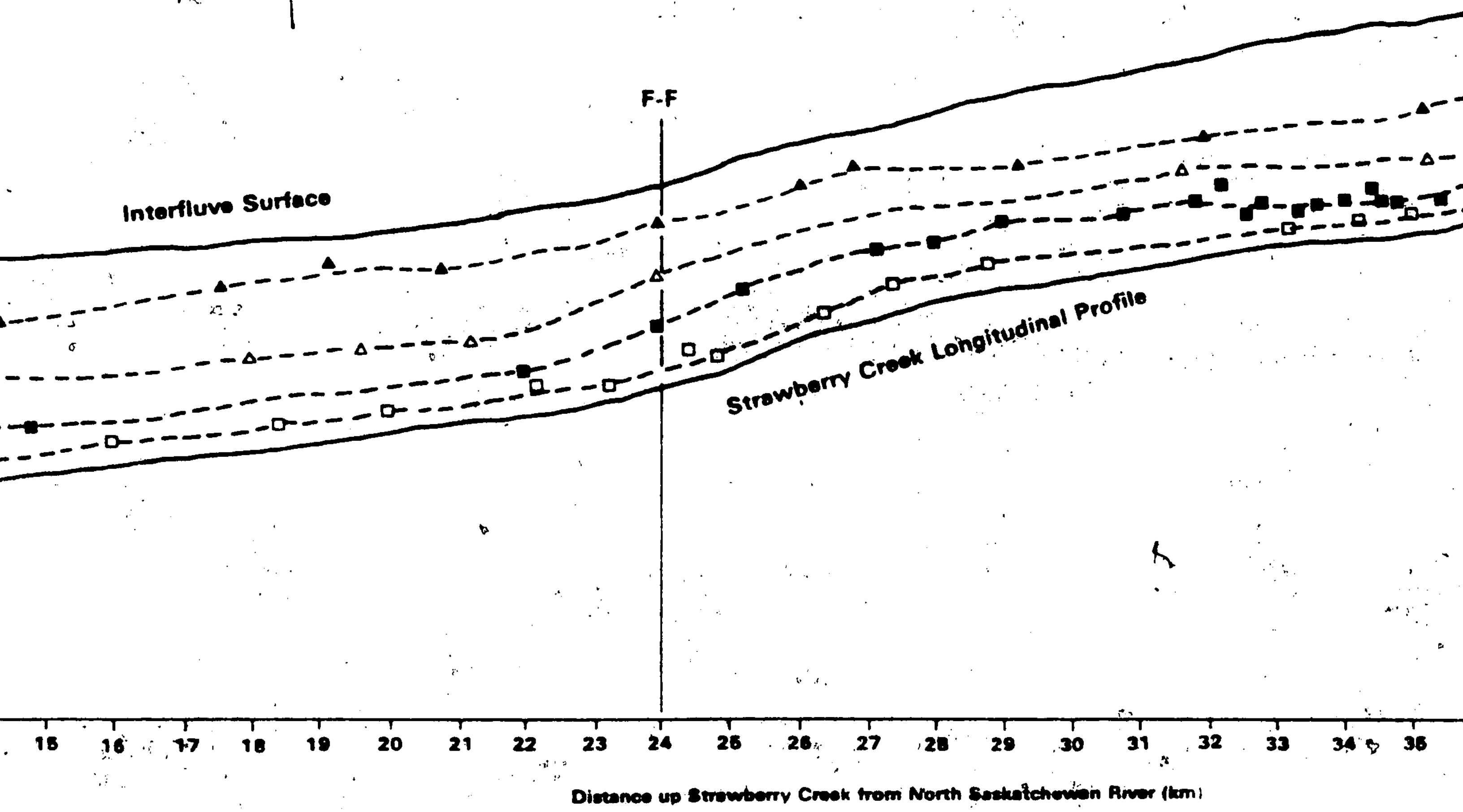
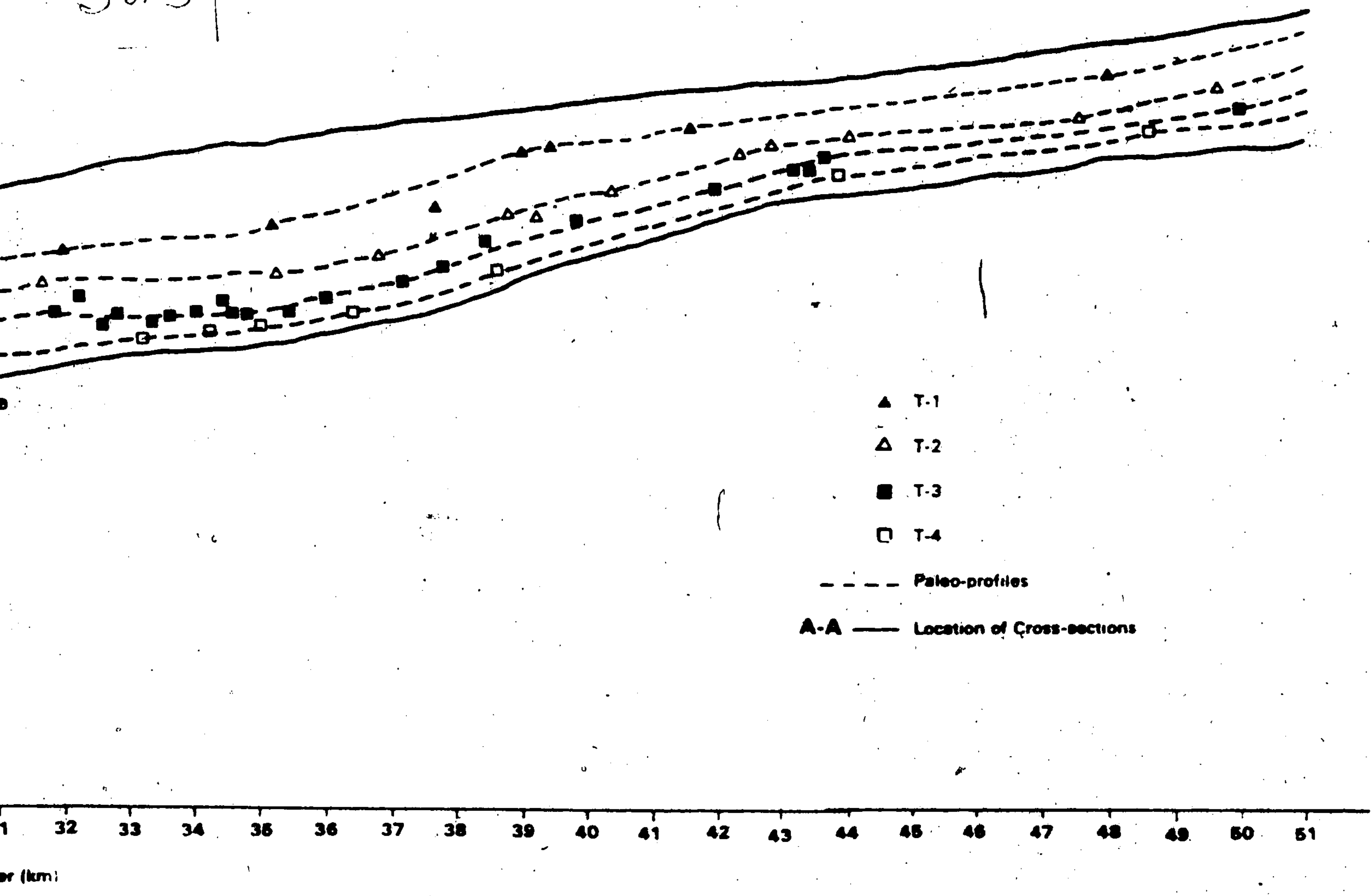


Figure 5.10. Longitudinal channel profile of the Strawberry Creek with plotted terrace heights.

3 of 3



n plotted terrace heights.

to categorize a remnant terrace tread to a specific terrace level. Therefore, in certain instances along the upstream, shallow valley reach, a degree of interpretation was necessary to assign some terrace treads of intermediate height to a particular terrace height range.

Paleo-profiles of former, stable, floodplain positions are approximated by dashed lines linking apparent, paired terrace units on Figure 5.10. Considering the concave-up segment of the main valley it can be inferred from the terrace distribution that profile concavity has not noticeably changed while the stages of valley incision and aggradation occurred through Holocene time. This suggests that the channel system episodically had sufficient time to reach some degree of stability following relatively fast incision phases. Terrace long-profile parallelism or, at most, slight divergence, may also be inferred and this indicates that mean channel slope has not changed significantly for given sectors of the valley throughout the time of valley evolution.

5.3.4 Valley Cross-sections

Valley cross-sections further demonstrate terrace morphology by partly illustrating their horizontal and vertical dimensions. Six valley cross-sections are presented in Figures 5.11 to 5.16. The locations of these cross-sections are shown on the planimetric maps (Figures 5.2 to 5.8). Following are brief descriptions of the valley

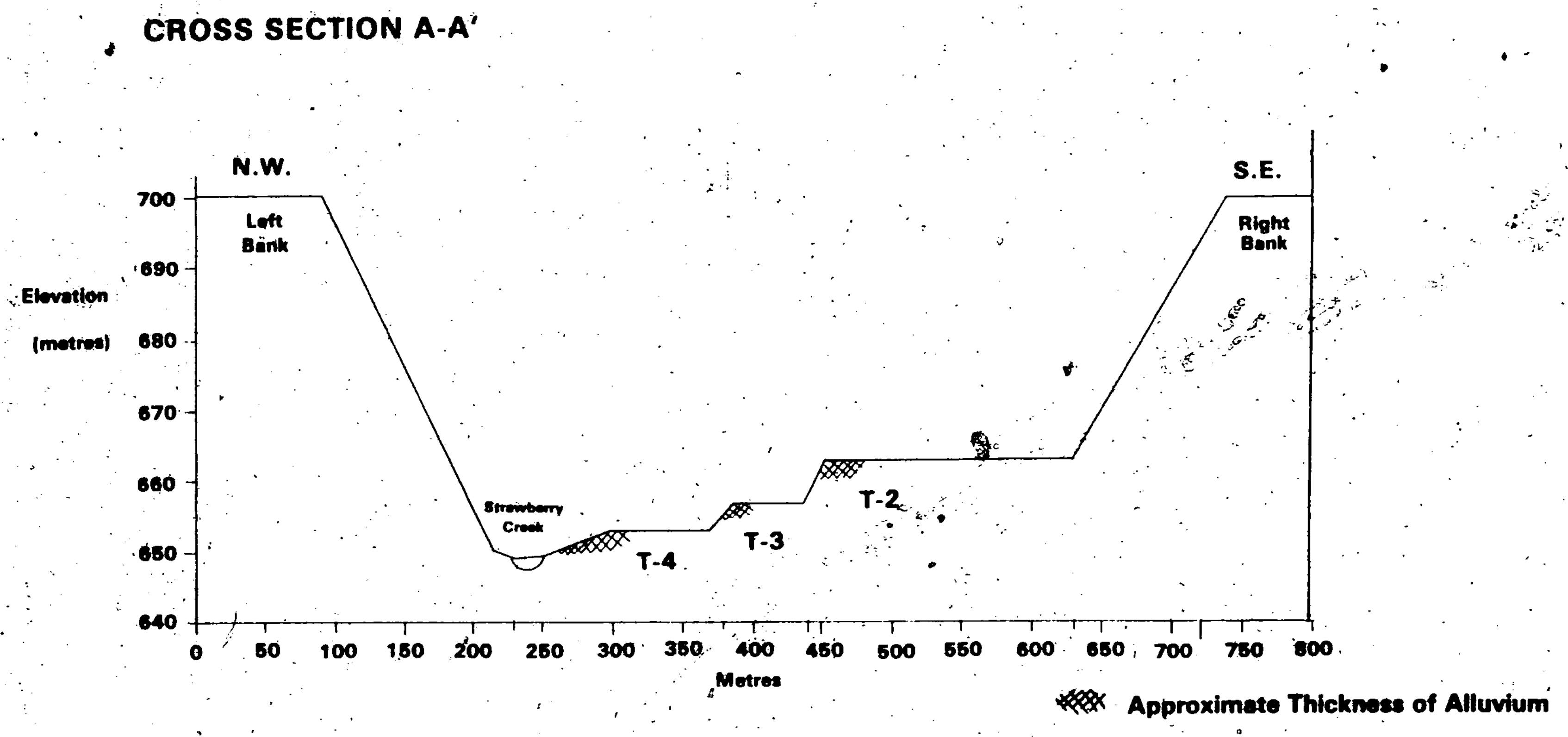


Figure 5.11. Valley cross-section A - A'.

CROSS SECTION B-B′

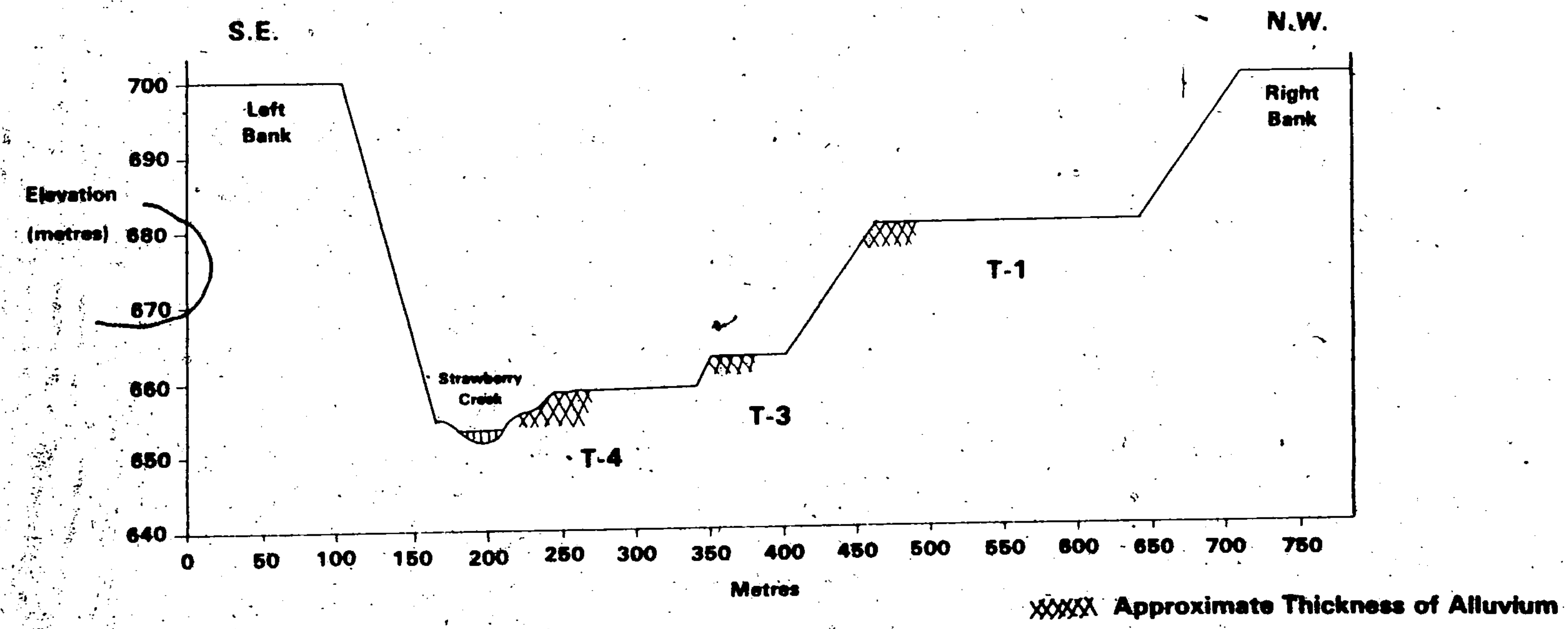


Figure 5.12. Valley cross-section B - B′

CROSS SECTION C-C'

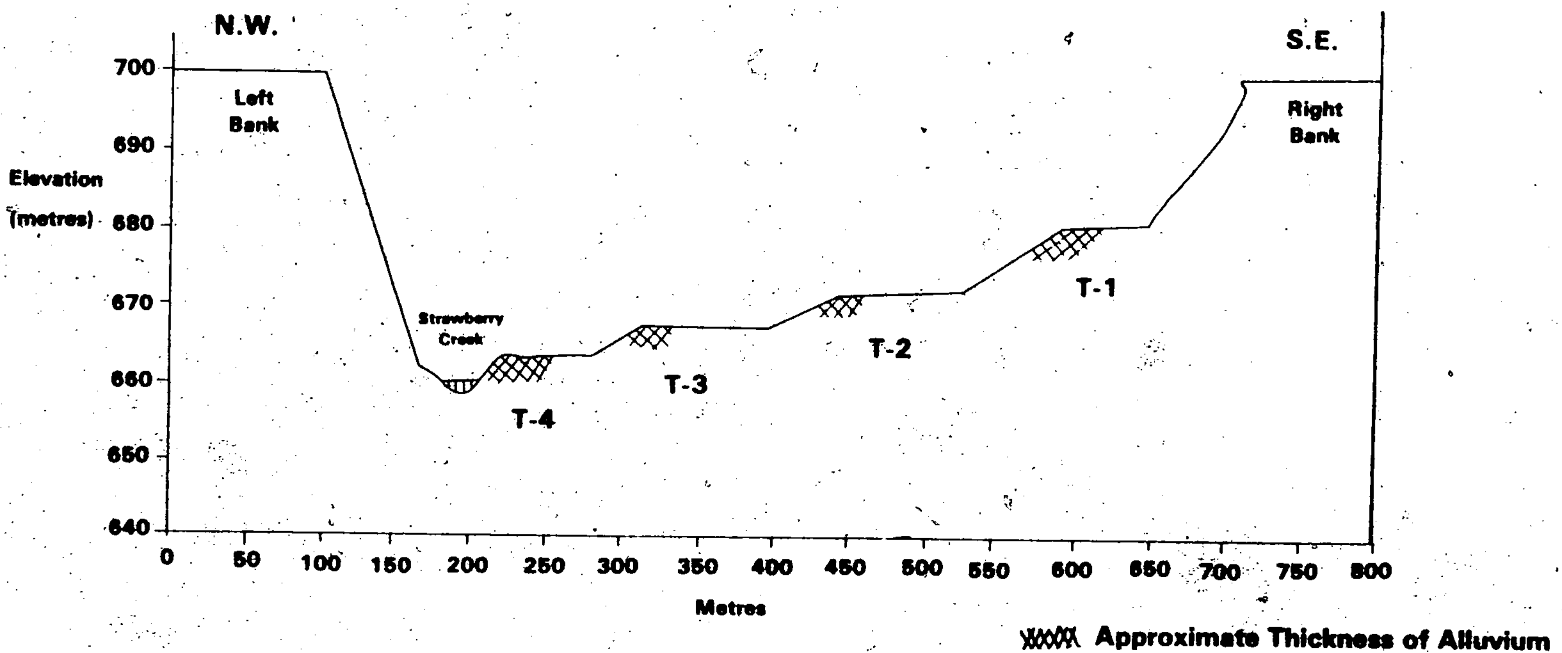


Figure 5.13. Valley cross-section C - C'

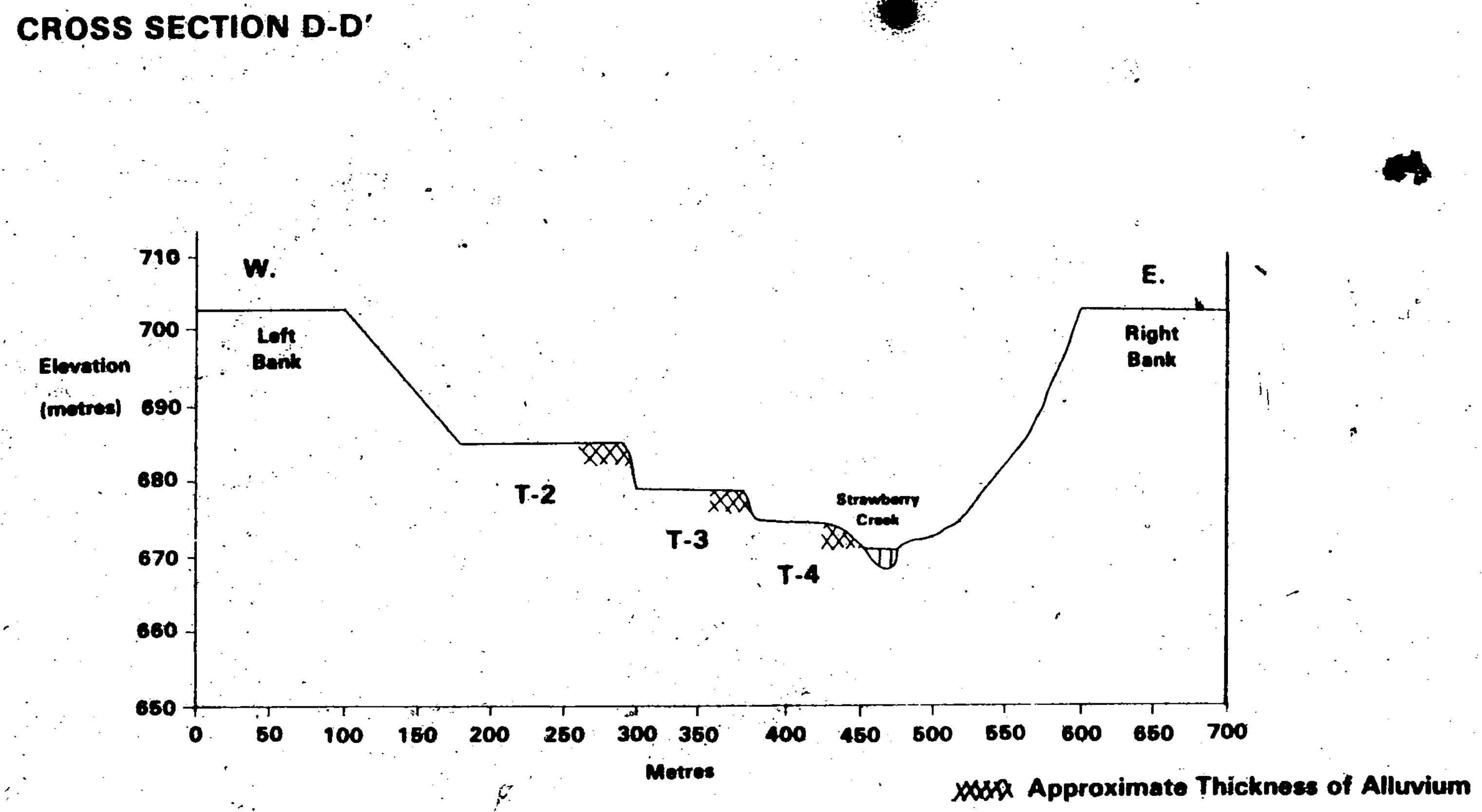


Figure 5.14. Valley cross-section D - D′.

CROSS SECTION E-E'

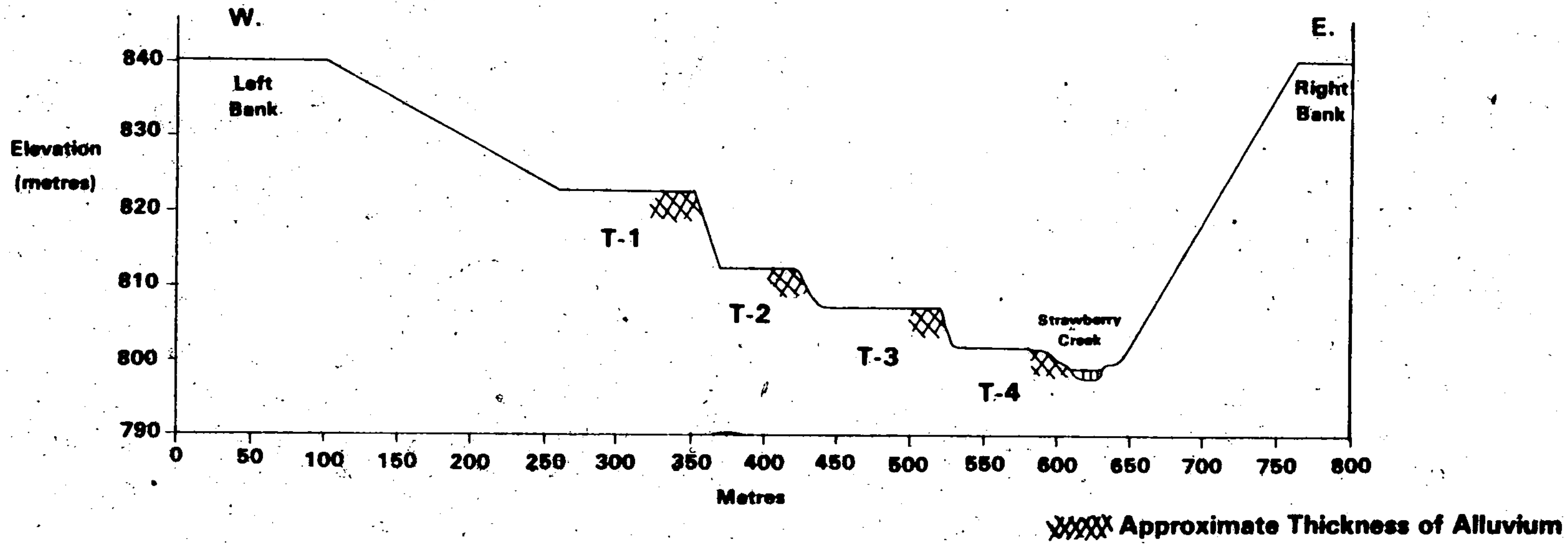


Figure 5.15. Valley cross-section E - E.'

CROSS SECTION F-F′

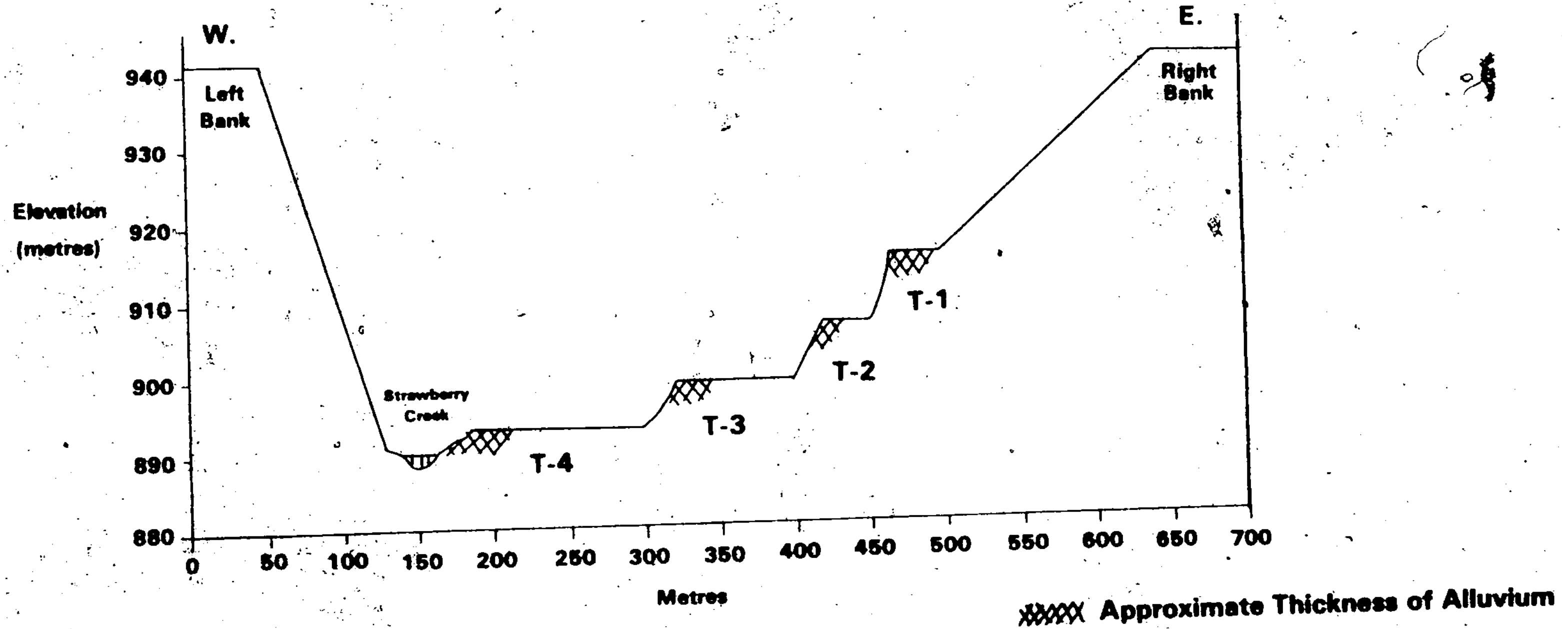


Figure 5.16. Valley cross-section F - F′

cross-sections which emphasize distinctive characteristics of the valley morphology. Logged exposures of terrace alluvium associated with the six cross-sections are noted, where applicable, in the alluvial stratigraphy section of this chapter.

Cross-section A-A′ (Figure 5.11) shows remnants of T-2, T-3 and T-4 in the lower reaches of the valley. From the location of this cross-section to the mouth of the valley only T-4 remnants are preserved. This suggests that through time the meandering activities of the channel along this downstream reach were quite intense, accomplishing the destruction of former terraces. Cross-section B-B′ (Figure 5.12) is located a short distance upstream of A-A′ and shows the first remnant of T-1 up-valley from the mouth. Although the T-1 remnant tread is relatively well preserved it is being slowly destroyed by the present channel, the outside meander bank of which is eroding the underlying bedrock of T-1. A remnant of T-2 has not been preserved but T-3 and T-4 remnants do occur in this locality. Cross-section D-D′ (Figure 5.14) has no preserved T-1 remnant but T-2, T-3 and T-4 remnants are evident. Cross-sections E-E′ (Figure 5.15) and F-F′ (Figure 5.16) again display the entire suite of four major terraces.

5.3.5 Representative Valley Terraces

Figure 5.17a exhibits a representative valley exposure of T-1 (section 39). This T-1 section consists of approximately 8m of bedrock, approximately 12m of preglacial gravels and sands and is capped by 2m of post glacial terrace alluvium. The T-1 alluvium at this site yielded bi-valve mollusc shells which have been radiocarbon dated at 8015 ±135 yrs. B.P. (S-1787). A distinctive terrace scarp is apparent on Figure 5.17a, characteristically inclined from the tread of T-1 to that of a T-3 tread visible to the right. Figure 5.17b illustrates T-2 (section 17) associated with cross-section D-D′. The bedrock base of the T-2 alluvium, approximately 7.2m above the present channel, is well depicted. Figure 5.18a and Figure 5.18b complete the presentation of cross-section D-D′ terraces by illustrating exposures of T-3 (section 16) and T-4 (section 15) respectively. The T-3 tread of Figure 5.18a is approximately 6m above the present channel. The basal lag gravels of this T-3 exposure included stringers of well bedded sands about 20cm thick. Furthermore, the 1.45m of overbank fines include stringers of sands and grits about 20cm thick. These stringers probably resulted from variations in discharge and channel levels while the deposits accumulated. The T-4 tread of cross-section D-D′ is about 3m above the channel (Figure 5.18b). The T-4 alluvium of Figure 5.18b displays a good fining-upwards sequence of sediment. Up to 1.2 m of gravels are succeeded by 90cm of point bar sands, in turn capped by

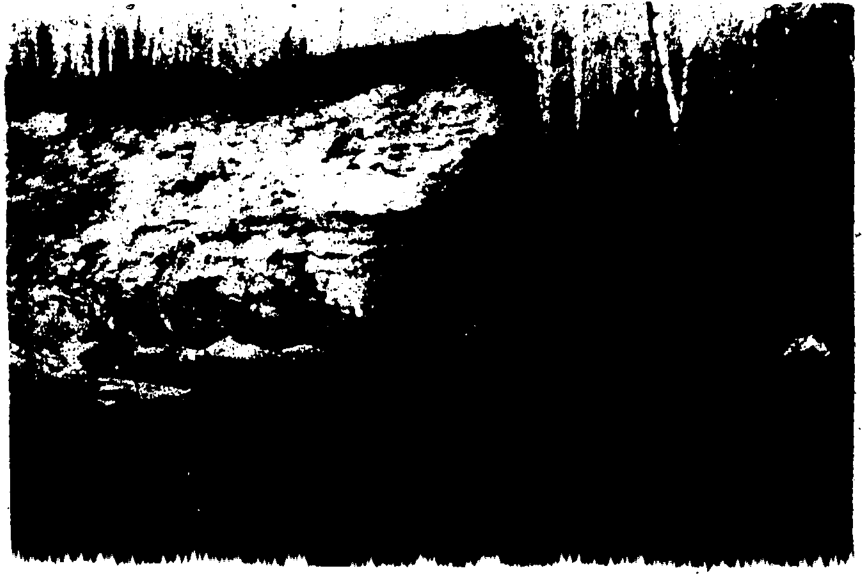
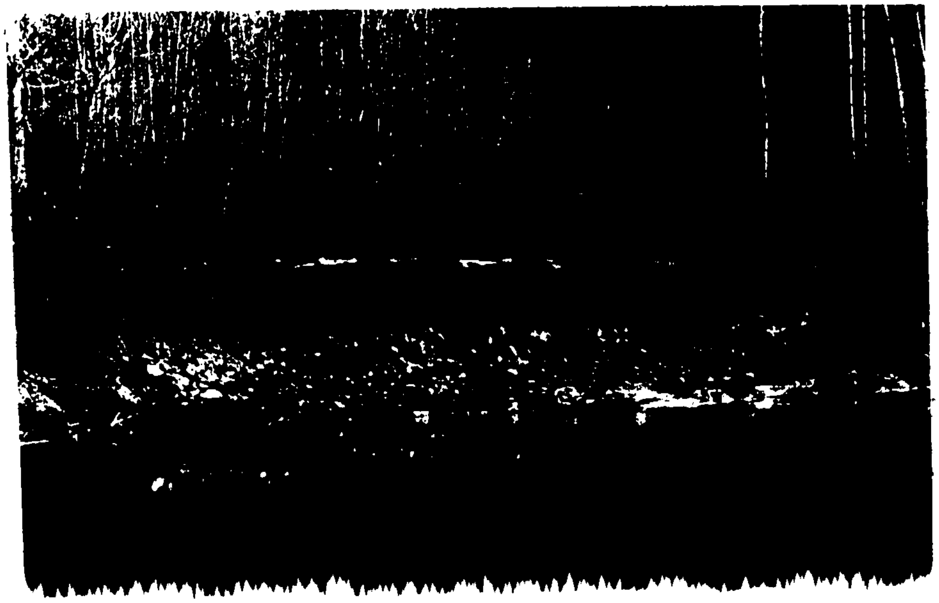


Figure 5.17a [illegible] section 10 Strawberry [illegible]

Figure 5.17b [illegible] 2 section 17 Strawberry Creek valley



10cm of overbank fines. A T-3 tread is apparent in the background of Figure 5.18b. The measured alluvial stratigraphy of these numbered terrace sections just mentioned is presented on Figures 5.19 to 5.22.

5.4 Alluvial Stratigraphy

5.4.1 Stratigraphic Sections and Their Implications

In this discussion the basic objective is to evaluate the significant stratigraphy revealed by the Holocene alluvial terrace deposits. From this evidence may be inferred the predominant depositional processes interrelated with terrace development in the valley.

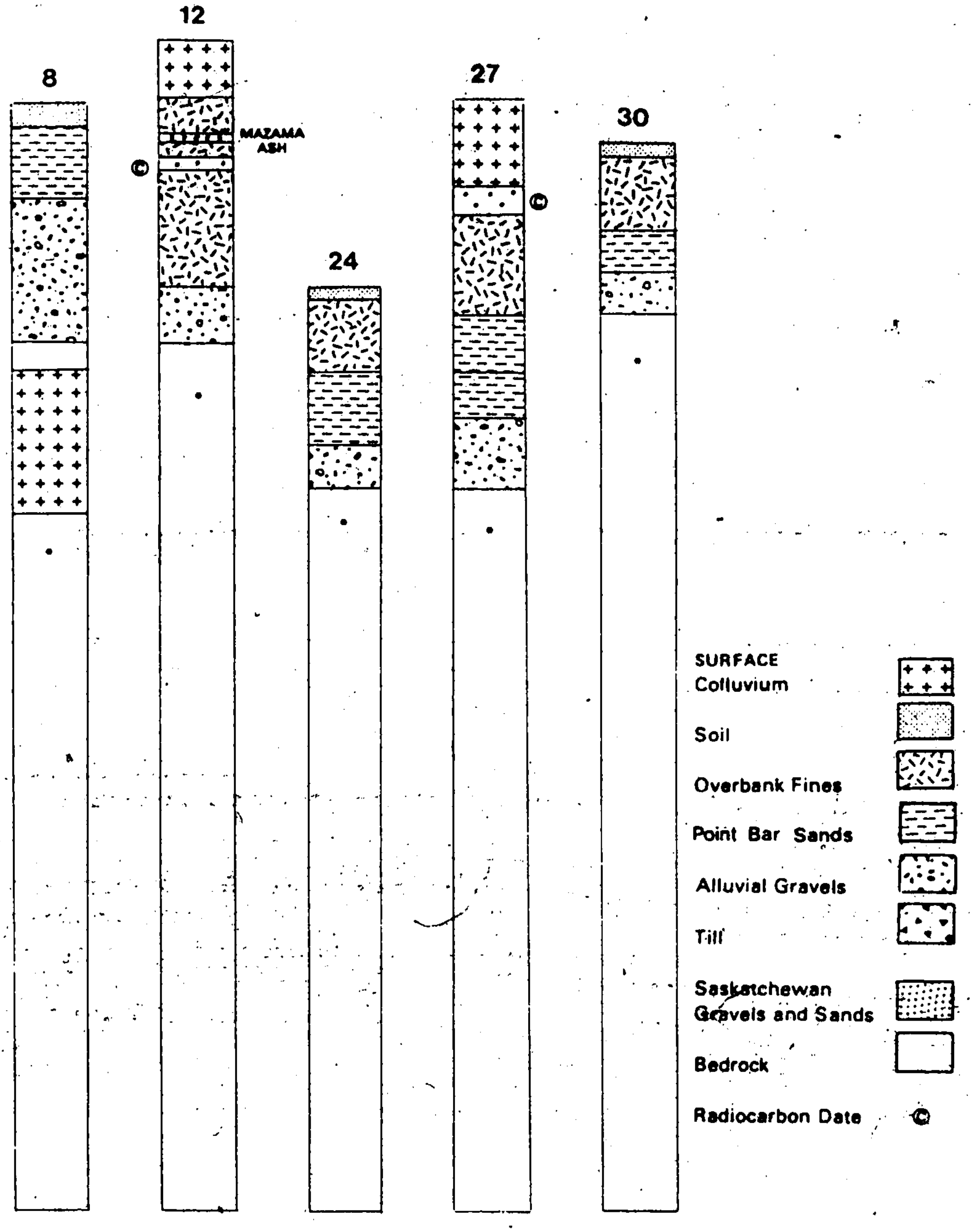
Descriptions and measurements of alluvium associated with the four remnant terraces were logged in the field by subdividing the sedimentary sequence into three main sets; (1) channel lag gravels (2) point bar sands and (3) overbank fines. The criteria used for this facies subdivision were:

(1) grain size (gravels, sands, silts, minor clays),
(2) sediment sorting and lithologic characteristics,
(3) stratification and type of bedding, and
(4) compaction (gradations from loosely, poorly, moderately to well-compacted).

The lag gravels occurring at the base of the alluvial sections were easily identified. This set represents downstream tractive transport and accumulation of coarse clasts along the main channel bed during times of high discharge and velocity. The lag gravels were formed largely by lateral accretion processes, probably in the form of riffle and pool deposits typical of the contemporary creek channels (Rains, 1969a). Point bar sands were identified and their boundaries defined by their distinctive, loosely compacted, sandy composition and primary bedding characteristics (cross-bedding, cross-laminations). These have resulted mainly from bedload transportation of sandy material with subsequent deposition by predominantly lateral accretion processes. Overbank fines, consisting mainly of finer grained, silty material with minor clay, were usually better compacted. Primary bedding structures, other than horizontal laminations, were poorly represented and this characteristic tends to indicate sedimentation by upper point bar, and overbank, vertical accretion during high discharges. Although point bar sands and overbank fines display their own distinctive characteristics, the identification of a discrete boundary between these sets is not always easy by field observation. For the purposes of this research, however, the field interpretations of the point bar sands and overbank fines are adequate and should entail only minor boundary errors.

Generalized, individual sections of the logged alluvial stratigraphies, spanning the entire terrace suite, are shown in Figures 5.19 to 5.22. The locations of the logged sections are presented in Appendix A. A generalized,

T-1 TERRACE SECTIONS

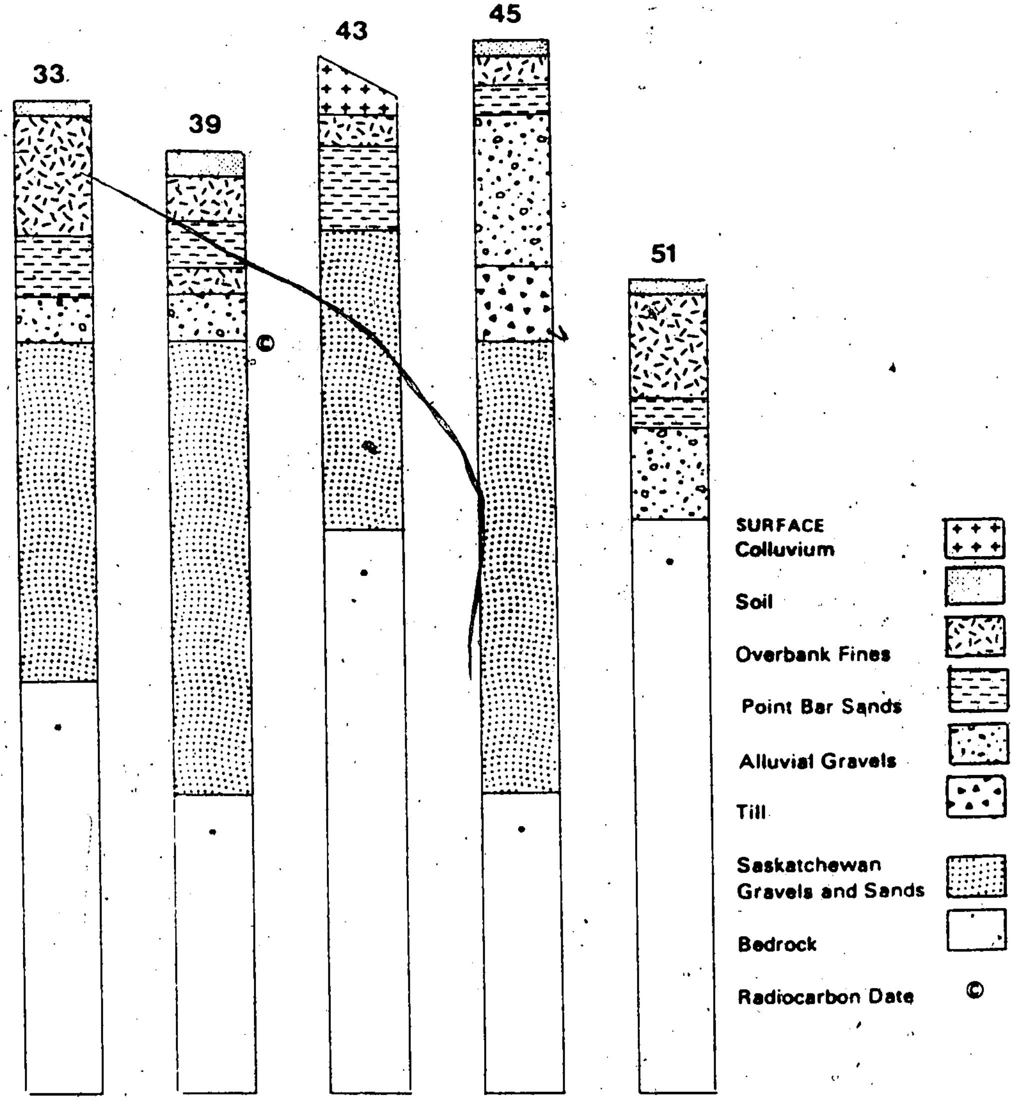


1cm = 1m (except where noted by asterisk)

*Note: Bedrock in 2m increments

Figure 5.19a. T-1 alluvial stratigraphic sections.

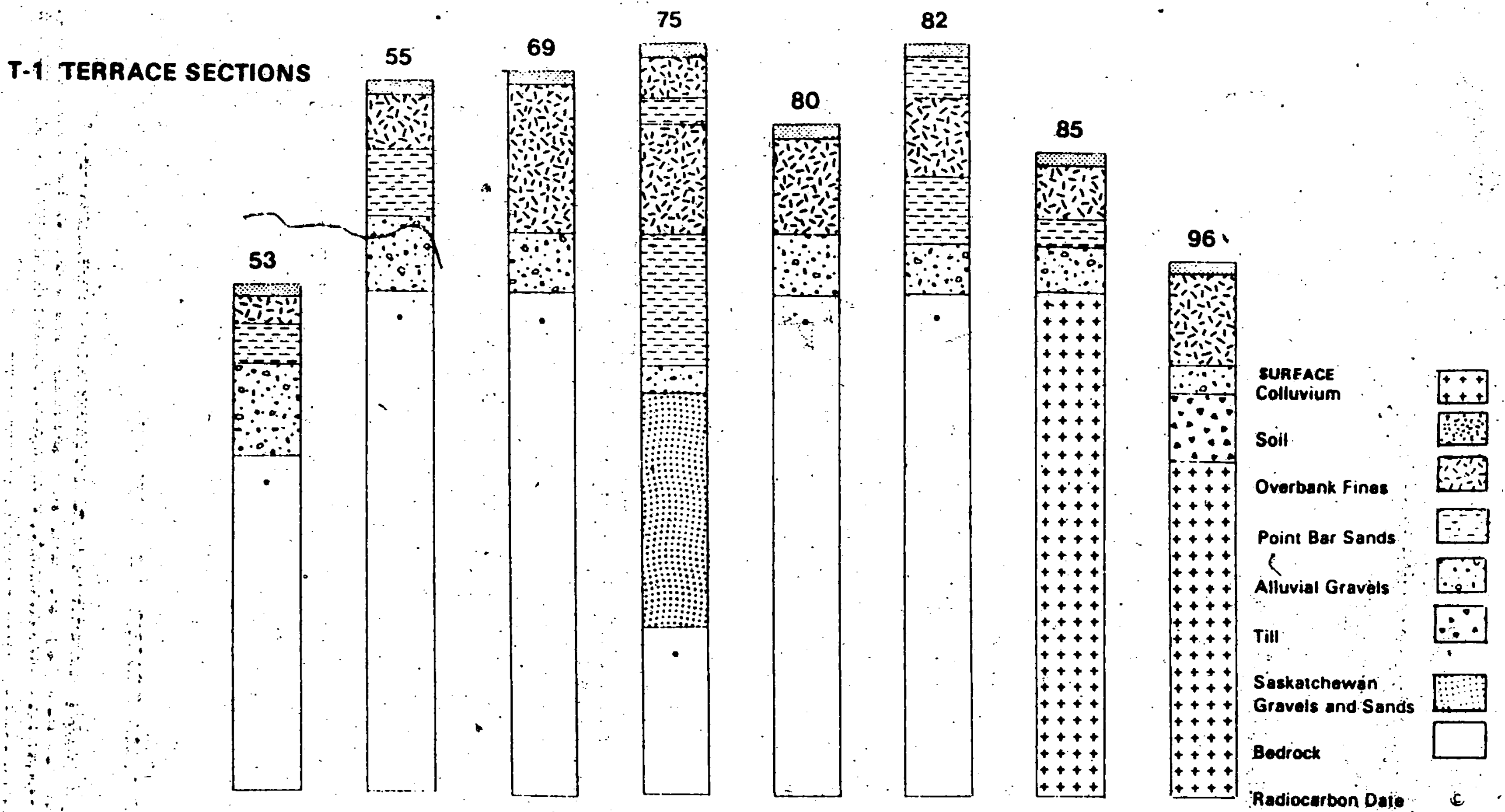
T-1 TERRACE SECTIONS



1cm = 1m (except where noted by asterisk)

*Note: Bedrock in 2m increments

Figure 5.19b. T-1 alluvial stratigraphic sections.



1cm = 1m (except where noted by asterisk)

*Note: Bedrock in 2m increments

Figure 5.19c. T-1 alluvial stratigraphic sections.

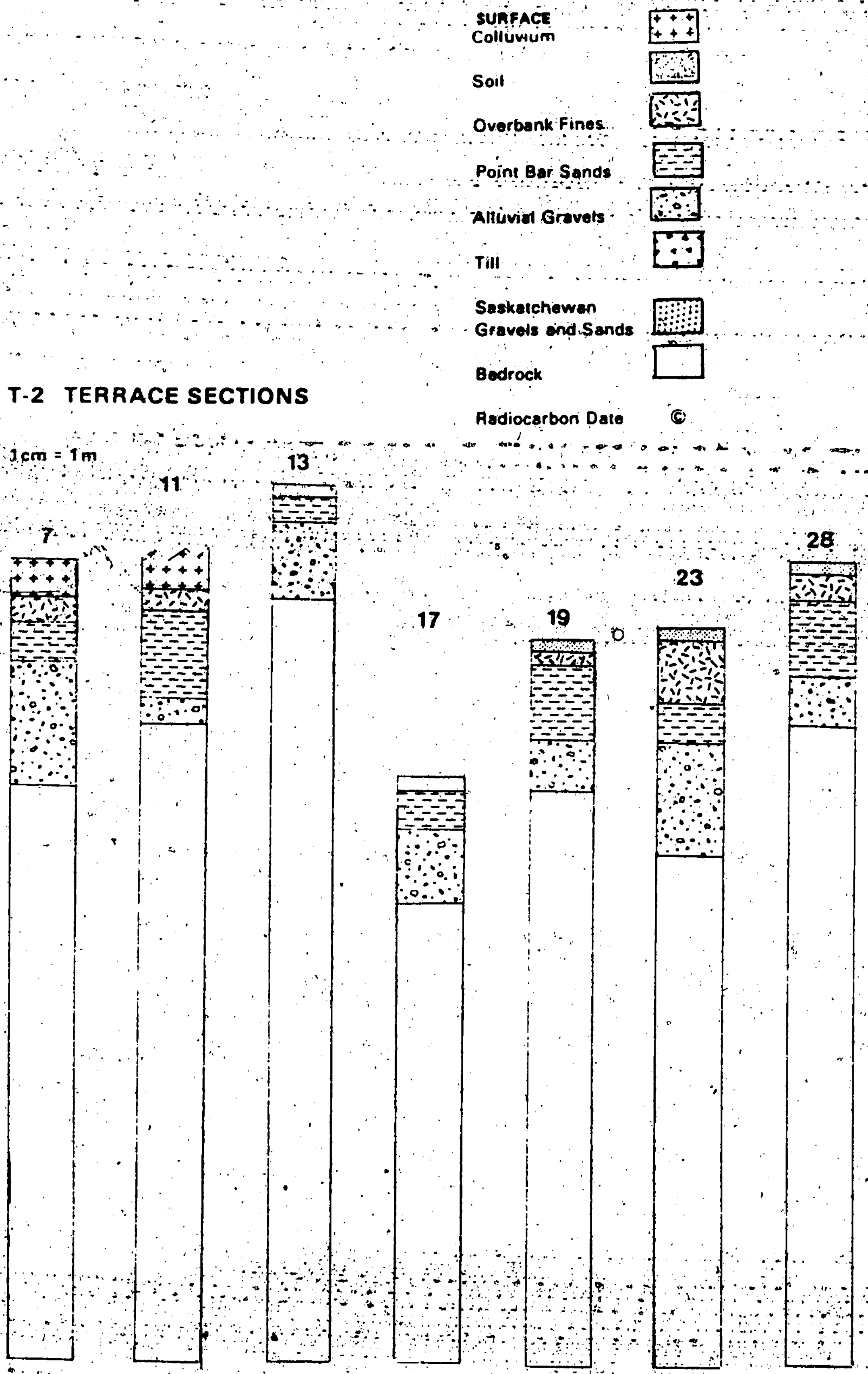


Figure 5.20a. T-2 alluvial stratigraphic sections.

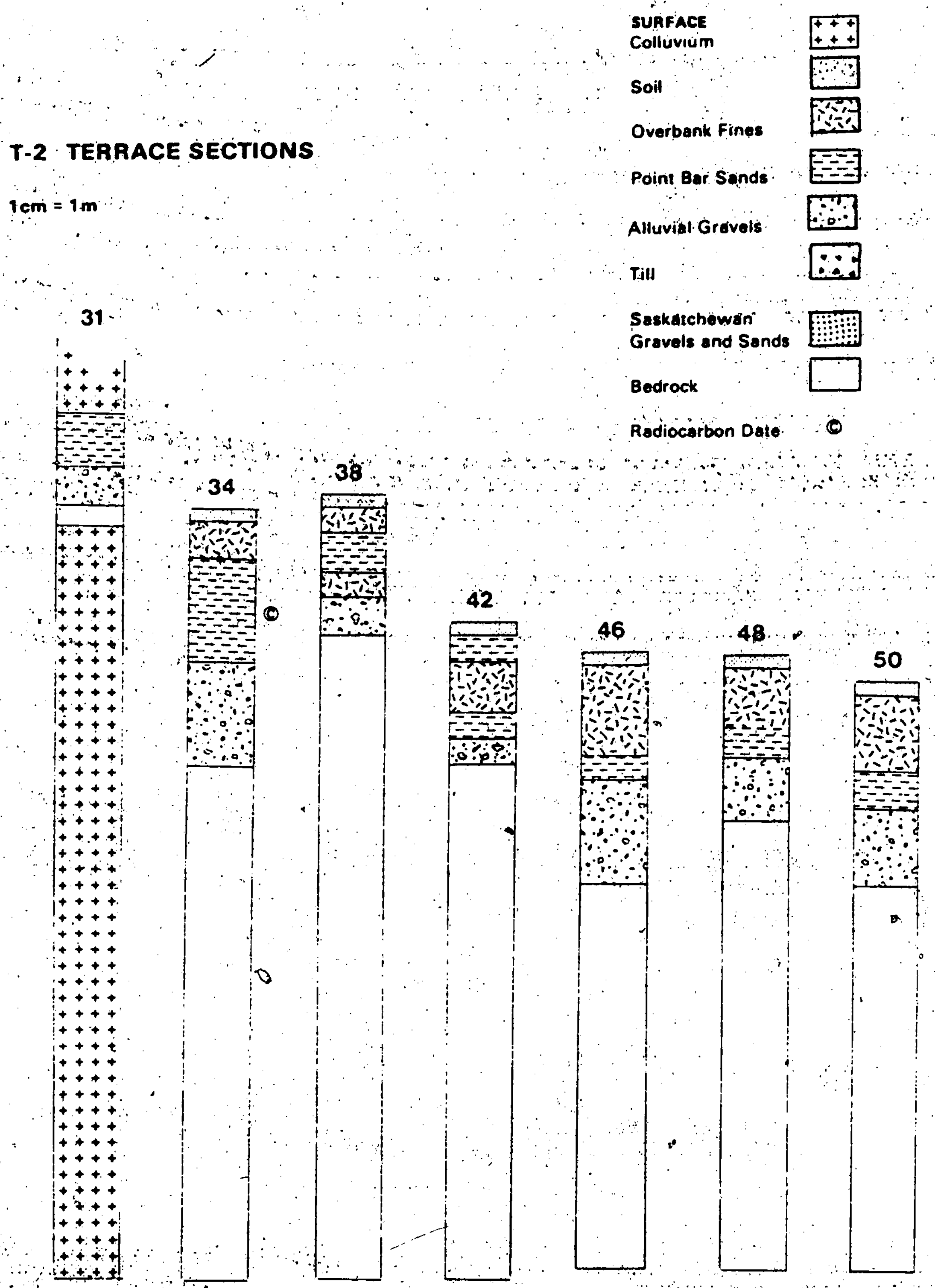


Figure 5.20b. T-2 alluvial stratigraphic sections.

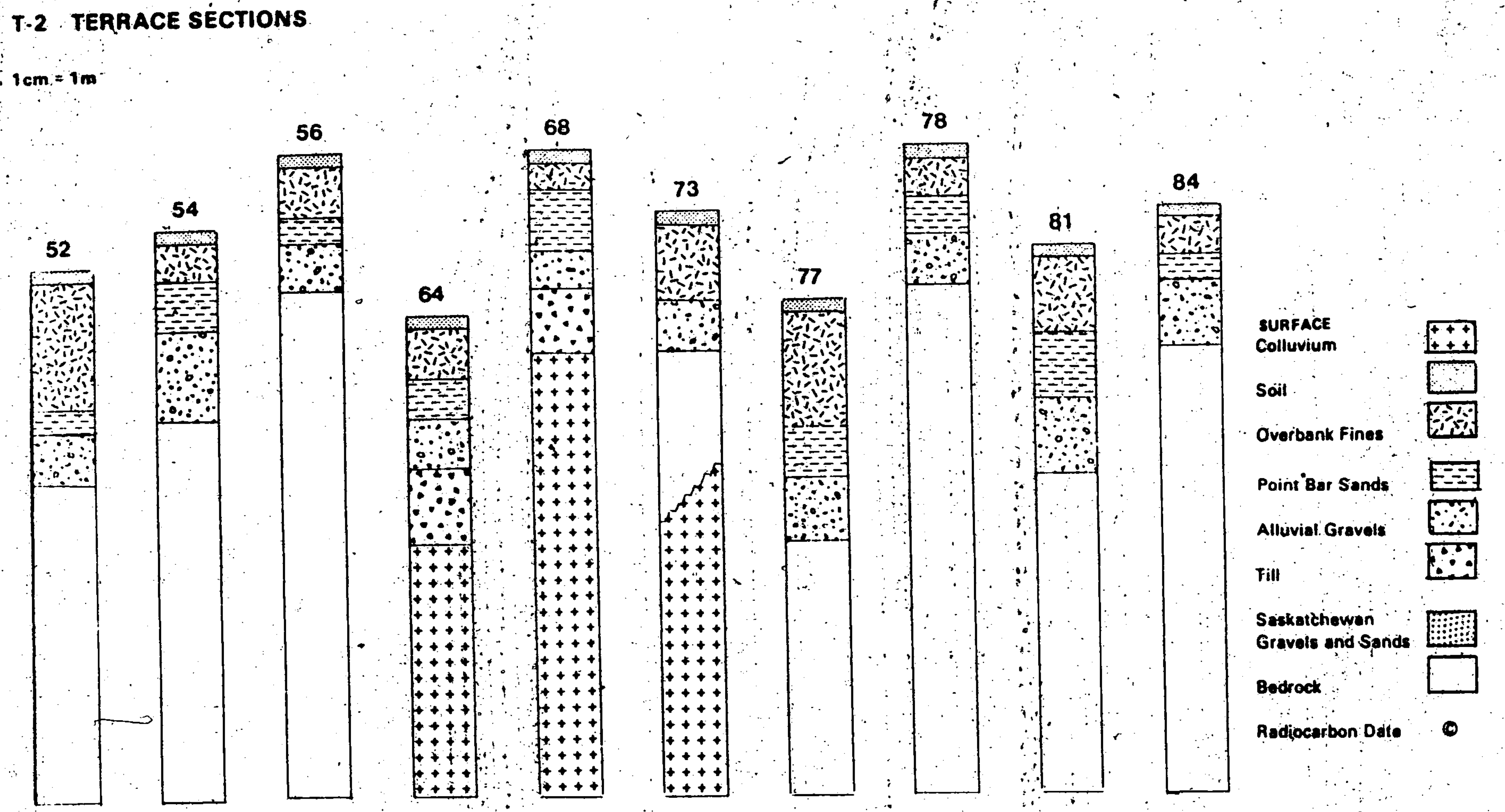


Figure 5.20c. T-2 alluvial stratigraphic sections.

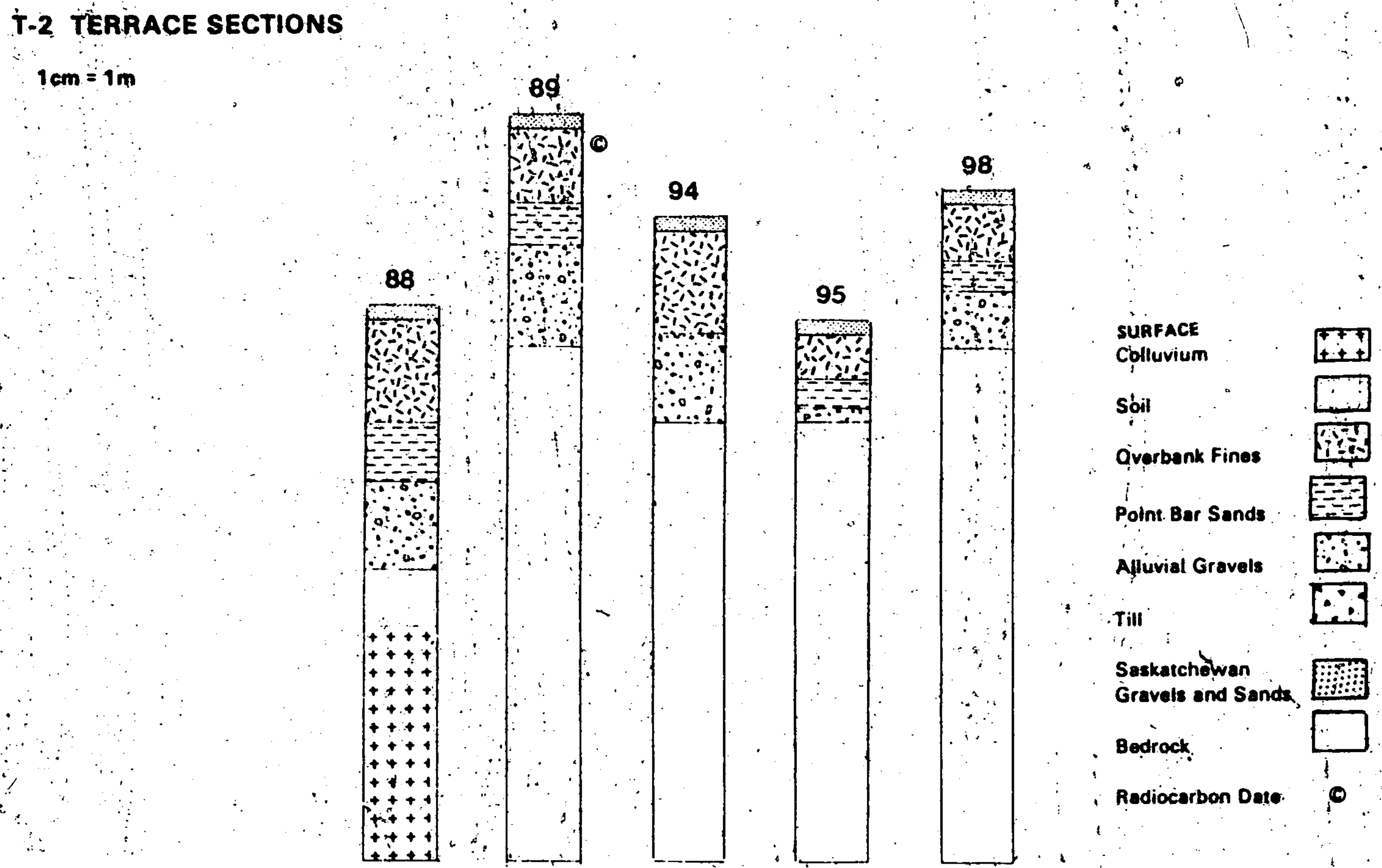


Figure 5.20d. T-2 alluvial stratigraphic sections.

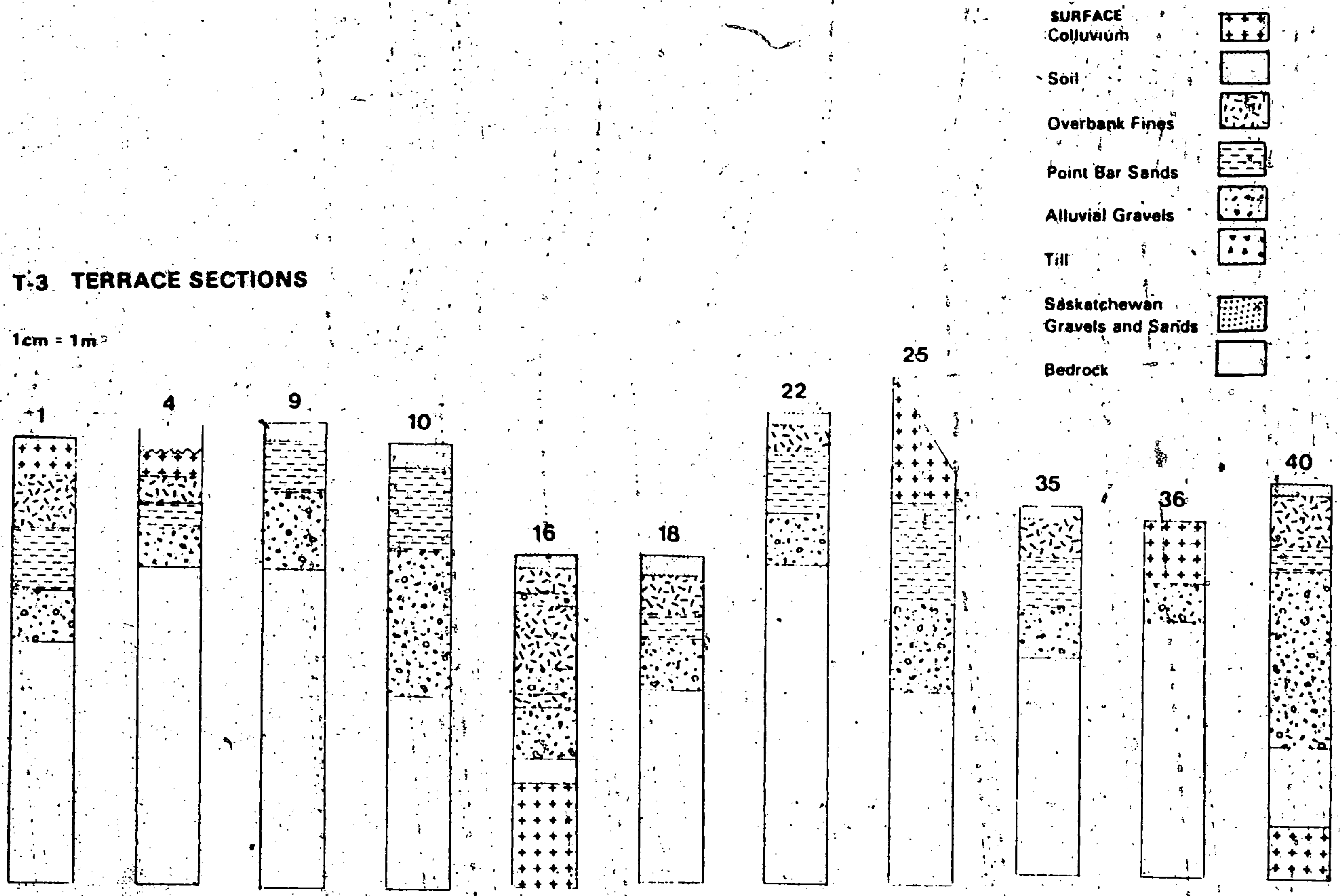
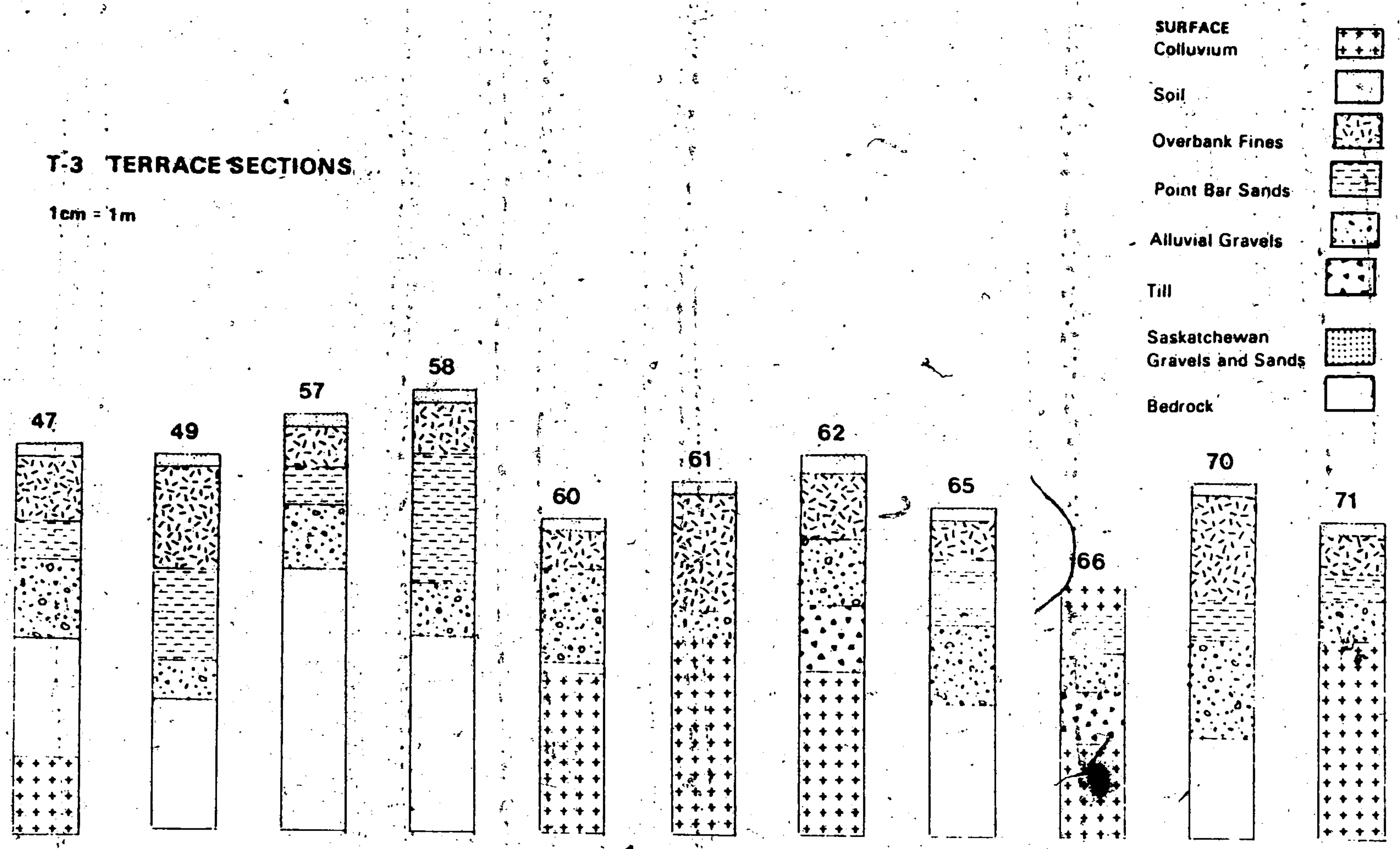


Figure 5.21a. T-3 alluvial stratigraphic sections.



T-3 TERRACE SECTIONS

1cm = 1m

Figure 5.21b. T-3 alluvial stratigraphic sections.

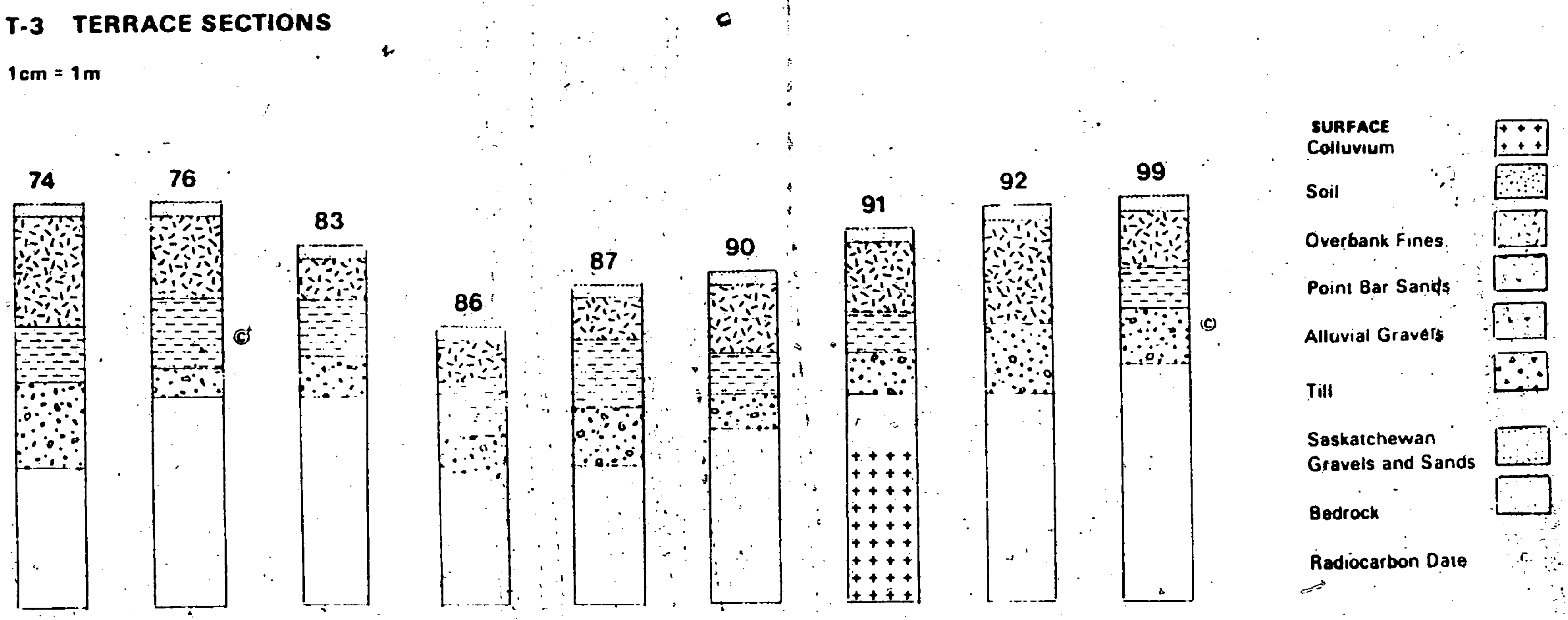


Figure 5.21c. T-3 alluvial stratigraphic sections.

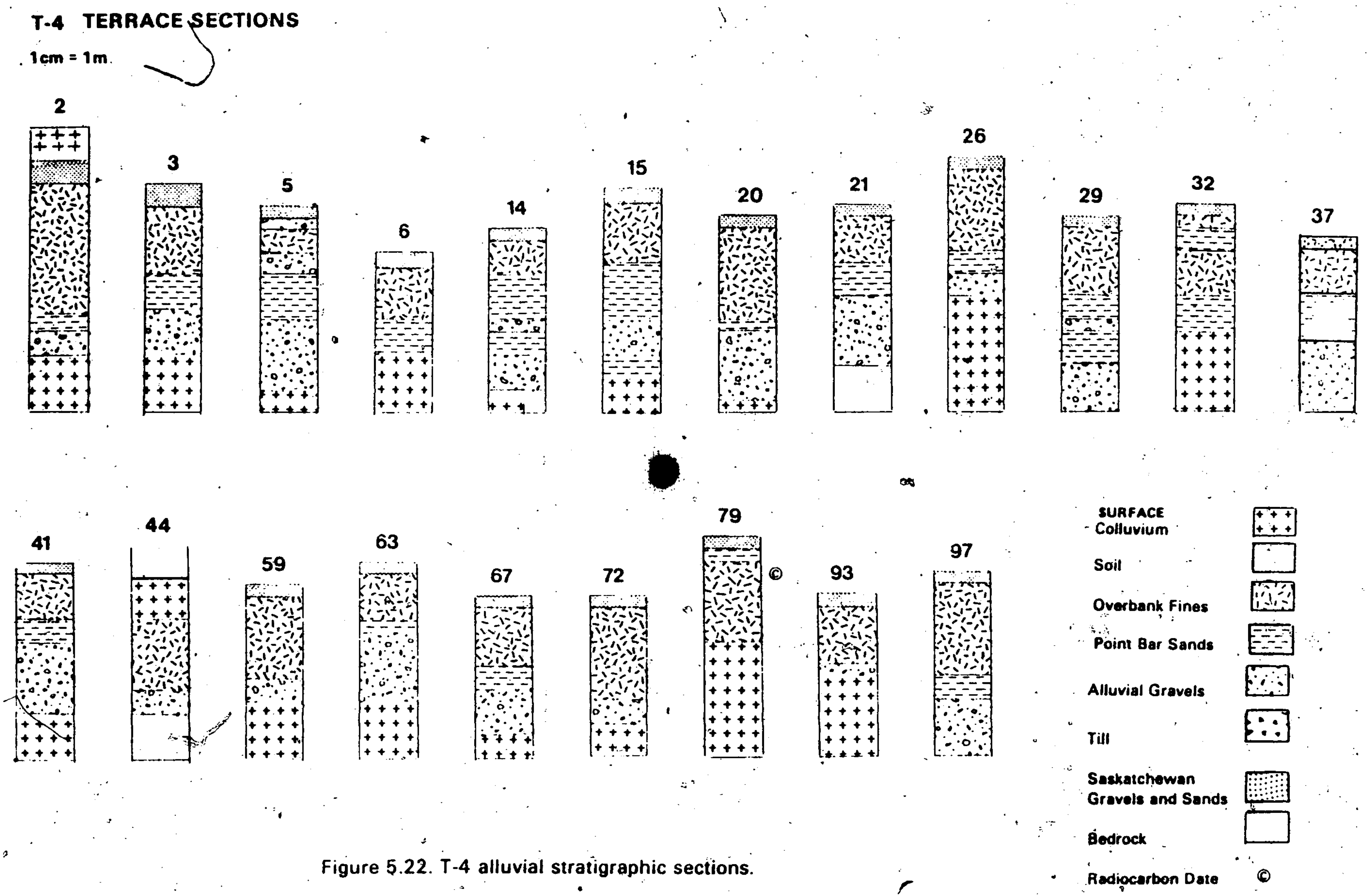


Figure 5.22. T-4 alluvial stratigraphic sections.

composite section which displays the predominant stratigraphy of Strawberry Creek terrace alluvium is presented in Figure 5.23. The thickness of individual sets in Figure 5.23 represents the average measured thickness for the generalized sections. This diagram indicates that the alluvial depositional environments during the four stages of terrace aggradation were related to sinuous or meandering channel systems. Figure 5.23 represents the typical alluvial exposure in the Strawberry Creek, yet for many of the alluvial exposures, sets of point bar sands or overbank fines were absent as is evident from the generalized sections presented. Deviations from the normal, fining-upward, stratigraphic sequence of lag gravels, point bar sands and overbank fines is indicative of neck and chute cutoffs, inherent in a meandering channel system.

A controversy that exists in contemporary fluvial geomorphology literature involves the assumed predominance of either lateral or vertical accretion in floodplain formation (Stene, 1980) Wolman and Leopold (1957) favored lateral accretion as the main depositional process but Schumm and Lichty (1963), from field observations, contended that vertical accretion was the major alluvial depositional process. Vertical accretion was found to dominate the form of alluvial deposition in the study of Ritter et al., (1973). Regardless of different observations on the type of sedimentation dominance in individual study areas local conditions must necessarily determine the major mode of

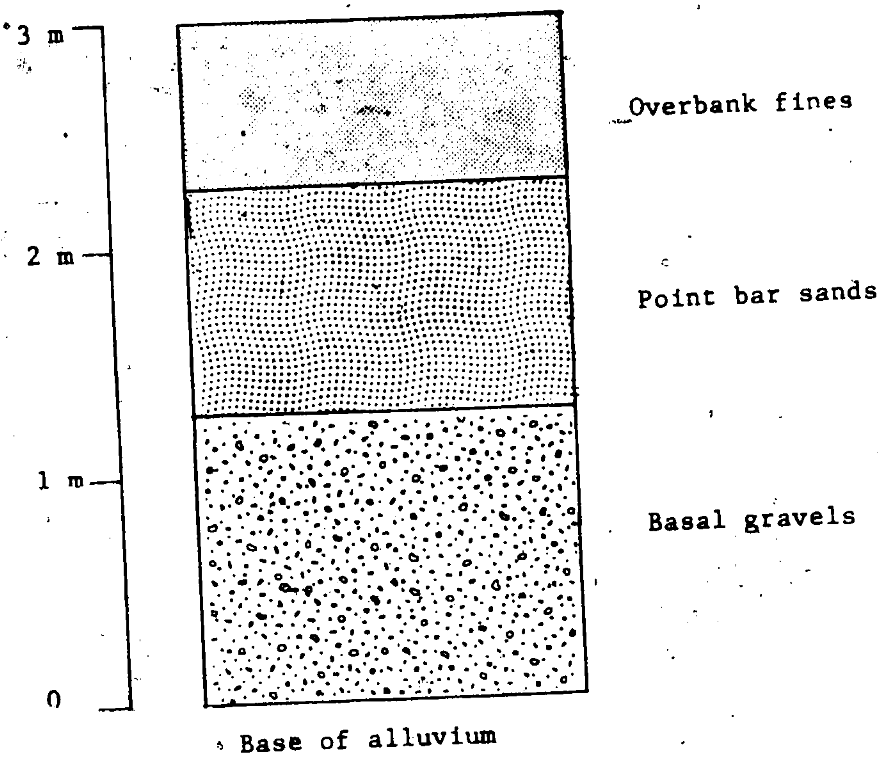


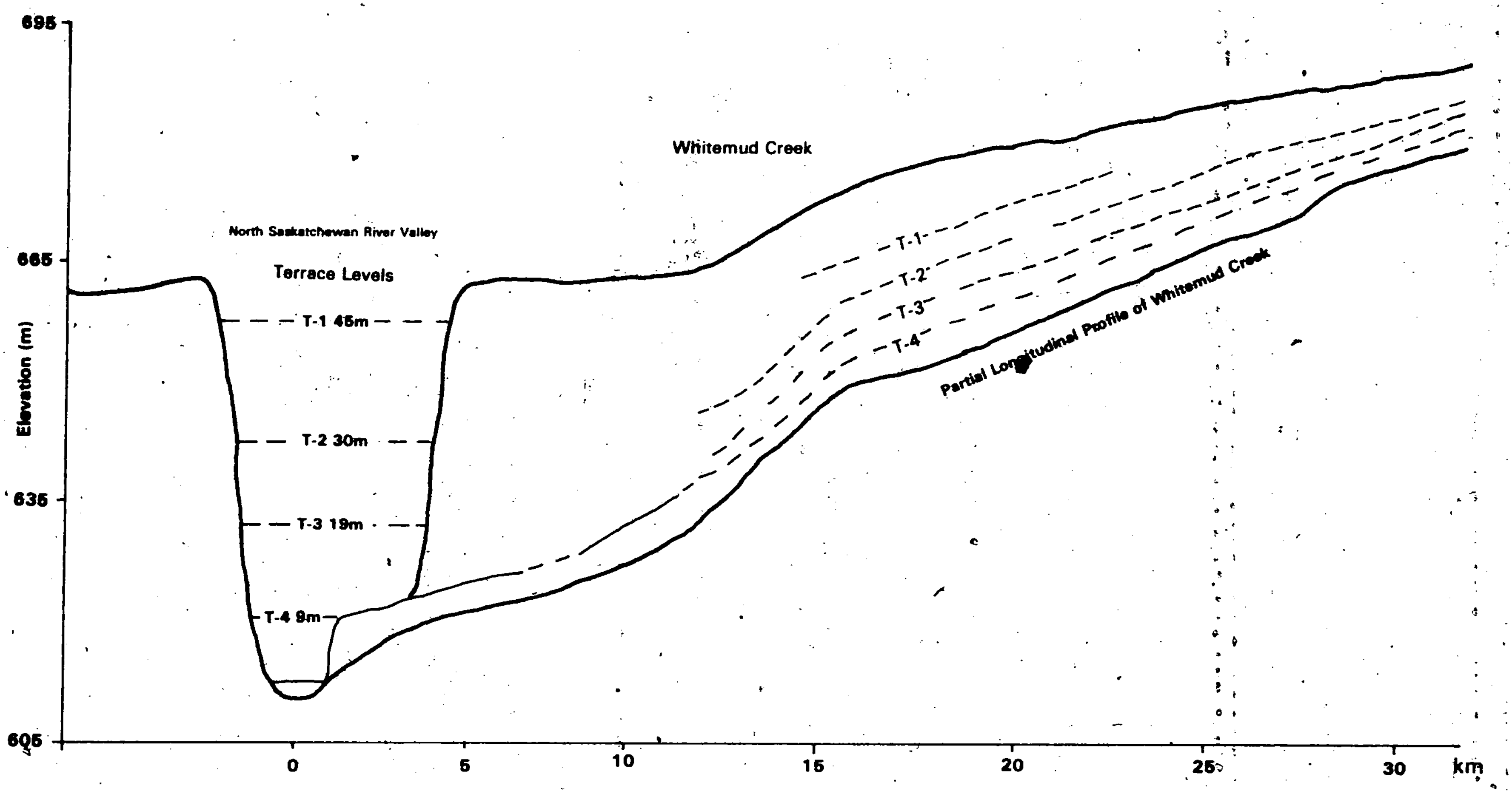
Figure 5.23. Composite section of Strawberry Creek terrace alluvium.

deposition. Local sedimentological and environmental attributes of a particular area are important depositional control variables. Local relief, climate and flooding habits thus relate directly to modes of floodplain deposition (Baker, 1977). From the generalized alluvial sections of this study area it is evident that the dominant processes of Holocene alluvial deposition in the Strawberry Creek valley have involved lateral accretion. The long-continued dominance of lateral accretion also allows some inference as to the nature of environmental factors related to the valley development through Holocene time.

5.5 Regional Correlation

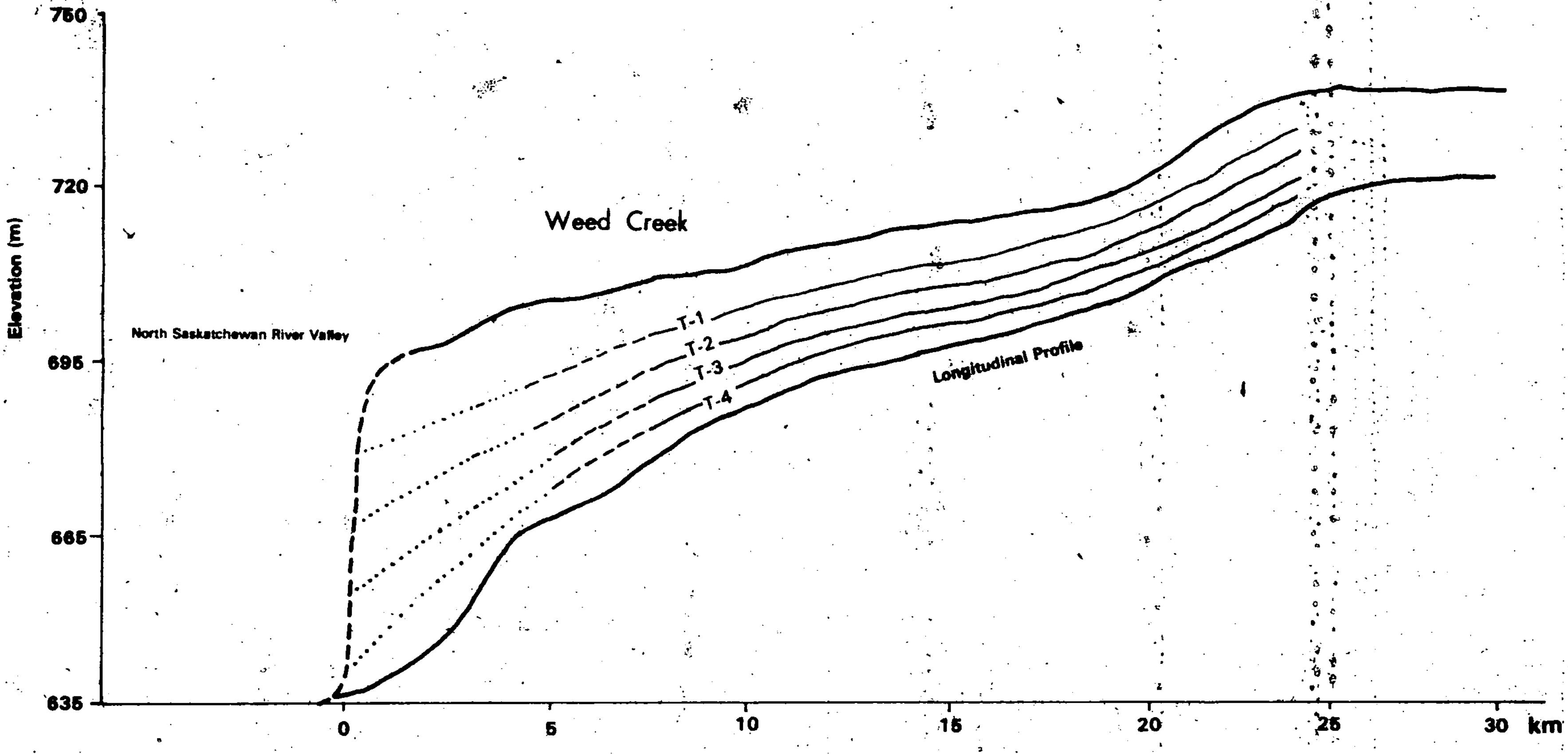
In Chapter 2 the studies of Rains (1969a) and Shelford (1975) were briefly reviewed and obvious similarities between the Whitemud, Weed and Strawberry Creek basins were mentioned. To further strengthen the inferred correlation between the three tributary basins relevant diagrams from their earlier work may now be compared with a similar diagram for the Strawberry Creek study.

Rains (1969a) and Shelford (1975) presented figures for their study basins showing terrace heights plotted above the long-channel profiles. Figure 5.24, for the Whitemud Creek (Rains, 1969a), and Figure 5.25 for the Weed Creek (Shelford, 1975), are reproduced for comparison with Figure 5.10 of the Strawberry Creek valley. The tributaries all



(Modified from Rains, 1969a)

Figure 5.24. Whitemud Creek: Terrace heights plotted above longitudinal channel profile.



(Modified from Shelford, 1976)

Figure 5.25. Weed Creek: Terrace heights plotted above longitudinal channel profile.

display composite concave-convex longitudinal profiles. In addition the terrace suites of the three valleys embody four main terrace levels. It may be seen in Table 2.3 that the average terrace heights above the contemporary channels, in downstream sectors of the three valleys, are mutually consistent.

It is evident that a strong morphological similarity exists between the tributary valleys. As reviewed in Chapter 2, the regional location, lithological foundation, area and relief of the three basins are relatively similar. It may be concluded that the three tributaries have probably evolved time-synchronously and have responded to individual development "controls" by evolving nearly identical morphological attributes.

5.6 Chronology of Valley Development

5.6.1 Objective

A chronologic framework for the valley cut and fill terrace development has been reconstructed on the basis of numerous radiocarbon dates, and the identification of Mazama Ash (Table 5.1) in one section of Strawberry Creek alluvium. The radiocarbon dated material includes bone, shell, wood and charcoal. Strawberry Creek sites yielded nine dates, and the Mazama Ash, while sites in the Whitemud Creek valley provided eight additional dates.

TABLE 5.1. ELECTRON PROBE ANALYSIS OF STRAWBERRY CREEK MAZAMA ASH.

	Published Averages (%) for Mazama Ash (Smith and Westgate, 1969)	Strawberry Creek Mazama Ash. Analysis by Pam Waters, Dept. of Geology, Univ. of Alberta
Na	5.23 ± 0.16	5.542
Mg	0.53 ± 0.03	0.458
Al	14.85 ± 0.17	14.338
Si	72.27 ± 0.65	73.215
K	2.67 ± 0.04	2.713
Ca	1.61 ± 0.04	1.344
Ti	0.49 ± 0.02	0.416
Mn	0.04 ± 0.01	0.050
Fe	2.02 ± 0.05	2.137 (Corr. value)

Composite cross-sections (Figure 5.26) of both the Strawberry and Whitemud Creek valleys delimit the four individual phases of terrace development with related dates. Appendix B details the alluvial stratigraphy for each of the Strawberry Creek dating sites. The sites described in Appendix B are arranged in chronologic order and individual dated sections are referenced by the dating laboratory designations. Also, throughout the chronologic discussion, the dated Strawberry Creek samples are referred to by related section numbers from Figures 5.19 to 5.22 with site locations presented in Appendix A. Each valley development phase will be discussed in terms of significant, related dates.

5.6.2 Phase I (T-1)

Materials furnishing four dates, and Mazama Ash, have been found in Strawberry Creek T-1 alluvium. Section 12 (Figure 5.27) fortuitously displayed the Mazama Ash, approximately dated at 6600 yrs. B.P., (Westgate et al., 1969). Prior to the deposition of the ash a paleosol developed indicating a relatively inactive fluvial environment at that site. The paleosol provided abundant charcoal fragments which dated at 8660 ± 125 yrs. B.P., (S-1926). The second oldest date for T-1 alluvium came from another exposure (section 39) in which the T-1 basal gravels and sands yielded bi-valve mollusc shells dated at 8015 ± 135 yrs. B.P., (S-1787). The deposition of the Mazama Ash

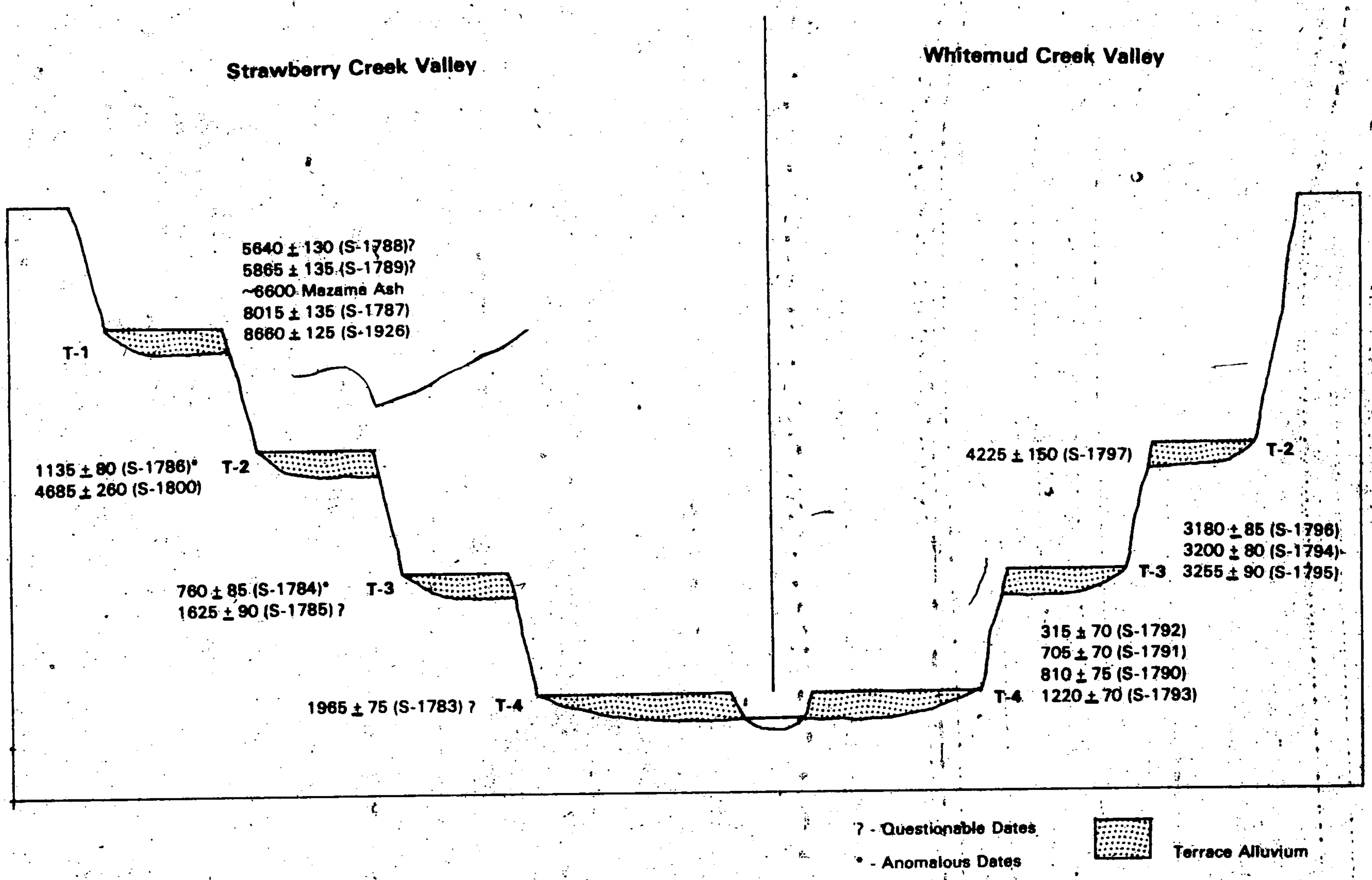


Figure 5.26. Composite cross-section of the Strawberry and Whitemud Creeks with representative radiocarbon dates.

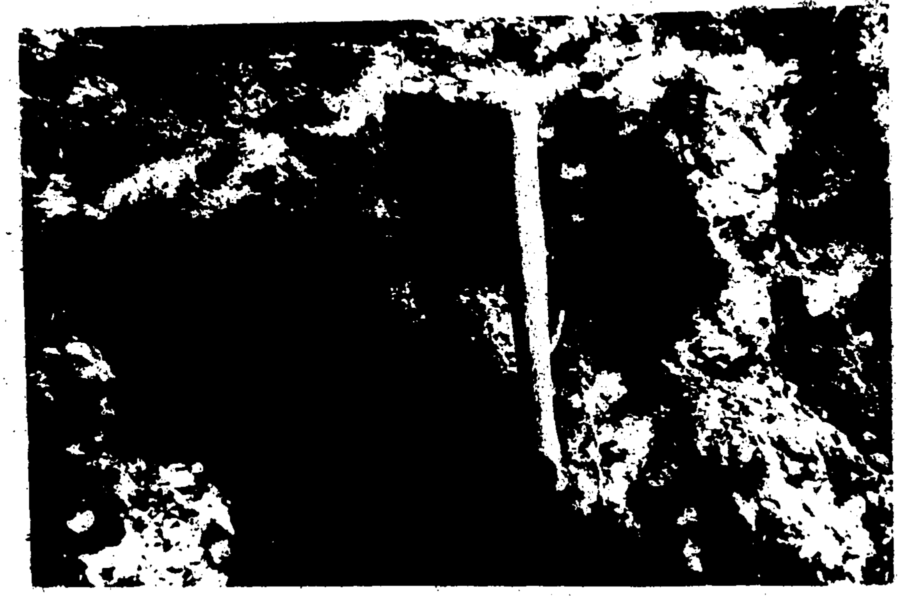


Figure 5.27. Mazama Ash with underlying dated paleosol. Mazama Ash horizon at the top of geology pick handle. Dated paleosol indicated by hammer head.

appears to have been followed by a period of alluvial aggradation. Related overbank fines include a dark grey, humus-rich organic band.

The dates of 5865 ± 135 yrs. B.P., (S-1789) and 5640 ± 130 yrs. B.P., (S-1788), associated with T-1 sites are stratigraphically questionable, but are not totally improbable in the chronologic sequence. The latter date was obtained for a <u>Canis lupus</u> (wolf) right mandible which was found on the surface of the terrace scarp well above the contemporary terrace floodplain at section 39, but not <u>in situ</u> of the alluvial or soil material. The bone appeared to have recently fallen out of the T-1 alluvium. The date of 5865 ± 135 yrs. B.P. (S-1789), obtained for bison bone from section 27, is questionable because the bone was extracted from a position directly on top of overbank fines, in a grey clay band associated with apparent mass-movement debris. No paleosol horizons were observed separating the overbank fines from the clay band. This may reflect a relatively small time interval between alluvial deposition and the slump, but such an interpretation is obviously speculative. However, these two dates are certainly not inconsistent with the general stratigraphy of T-1 alluvium as illustrated at section 12 (Appendix B).

Thus it appears that following deglaciation, and drainage of the regional proglacial lake systems, the initial, post glacial, Strawberry Creek began incision and attained relative stability at the T-1 level by approximately 8500 years ago. The T-1 channel remained close to this level, and was still partially aggrading, following the deposition of Mazama Ash at 6600 years B.P., and possibly as late as 5600-5900 years B.P..

5.6.3 Phase II (T-2)

Four dates are available for T-2 alluvium which formed after an incision episode below the floodplain level of T-1. A date of 1135 ± 80 yrs. B.P., (S-1786) was derived from a bison skull in Strawberry Creek, section 89. This T-2 date is most anomalous and appears to be far too young. The skull was extracted from the uppermost portion of the overbank fines only 55 cm below the terrace tread. The skull may have been contaminated with new carbon or, alternatively, it might have been buried by human or animal agents.

Sharma (1973) obtained a date from T-2 alluvium in the distal reach of the Weed Creek valley. A date of 1075 ± 80 yrs. B.P., (no laboratory number given) was yielded by charcoal found in the uppermost 65 cm of terrace alluvium, which Sharma (1973) described as sandy loam. He attributed the sandy loam alluvium to overbank deposition of recent flood deposits, enhanced by high magnitude floods of the North Saskatachewan River. Thus the stratigraphic position, and character of the material encasing this dated charcoal, suggest that its formation is probably not related to the main T-2 aggradation phase.

A date of 4685 ± 260 yrs. B.P., (S-1800) was obtained for a bone fragment buried in T-2 alluvium (section 34) in the Strawberry Creek valley. In addition, a date of 4225 ± 150 yrs. B.P., (S-1797) is available from the Whitemud Creek T-2 alluvium. For Phase II these two dates suggest that incision, with subsequent stability and aggradation of T-2 alluvium, may have been achieved by about 5000 years B.P. and that the T-2 system was actively aggrading at approximately 4000 years B.P.

5.6.4 Phase III (T-3)

Six dates are available from T-3 alluvium. Three dates are from the Whitemud Creek valley, one from the Strawberry Creek valley, and one from the Weed Creek valley. The Weed Creek information is tentatively extrapolated for T-3 from Shelford (1975) who obtained a bison bone date of 2765 ± 90 yrs. B.P. (S-804) for terrace alluvium he considered to be that of T-4. Shelford (1975) stated that this dated terrace section had a bedrock-basal gravel contact at 9.5 ft (3 m) above the channel, and that the top of the alluvial section (the terrace tread) has an elevation of 15 ft (4.5 m) above the present channel. From these height dimensions it is interpreted that Shelford's (1975) dated terrace section may be at least intermediate between T-3 and T-4, and is probably more closely related in height and age to T-3.

In the Whitemud Creek valley three T-3 dates were obtained from the same alluvial section and these provide a strong, consistent base for the general chronologic framework of T-3. The Whitemud T-3 section from which the three dates come is of critical interest in that it reveals a relict beaver dam constructed across the former T-3 channel, approximately 4 m above the contemporary creek. A date of 3180 ± 85 yrs. B.P., (S-1796) is from beaver dam wood while the other two dates, 3200 ± 80 yrs. B.P., (S-1794) and 3255 ± 90 yrs. B.P., (S-1795), are from bison bones trapped in the beaver dam materials. These strikingly similar dates, on wood and bone from the same section, very strongly substantiate that the channel was at the T-3 basal alluvium level about 3000 years B.P., or somewhat earlier.

In the Strawberry Creek valley two exposures of T-3 alluvium have furnished bone material suitable for dating. A bison skull was extracted from lag gravels 30 cm above the base of one section (section 99). This skull was dated at 1625 ± 80 yrs. B.P., (S-1785), but the date may be questionable in relation to the general chronologic framework. Another exposure yielded a bison vertebra from point bar sands (section 76). This sample dated at 760 ± 85 yrs. B.P., (S-1784) and also presents a questionable, if not anomalous, fit in the chronologic framework. An exact reason for the significant chronologic divergence of the two dates from those of the critical Whitemud Creek site is not known. However, it will become evident from the presentation of the Phase IV (T-4) chronology, that these dates probably entail an unknown error factor, and appear too young to be contemporaneous with the bulk of T-3 sedimentation.

5.6.5 Phase IV (T-4)

Five dates are available from T-4 alluvium. A Strawberry Creek T-4 deposit (section 79) was dated, from a bison bone sample, extracted from overbank fines, at 1965 ± 75 yrs. B.P., (S-1783). The age and stratigraphic position of this bone suggest that it was possibly re-deposited from older materials. The Whitemud Creek valley has yielded four T-4 dates on bone and wood samples, ranging in age from about 300 to 1200 years B.P. Two dates from separate bison bones were extracted from the same T-4 Whitemud Creek alluvial section. The stratigraphically lower sample dated at 705 ± 70 yrs. B.P., (S-1791) and the stratigraphically higher sample dated at 810 ± 75 yrs. B.P., (S-1790). At another Whitemud Creek T-4 alluvial section, a bison scapula was extracted from overbank fines and was dated at 1220 ± 70 yrs. B.P., (S-1793). The youngest date available for T-4 alluvium, also in the Whitemud Creek valley, is from a buried tree trunk in overbank fines. This wood dated at 315 ± 70 yrs. B.P., (S-1792).

In summary of Phase IV chronology, it can be stated that the channel had incised from the T-3 level and reached stability at the T-4 level possibly by about 1900 years B.P. but almost certainly by 1300 years B.P.. Since that time the predominant fluvial processes of the channel have reflected lateral channel migration with only minor incision.

5.7 Conclusions

The alluvial chronologic sequence has been developed on the basis of seventeen radiocarbon dates, the presence of Mazama Ash, and two previously published dates. The relative morphological stages of valley development had been previously defined by Rains (1969a) and Shelford (1975). The present work refines the chronological sequence of those morphological stages. To arrive at this chronological framework from the available dates it was necessary to reject three apparently anomalous dates and reinterpret the stratigraphic position of a date reported by Shelford (1975). This is not considered to be "tampering" with the data, because inconsistencies often occur when dealing with radiocarbon dates. The fact that a total of fourteen dates are mutually consistent provides substantial verification for a satisfactory, general chronology of the tributary valley development stages, indicated by their alluvial terraces.

Thus, in summary, the evidence presented on the morphology, distribution, stratigraphy and chronology of remnant alluvial terraces, specifically for the Strawberry Creek valley, but with correlative interpretation for the the Whitemud and Weed Creek systems, shows that:

(1) A suite of four terraces exists in each valley.

(2) The terrace remnants display prominently paired characteristics.

(3) The three creeks display composite, concave-convex

long-profiles.

(4) The stratigraphies of the alluvium are related to persistent depositional environments of sinuous or meandering channel systems.

(5) Lateral accretion was the dominant mode of floodplain sedimentation throughout Holocene time, but vertical accretion of overbank fines was also significant.

(6) The geomorphic development of the Strawberry, Weed and Whitemud Creek valleys was generally time-synchronous, and resulted in very similar morphologic and alluvial stratigraphic characteristics.

(7) The general alluvial chronology now established is;
(a) Phase I (T-1): from some time before 8600 years B.P., until possibly as late as 5600-5900 years B.P.
(b) Phase II (T-2): approximately 4000-5000 years B.P.,
(c) Phase III (T-3): circa 3200 to 2800 years B.P., and (d) Phase IV (T-4): from at least 1300 years B.P., partially including modern lateral and vertical accretion sediments.

Furthermore, from the evidence presented in Chapter 2, it must be stressed that the sequential phases of morphological development of the North Saskatchewan River and the three local tributaries have not been time-synchronous. The North Saskatchewan River valley achieved most of its valley deepening relatively early in Holocene time. The tributary valleys, in contrast, lagged behind and have developed much of their form in late Holocene time.

6. INTERPRETATIONS AND CONCLUSIONS

6.1 Introduction

Preceding chapters have outlined the characteristic morphologies and Holocene chronologies of the North Saskatchewan River valley and three, local, tributary valleys in part of central Alberta. Figure 6.1 illustrates the major disparity between the generalized progression of valley incision of the North Saskatchewan River valley and Strawberry Creek valley, representing the three tributaries. This finding diverges from the common assumption that tributaries are strongly controlled by, or respond directly to, geomorphic adjustments of the master stream. Leopold and Bull (1979) recently discussed examples of ephemeral channels which also contest that assumption and, conversely, they proposed that the influence of local base-level on the longitudinal profile of tributary streams extends only a short distance upstream.

In the present study field evidence, with radiometric dating, indicates that valley deepening by the tributary creeks has taken place at quite different times than for the North Saskatchewan River which acts as their local base-level. The clearest morphological expression of this is the persistent preservation of an over-steepened reach in the downstream segments of the tributary valleys. There is no simple explanation for the preservation of the

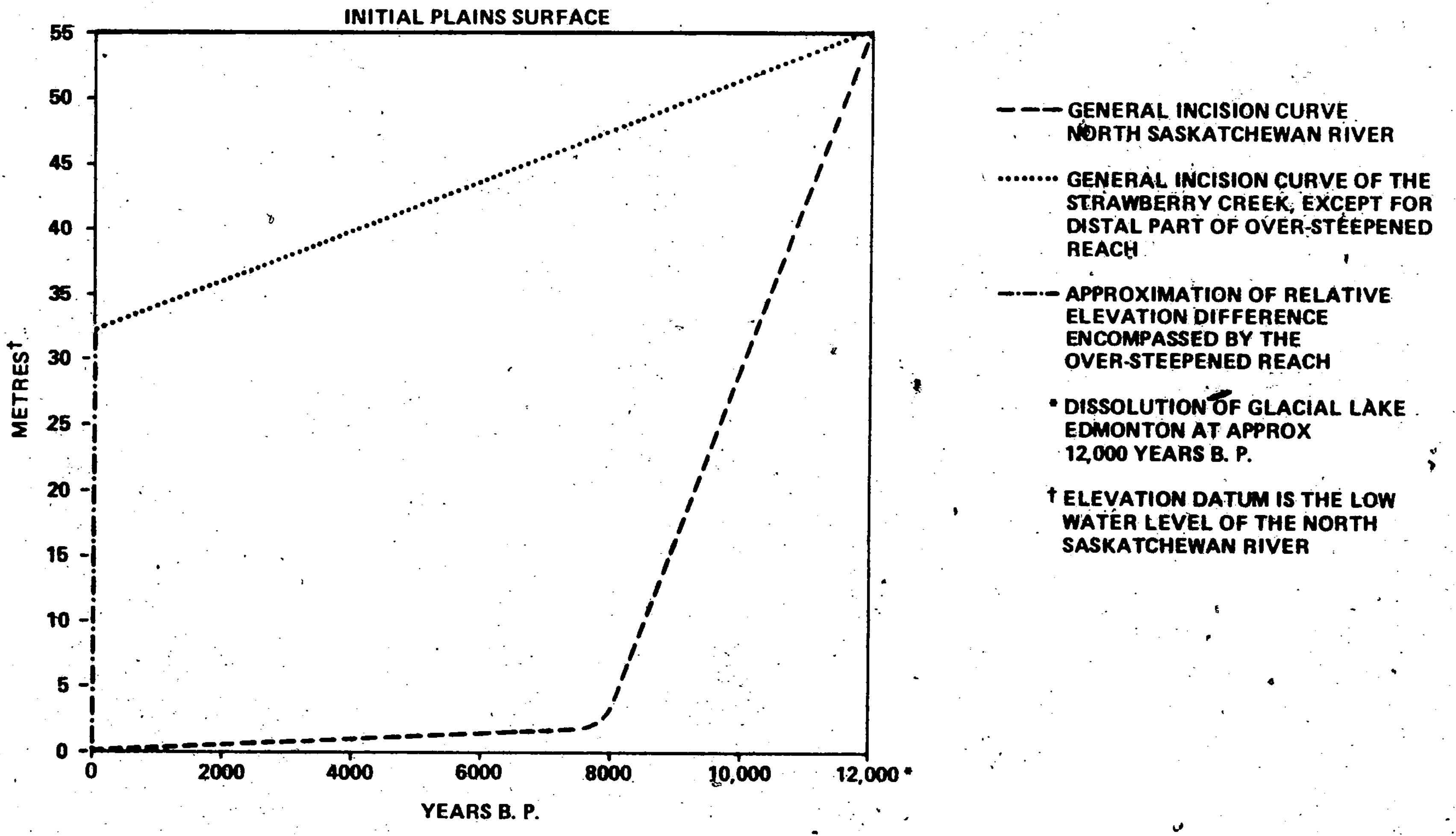


Figure 6.1. General incision curves for the North Saskatchewan River and the Strawberry Creek.

over-steepened reach. For example, Ozoray (1972) suggested that the steep tributary reaches in this area result from an accommodation to ancient tectonic trends, and possibly, reaction to more recent orogenic activity. Earlier, Rains (1969a) attributed this over-steepening to a possible combination of bedrock control and/or "rejuvenative" effects of the master river. A number of factors have probably contributed to the preservation of the over-steepened reaches, but, as will be discussed later, these may have little to do with lithologic, tectonic or orogenic elements.

In the tributary valleys alternating phases of stream degradation and aggradation have occurred, resulting in the formation of four, mainly paired, alluvial terraces. At no time during the Holocene have the tributary channels achieved a "graded" longitudinal profile, fully adjusted to their local base-level. Furthermore, it is clear from radiocarbon dating that the local base-level, the North Saskatchewan River, has not significantly changed during approximately the past 8000 years. Conversely, much of the valley deepening and terrace development within the tributary valleys has occurred over perhaps the last 5000 years, or less. A predominantly concave, upstream, channel profile has persisted through Holocene time, re-establishing itself within the individual incision episodes during the phases of tributary valley development. This concave channel segment has repeatedly adjusted to a hypothetical "temporary base-level" at the apex of the over-steepened reach and has not been noticeably influenced by its local base-level (the North Saskatchewan River).

This chapter is thus divided into discussions of factors which may have been significantly related to tributary valley evolution. First, selected studies of Holocene paleo-environmental changes are reviewed, as an outline of some external variables which possibly contributed to valley development. Second, the preservation of the over-steepened reach is examined. Third, the origin of the alluvial terraces, within the tributary valleys, is discussed in terms of the geomorphic threshold concept.

6.2 Holocene Paleo-Environmental Factors

The preservation of te[illegible]a marker beds, plus palynological, pedological, paleontological and stable isotope data, provide some insights as to variations of Holocene environments in southern and central Alberta. For example, Waters (1979) investigated the paleo-environments of south-western Alberta by studying selected sites where the stratigraphy displayed paleosols associated with the important Mazama Ash marker-bed. Her study entailed positive identification of the tephra bed, classification of the paleosols, paleosol phytolith identification and laboratory analysis of sedimentary units to determine modes of deposition. Through detailed examination of the related variables, plus the use of radiocarbon dates, Waters (1979) demarcated a well-documented Altithermal interval for southern Alberta between 8500 and 6600 yrs. B.P. Her study was opportune because some refinement of the area's Altithermal time-span was needed. As shown by Table 6.1 a number of contrasting time intervals had been previously proposed for the Altithermal episode in Alberta.

From a variety of unpublished sources, Waters (1979) included ten radiocarbon dates representing basal ages of lake and bog cores recovered in the Edmonton area (Figure 6.2). The basal core dates are presented as evidence of the earliest, recognized development of the particular lakes and bogs from from which they were extracted. These were probably activated in conjunction with a rising water table, with concurrent accumulation of surface water in topographic lows. Nine of the dates range from 7380 ± 245 yrs. B.P. to 3970 ± 170 yrs. B.P. (Figure 6.2), reflecting the onset of moister conditions and termination of the Altithermal (Waters, 1979).

A palynological investigation by Lichti-Federovich (1970) revealed a complete post glacial vegetation succession for part of central Alberta. The area's vegetation history was reconstructed by pollen analysis of a sediment core extracted from Lofty Lake, approximately 150 km north-northeast of Edmonton. A basal date of 11,400 ± 190 yrs. B.P. (GSC-1049), plus four younger radiocarbon dates and a band of Mazama Ash, provided an excellent chronological framework for the core. A five-stage

TABLE 6.1. PROPOSED ALTITHERMAL INTERVALS, SOUTH-CENTRAL ALBERTA[1].

Interval (Years B.P.)	Sources
3000-6000	Reeves (1975)
3500-7000	Heusser (1956)
4500-6000	Stalker (1969)
5000-7000	Reeves (1969)
5000-7000	Alley (1972)
5500-8500	Kearney and Luckman (1979)
6000-8000	Reeves and Dormaar (1972)
6300-8700	Schweger and Hickman (1980)
6600-8500	Waters (1979)
7000-9200	Harris and Pip (1973)

[1] Partially compiled from Smith (1979)

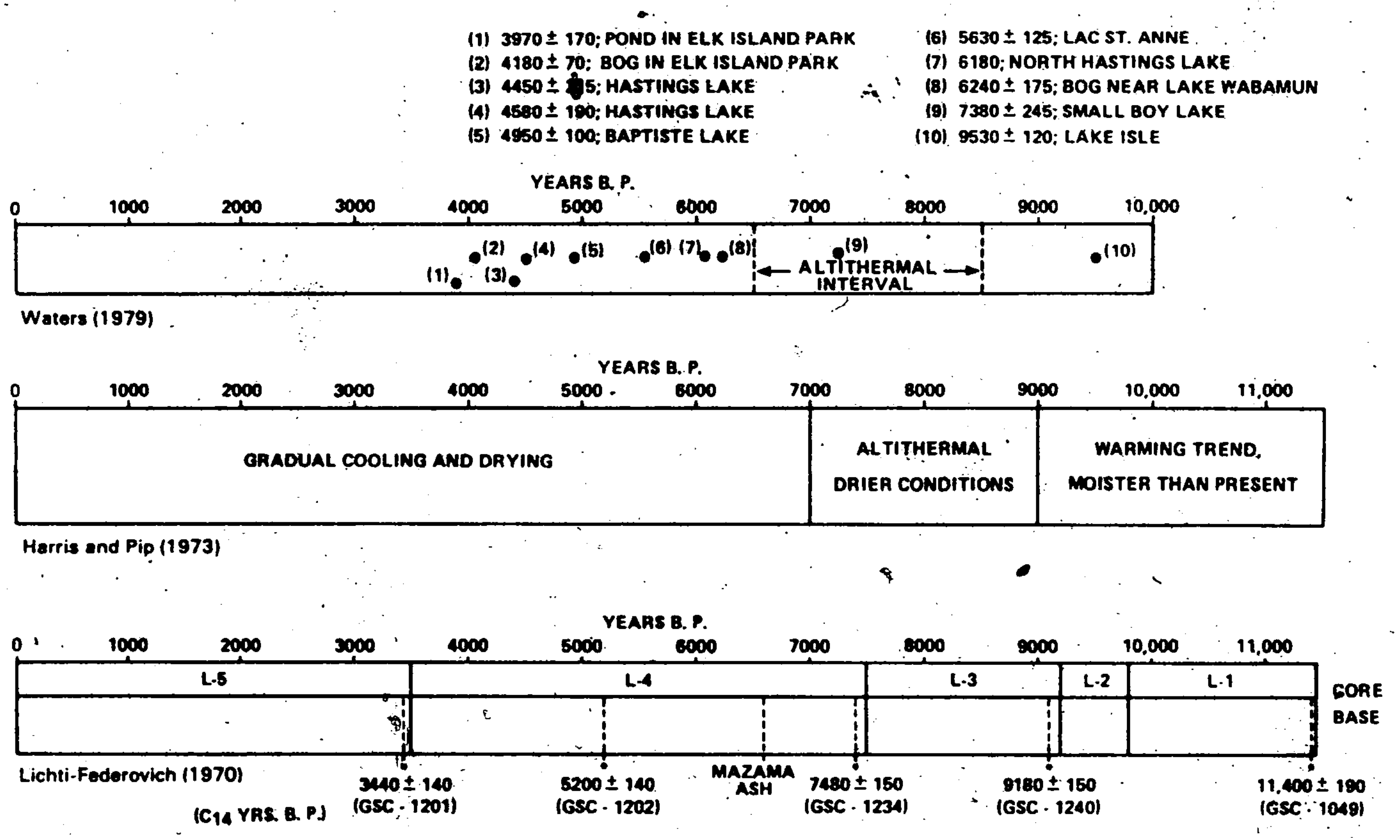


Figure 6.2. Paleo-environmental studies of Waters (1979), Harris and Pip (1973) and Lichti-Federovich (1970).

vegetation succession was identified and chronologically defined (Figure 6.2). She stated that no climatic inferences could be made from the early colonization by aggressive pioneer shrubs and trees following deglaciation (L1). Immediately following this time (by approximately 9800 years B.P.) a dominance of spruce became evident, possibly reflecting a slightly cooler and moister climate than at present (L2). From 9200 to 3500 years B.P. the vegetation succession of phases L3 and L4 implied increased warmth and decreased precipitation. This trend apparently reached a maximum at about 5500 to 6000 years B.P., to be followed by climatic deterioration and cooling. From 3500 years B.P., to the present (L5), no appreciable vegetation changes were evident from the Lofty Lake core. Throughout this latter period the fossil pollen paralleled the modern vegetation of the area. In addition, Lichti-Federovich (1972) reports on the pollen stratigraphy of a sediment core from Alpen Siding Lake, which is located near Lofty Lake. For the Alpen Siding core a basal date of 10,700 ± 170 yrs. B.P. (GSC-1093) was the only absolute chronologic control. Yet, the pollen stratigraphic record of the second core was very similar to that of the Lofty Lake core, thus strengthening the interpretations presented by Lichti-Federovich (1970).

Fritz and Krouse (1973) studied the oxygen-18 content of fossil carbonate shells retrieved from Wabamun Lake sediment cores. This lake lies 70km west of Edmonton and 40km north-west of the Strawberry Creek basin. Warming and cooling trends of the lake water are inferred from the increase or decrease, respectively, of the oxygen-18 content of the shells. Thus, a general paleo-environmental history of Wabamun Lake was interpreted from the aquatic habitat of shells. Although an absolute chronology was not available from their study they suggested that a stratigraphically low tephra layer had an approximate age of 10,500 years B.P.. No mention of tephra origin was presented, although the tephra originally was assumed to be the Mazama Ash, which is often found preserved in central Alberta. That assumption was subsequently found to be incorrect (Fritz and Krouse, 1973, p.249, Fig. 3). Provided that their tephra age approximation of 10,500 years B.P. is fairly accurate, the recorded stratigraphic sequence spans the Holocene. The results presented by Fritz and Krouse (1973) indicate that post glacial water temperatures were shifting from warmer to cooler. This temperature shift was then interrupted by an abrupt warming trend, a climatic "optimum" known as the Altithermal. From the end of the Altithermal, until the present, temperatures appear to have progressively cooled. Waters (1979) refers to the work of Fritz and Krouse (1973) and suggests (based on the tephra age approximation of 10,500 years B.P.) the confining dates of 6500 to 8500 years B.P. for the warming trend indicated by the increase of the oxygen-18 content of the shell samples.

A paleontological study by Harris and Pip (1973) enabled them to propose a Holocene paleo-environmental sequence (Figure 6.2). Their study concentrated on dated molluscan fauna collected by many workers from sites throughout southwestern Alberta. Identification of species type, correlated to present day habitat and substantiated by an absolute chronology, enabled classification of post glacial climatic trends with inferred terrestrial vegetation. Samples, from proglacial and supra-glacial lake sediments, identified as southern species allowed them to speculate that climate during the late Wisconsinan deglaciation was similar to the contemporary climate of the area. Harris and Pip (1973) concluded from their data that temperatures continued to rise, cresting above those known at the present, within the Altithermal phase. They demarcated this phase between 7000 and 9000 years B.P. Their data suggested that since the deposition of Mazama Ash (approximately 6600 years B.P.) temperatures have been gradually cooling.

Unfortunately Lichti-Federovich (1970), Fritz and Krouse (1973) and Harris and Pip (1973) present somewhat varying interpretations for the period following deglaciation, and for the duration of the Altithermal, although general agreement does exist relative to post-Altithermal time. For the purpose of the present study the Altithermal phase proposed by Waters (1979) is accepted as a reasonable guide.

6.3 Altithermal Episode: Reaction of Fluvial Systems

Conflicting interpretations have been suggested concerning the reaction of particular fluvial systems to the Altithermal episode in Alberta. Reeves (1967) concludes that degradation prevailed, while Alley (1972), Stene (1976) and Wilson (1981) favor aggradation. In contrast, Waters (1979) suggests that the Altithermal was a period of decreased fluvial activity, with infrequent deposition by flooding, and thus no major net aggradation or degradation.

Wilson (1981) reports, from a radiocarbon-dated alluvial sequence, that the Altithermal interval was a phase of fluvial aggradation in his study area, the Bow River, southern Alberta. He notes that this "contrasts with marked erosion in the southern plains" (Wilson, 1981, p.62) and warns of the "danger of extrapolating" the effects of the Altithermal on fluvial systems over broad areas.

The relationship between Holocene paleo-environmental changes and the response of fluvial systems is basically "site specific". The initiation of change in a fluvial system responding to climatic shift depends on numerous influential variables which are unique and characteristic of individual drainage systems. Physical drainage basin attributes such as hypsometry, catchment area, surficial sediments, type of bedrock, and source of discharge must be considered. Within a basin's unique physical framework, climatic induced change regarding local water table, amount of discharge, immediate-area climatic peculiarities and precipitation, type of vegetation and rate of change, are just several variables that would influence the relationship of paleo-environmental change and response of a fluvial system. The many possible combinations of unique and individualized drainage basin attributes could possibly implement contrasting changes in separate fluvial systems reacting to the same paleo environmental variations. Therefore, the question of the Altithermal's influence on fluvial systems should be directed locally to determine the possible responses of aggradation, degradation, or stability.

6.4 Over-steepened Tributary Reach

6.4.1 Persistence of the Over-steepened Reach

Slope reduction of the over steepened reach would cause a progressive linear change in channel gradient, and lead towards a more general upconcavity of the creek's longitudinal profile. This adjustment process usually occurs when discharge increases exponentially downstream. The influence of the basin's bedrock, reviewed in Chapter 3, cannot be considered substantial because the rocks are of low resistance to fluvial erosion. These would not have presented a major obstacle to a channel undergoing gradient reduction. Furthermore, the Strawberry Creek valley, postglacially, has re-established itself in its preglacial valley. Thus, during Holocene time the valley evolution has developed mainly within easily eroded valley fill material, consisting of preglacial fluvial deposits, plus a variety of younger glacigenic sediments.

The establishment of a particular longitudinal channel profile results from the mutual adjustments of paleo-environmental variables and their interrelations within a geologic and geomorphic framework. From the first order channels to the mouth of the basin, discharge and velocity increase, along with the availability of stream power. The energy of flowing water, stream power, is expended by various hydraulic and geomorphic processes, one of which is the inherent reduction of stream gradient to attain an equilibrium profile. In the tributaries under consideration the amount of time and/or energy available has been insufficient to allow the establishment of a fully concave-up channel long-profile "graded" to the North Saskatchewan River. This is reflected by the geomorphic evidence which shows that the downstream reach of the creek has persistently maintained a relatively steep gradient throughout Holocene time. In turn, this has imparted a general up-convexity to the related segments of the stream channel.

6.4.2 Evolution of the Over-steepened Reach

An interpretation of the Holocene development of the over-steepened reach is shown in Figure 6.3. Intuitively it seems that the upstream limit of the over-steepened reach must have migrated slowly headward and reduced its elevation since its initial development. As climatic, and other, variables permitted the drainage network would have slowly evolved on the plains surface.. Throughout the evolution of the drainage system mutual adjustments between the over-steepened reach and the valley upstream resulted in slight headward extension of that reach. In this interpretation the longitudinal profile changes are related mainly to intrinsic adjustments within the tributary valley rather than to base-level alteration, an extrinsic variable. Although the over-steepened reach is related to both base-level and the upstream valley factors, base-level has not significantly changed during the past 8000 years. The over-steepened reach, then, is maintaining an unstable equilibrium between the tributary valleys and the North Saskatchewan River.

6.4.3 Meandering Channel Pattern

Proposals regarding the origins and habits of meandering channels are numerous in the fluvial literature but no single factor fully explains the cause of meandering. An early idea related meandering channels to the Coriolis effect (Babinet, 1859) but more contemporary ideas relate

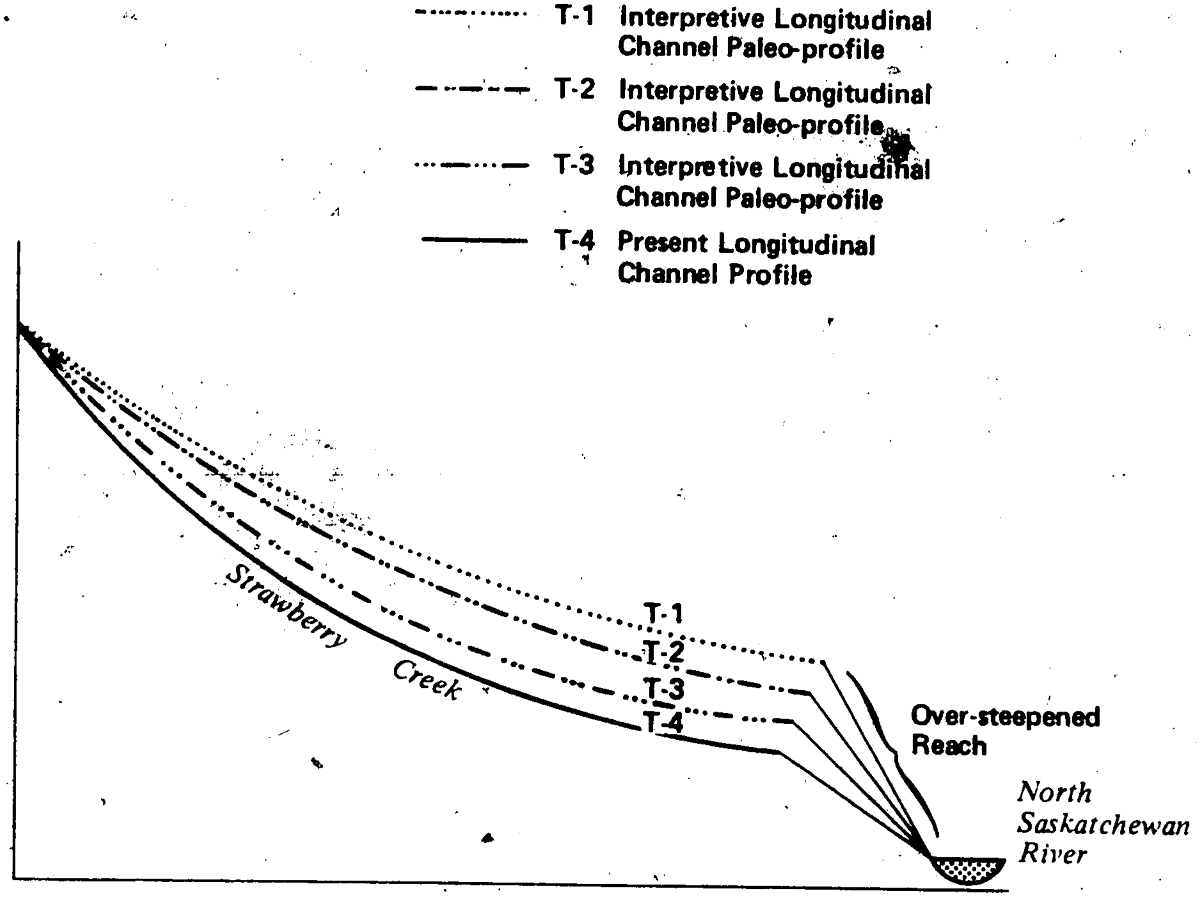


Figure 6.3. Interpretive Holocene developmental stages of the over-steepened reach.

meandering mainly to factors of bank erodibility, dominant sediment load and energy distribution in the channel. An exhaustive review of this subject would produce volumes of text, therefore an in-depth analysis will not be attempted. Instead, the most obvious variables related to sinuosity in the vicinity of the over-steepened reach will be briefly presented.

In the Strawberry Creek over-steepened reach sinuosity increases along with an increase in local valley width. In this reach an obvious difference exists between general valley slope and channel gradient. The longitudinal channel profile is markedly less steep than the longitudinal valley profile. This implies that the channel has adjusted, within the over-steepened reach, by increasing sinuosity in order to reduce its gradient. Along with gradient reduction, increased sinuosity tends to dissipate stream power laterally by erosion on the outside, and deposition on the inside, of meander bends. Streamflow velocities and potential energy are probably retarded in comparison to possible values a straight channel could maintain at the same valley slope. In relation to meandering channels Leopold et al., (1964, p.308) state "the channel tends to adjust to a condition in which the rate of work expended in the system is minimum". The over-steepened channel reach appears to be adjusting in this manner. Another example of a channel adjusting to a comparatively steep valley slope by developing a sinuous course is presented by Brice (1964) from a study of the Calamus River, Nebraska. An abrupt steepening of that valley slope resulted from the deposition of large quantities of sediment from a major tributary during the Pleistocene. The accentuated valley slope has been compensated by an increase in channel sinuosity rather than by enhanced incision to remove unconsolidated sediments. Sinuosity dramatically increases over two-thirds of the steep reach and then decreases over the last one-third of the reach where the channel steepens slightly.

For the Strawberry Creek case, the lower reach of the valley, with the over-steepened reach, is shown by Figure 6.4. This reach is divided into various segments for discussion purposes. Segments Z-X and X-V are of comparable valley lengths with line X marking the apex of the over-steepened reach. Upstream of the over-steepened reach segment Z-X has a valley slope of 3m/km and a channel gradient of 1.3m/km. In contrast, the over-steepened reach (segment X-V) has a valley slope of 7.5m/km and a channel gradient of 3.3 m/km. In both segments the length of the channel is approximately twice that of the related, valley reach lengths.

For the following discussion a standard sinuosity index has been adopted. This is derived by dividing the length of the channel by the length of valley reach (Schumm, 1963). For the measurement of channel sinuosity in the indicated Strawberry Creek valley reach (Figure 6.4) it has been divided into three segments of comparable valley length. The

SEGMENT	VALLEY SLOPE	CHANNEL GRADIENT
Z - X	3m/km	1.3m/km
X - V	7.5m/km	3.3m/km

SINUOSITY	
Z -Y	2.16
Y - W	3.04
W - V	1.6

LENGTH OF VALLEY SEGMENTS	
Z - X	3.6km
X - V	4.0km
Z - Y	3km
Y - W	2.4km
W - V	2.37km

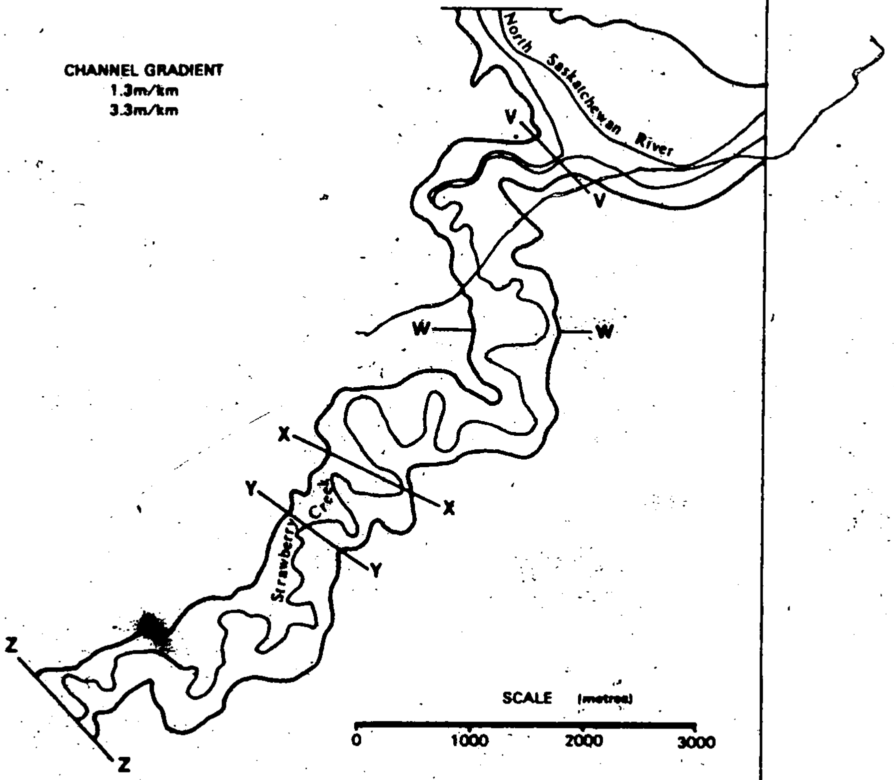


Figure 6.4. Sinuosity measurements of the over-steepened reach.

sinuosity measurement segments were defined on the basis of the observable increase in intensity of channel sinuosity in the immediate area of the apex of the over-steepened reach. Segment Y-W delineates that area while Z-Y is upstream and W-V downstream. Segment Z-Y has a sinuosity of 2.16. In segment Y-W the sinuosity increases to 3.04 and then in segment W-V it reduces to 1.6, a value lower than for Z-Y, the segment upstream of the over-steepened reach. In addition, the W-V segment has no preserved remnant terraces, other than T-4, adjacent to the channel. This paucity of terrace remnants probably relates to the initial episodes of valley evolution where a steep-sided gully system would have existed in this segment. Thus, much of the valley evolution in this segment probably took place in early Holocene time.

6.4.4 Complex Adjustments

Complex adjustments are inherent to a drainage basin in the process of rejuvenation. Schumm and Parker (1973) provide an example of complex response in an experimental basin. The laboratory drainage basin was rejuvenated by a drop in base-level and basin responses were subsequently monitored. Adjustments by incision occurred quickly near the mouth of the basin and, as expected, this incision migrated headward. But, as incision migrated progressively headward sediment production increased until it exceeded the transporting capacity of the laboratory stream. This resulted in deposition within the downstream reach. Thus, the basin responded to rejuvenation by a complex adjustment involving both net incision and net aggradation in different reaches. Schumm (1977) further propounds the significance of complex responses and refers to several field examples. Additional field examples of this occurrence are presented by Berger (1978), Hey (1979), Hiable (1980) and Patton and Schumm (1981).

The tributaries in this study may have adjusted to the incision episodes of the valley development by comparable complex responses. It is suggested that during incision episodes increased sediment yields promoted deposition within the over-steepened reach. The potential for storage of abundant sediment (Schumm, 1977) is best in the upstream section of the over-steepened reach where the valley is relatively wide and a large floodplain may be maintained. Concomitant with aggradation would be the reduction of channel gradient along parts of the reach. An additional factor is that during the spring, when peak discharges occur, hydraulic damming of tributary creek flows by the North Saskatchewan River would tend to decrease their velocities and promote backwater deposition in the vicinity of the creek mouths.

Thus, in the tributaries complex responses to the incision episodes of their valleys may have temporarily reduced the channel gradients, along parts of the over-steepened reaches, by aggradation. The amount of time required to remove the aggraded sediments cannot be estimated, but the repeated occurrence of the complex response processes would have assisted in the preservation of the over-steepened reach.

6.4.5 Bed Armoring

Gessler (1970) suggests that bed armoring is a "self-stabilizing process" in alluvial channels. Selective erosion may result in the progressive removal of finer material with the development of a stable, coarse bed material, armor coat that inhibits further degradation of the channel. Not only does a continuous armor retard general degradation but, also, this may be locally effective for a series of armored reaches. This implies that under certain conditions the development of armoring is an inherent limitation of the degradation process. Begin (1979) investigated degradation of alluvial channels in a laboratory flume. Part of that study entailed measuring the rate of knickpoint migration induced by lowering of base-level. In several of his experiments knickpoint migration came to a complete halt in response to "visually" apparent bed armoring.

The process of bed armoring was suggested by Rains (1969a) as a possible factor inhibiting degradation in the over-steepened reach of the Whitemud Creek. Rains (1969a, p.189) noted the occurrence of a continuous "gravel veneer" along the over-steepened reach with an abrupt change of channel bed material to "fine grained debris" upstream of that reach. The sources of bed armoring gravels were attributed to the redistribution of alluvial terrace deposits, Laurentide till, preglacial gravel and sand and suitable bedrock. The scarcity of bed armoring upstream was related by Rains (1969a) to the comparatively shallow upstream depth of valley incision, thus limiting the sources of suitable material.

During the valley development phases of the local North Saskatchewan River tributaries, progressive excavation would have provided the over-steepened reach with abundant sediments. The repeated addition of large amounts of sediment to the over-steepened reach, with subsequent winnowing of the finer materials, may have caused renewed accumulations of coarse lag gravels. Once bed armoring is established the ultimate removal of coarse clasts is dependent on magnitude and frequency of discharge to overcome the resistance imposed by the coarse channel bed materials. This process has likely been a factor contributing to the delayed slope reduction of the over-steepened reach.

6.4.6 Basin Relief

Basin relief is a variable affecting the drainage system's potential energy and it partially regulates the relative speed of denudation (Anhert, 1970, Schumm, 1977). The relief of the tributary basins is relatively minor. Predominantly, this results from bedrock topographic relief and, also, the surficial deposits which include a relatively flat mantle of glaciolacustrine sediments. The low relief of the basins, combined with their characteristically short seasonal peak flows, and other factors, have prevented the tributary streams from establishing a channel profile "graded" to the North Saskatchewan River

6.5 Origin of the Terraces

The terrace remnants in the tributary valleys record four stages of relative channel stability during which floodplain development was dominated by lateral planation and accretion. The chronology established in this study indicates that two of the major phases of net incision occurred approximately between the time of deglaciation and 9000 years B.P., and circa 6000, 4000, and 2000 years B.P. Within at least the past 4000 years the tributaries have experienced two additional net incision phases culminating in the contemporary floodplain and channel. The chronology of the last two net incision phases cannot be clearly distinguished because of the occurrence of "overlapping" in the presently available radiocarbon dates. The dated samples do indicate, though, that the channel probably lay close to the elevation of T 3 about 3000 years B.P. Sometime thereafter the channel incised to roughly its contemporary level, certainly by about 1300 years B.P.

An interpretation of the mechanisms responsible for the geomorphic features representing the phases of creek stability and incision is necessary to conclude this thesis. There may be several approaches to this challenge. A traditional historical interpretation would emphasize paleo-environmental changes, and their interaction, to explain physical adjustments of the fluvial system through time. However, the elements contributing to these valley development phases cannot be adequately explained in terms of adjustments to climatic variations. Thus, general characteristics of the post glacial paleo environment are first outlined in relation to the valley development [illegible] For the purpose of this discussion the Holocene [illegible] is somewhat arbitrarily divided into Pre-Altithermal, Altithermal and Post Altithermal episodes.

Undoubtedly complex ecological adjustments, related partly to climatic changes, played a significant role in the evolution of the Strawberry Creek valley. In addition, though, the concept of geomorphic thresholds (Schumm, [illegible]) should be considered as a probably important element in the evolution of the valley. Certain geomorphic features are evident from this study that support the adoption of the geomorphic threshold concept as the [illegible] variable in the valley evolution.

Pre-Altithermal Episode

The exact character of the local paleo-environment during the period between deglaciation and the onset of the Altithermal is not clear. For example, Fritz and Krouse (1973) suggest that an initial period was warmer than at present. Harris and Pip (1973) conclude that early post glacial temperatures were similar to those at present, while Lichti-Federovich (1970) infers a cooler, moister climate than at present.

Whatever the specific climatic characteristics were during this episode only general speculations regarding fluvial processes may be made. In simple terms, the earliest post glacial development of drainage networks in the tributary basins probably involved two main elements. First, the downstream valley segment underwent progressive, rapid adjustment as the local base level (North Saskatchewan River) quickly lowered. This segment probably began its development as a major gully or ravine system. Second, the development of lower order channels began on the gently sloping drainage basin surfaces. The magnitude and direction of post glacial climatic changes, and the type of vegetation successions, would have partly determined the speed and extent of growth of the drainage networks in the developing tributary basins. The early phase of tributary valley evolution produced a main channel which had reached stability with a predominantly concave up long profile at the [illegible] position by approximately 8500 years B.P. The downstream over steepened [illegible] represented a morphologically unstable link between the major part of the tributary network and the North Saskatchewan River (Figure 6 3).

Altithermal Episode

The record from the Strawberry Creek valley reflects a period of morphological stability during the Altithermal interval. A dated paleosol found below Mazama Ash in the T-1 alluvium (section 12) supports Waters' (1979) interpretation of the Altithermal as a period of reduced fluvial activity, indicated by numerous sites in southwestern Alberta Alluvial deposits which lie above the Mazama Ash may reflect a climatic shift at the end of the Altithermal towards moister conditions, with delayed response of the vegetative suite adjusting to the moister conditions. The probability of enhanced flood discharges, with increased sediment yields at the end of the Altithermal, would be reasonable if a climatic shift proceeded faster than vegetation successions.

During the comparatively precipitation-deficient Altithermal the local tributary streams may have adopted more extremely ephemeral discharge characteristics. The possible lowering of the regional water table during the Altithermal (Ritchie, 1976), coupled with the relatively small size and low relief of the local tributary catchment areas, means that a shift towards ephemeral discharge conditions would be probable. This would result in the reduction of stream power to execute significant geomorphic/morphologic changes in the tributaries.

The effect of Altithermal conditions on the Strawberry Creek was neither degradation nor major aggradation. The Strawberry Creek evidence suggests that the Altithermal interval was one of general morphological stability, resulting in a delay of the progressive evolution of the channel's intrinsic attempt to attain a "graded" profile relationship to the North Saskatchewan River.

Post-Altithermal Episode

A general climatic shift from Altithermal characteristics has prevailed in post-Altithermal time. Progressively cooler temperatures, with increasing precipitation, have resulted in a shift of vegetation zones and a rise in the water table, with infilling of local lakes. Within this time-span the greater part of the tributary valley degradation has occurred in three developmental phases. It is very difficult to isolate the climatic element as a major factor in these fluvial adjustments because the general, post Altithermal, climatic trend appears to have been one of a progressive shift towards cooler and moister conditions.

The magnitude of this progressive climatic change has not been sufficient to cause any major fluvial adjustments of the local North Saskatchewan River system during post-Altithermal time. Although the North Saskatchewan basin is relatively large, and climatic change would need to be significant to promote morphological adjustments, the fact remains that the depth of its valley in the Edmonton area has remained virtually unchanged during the past 8000 years.

Geomorphic Thresholds

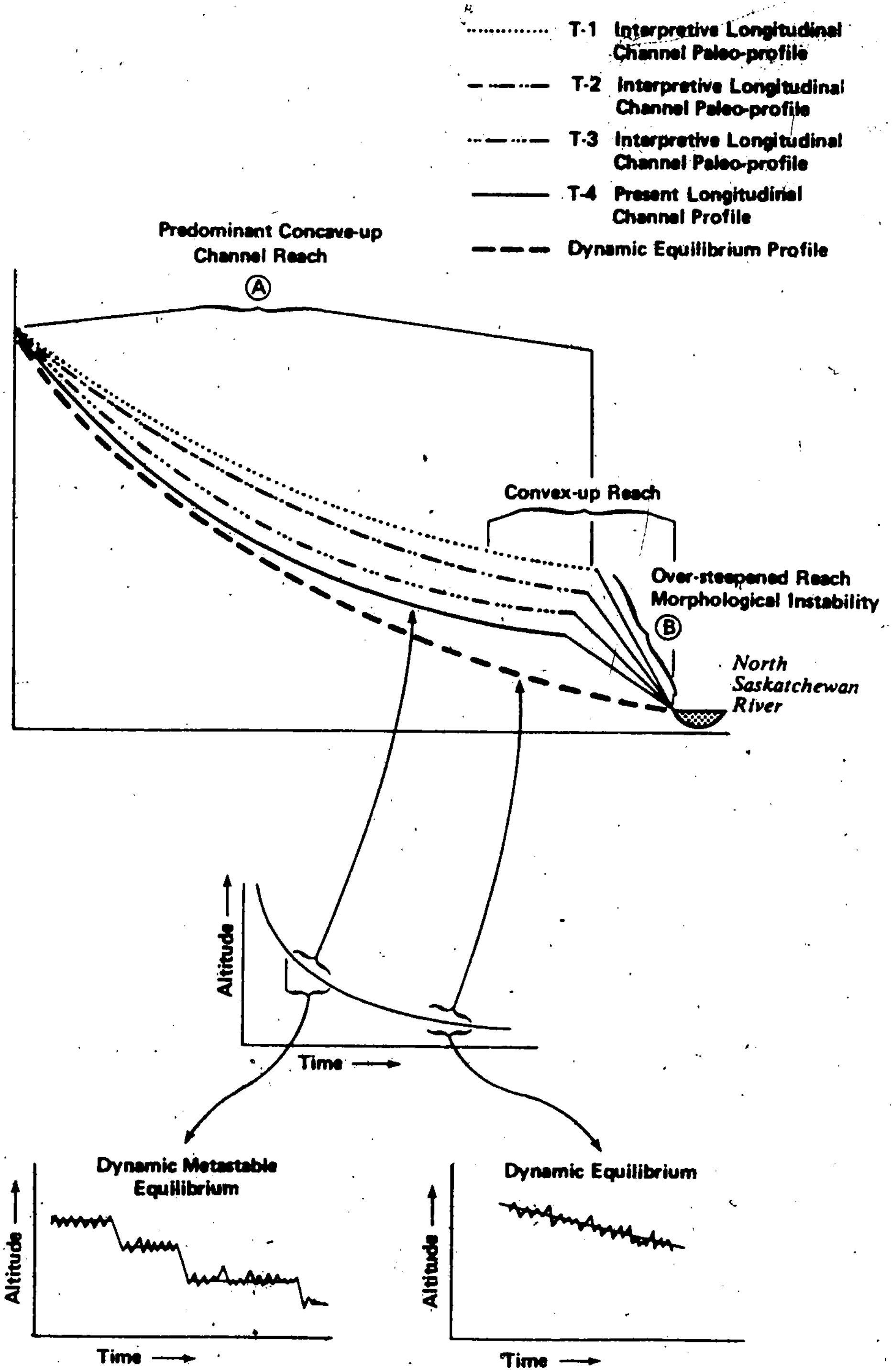
The characteristic concave-convex channel profiles of the tributary valleys imply that a "graded" condition, has yet to be achieved relative to the local base-level of the North Saskatchewan River. The evolution of the tributary valleys to date has not been by continuous erosion but, rather, adjustments have been made by relatively rapid incision phases. Following each incision phase the channel attained comparative stability along the predominant valley [illegible]at displays a concave-up channel profile.

Schumm's (1977) geomorphic threshold concept is proposed as a probable explanatory model for the characteristic forms of the tributary drainage basins, including their terraces. With the adoption of the threshold concept it can be stated that the tributaries are adjusting by intrinsic thresholds in an attempt to attain a profile "graded" to the North Saskatchewan River.

From the terrace morphology data presented it is evident that four paired terraces exist. By extrapolation, of the terrace treads, paleo-floodplain curves were constructed. The paleo-floodplain profiles reveal that the incision episodes individually re-established a predominantly concave-up channel profile thus attaining stability. These stable periods existed for significant time periods and were followed by the probably rapid occurrence of incision episodes.

A significant attribute of intrinsic thresholds is the presence of morphological instability. The existence of a downstream, convex-up profile in the tributaries reflects such morphological instability in their systems. This implies that the tributary valleys have yet to achieve equilibrium with respect to the North Saskatchewan River. It is proposed that the tributary valleys are adjusting by phases of episodic erosion followed by adjustments to the prevailing morphological instability inherent in the system. The substantial developmental time-lags which have persisted between the tributaries and the North Saskatchewan River valley are clearly demonstrated by the radiocarbon dating evidence presented earlier.

A combination of Schumm's (1977) theoretical threshold concept and the results of this study are shown in Figure 6.5. The top diagram of Figure 6.5 displays a small-scale version of the valley developmental phases. The longitudinal channel profile is divided into two components; (a) the predominant concave-up channel reach showing the episodic erosion phases and, (b) the over-steepened reach that constitutes the inherent morphological instability. In comparison with Schumm's (1977) theoretical threshold concept, it is suggested that the tributary systems are representative of a "dynamic metastable equilibrium" stage



FROM: Schumm (1977)

Figure 6.5. Valley development phases in context of Schumm's (1977) geomorphic threshold concept.

The ultimate goal of "dynamic equilibrium" may be obtained after the tributaries have progressed through phases of aggradation and degradation until the channel profile is at "grade" with the North Saskatchewan River. The dashed line on Figure 6.5 is the writer's conception of a future channel profile and "dynamic equilibrium" of the system.

The Holocene paleo-environmental variables are of importance in consideration of the intrinsic thresholds. The climatic variables regulate the energy input to the fluvial systems. Variations of paleo-hydraulics, vegetation successions, pedogenesis and sediment supplies allow the systems to reach intrinsic thresholds. In essence the variability of the extrinsic, paleo-environmental factors are regulating the sequential development of the tributary valleys by dictating the amount of time required for the systems to attain intrinsic thresholds. This explains why in the first 5000 years following deglaciation only one major incision and aggradation phase occurred in these valleys. The Altithermal interval reflects a phase during which little evolution of the tributary valleys appears to have occurred. In contrast, over the last 5000 years, with progressive climatic shift, three incision/aggradation phases have taken place. Thus, the later Holocene evolution of the tributary valleys has been comparatively active while the North Saskatchewan River valley has remained more or less in equilibrium.

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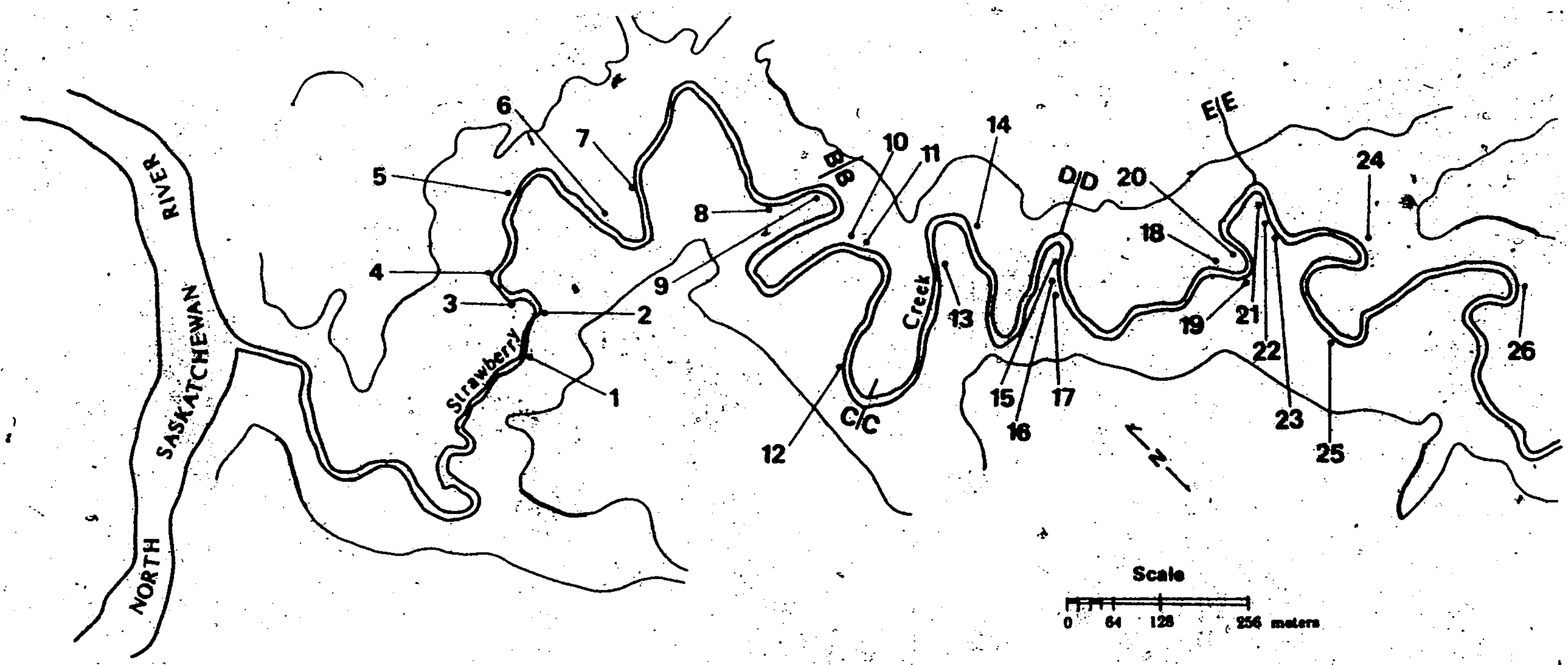
8. Appendix A

Locations of the logged alluvial stratigraphic sections.

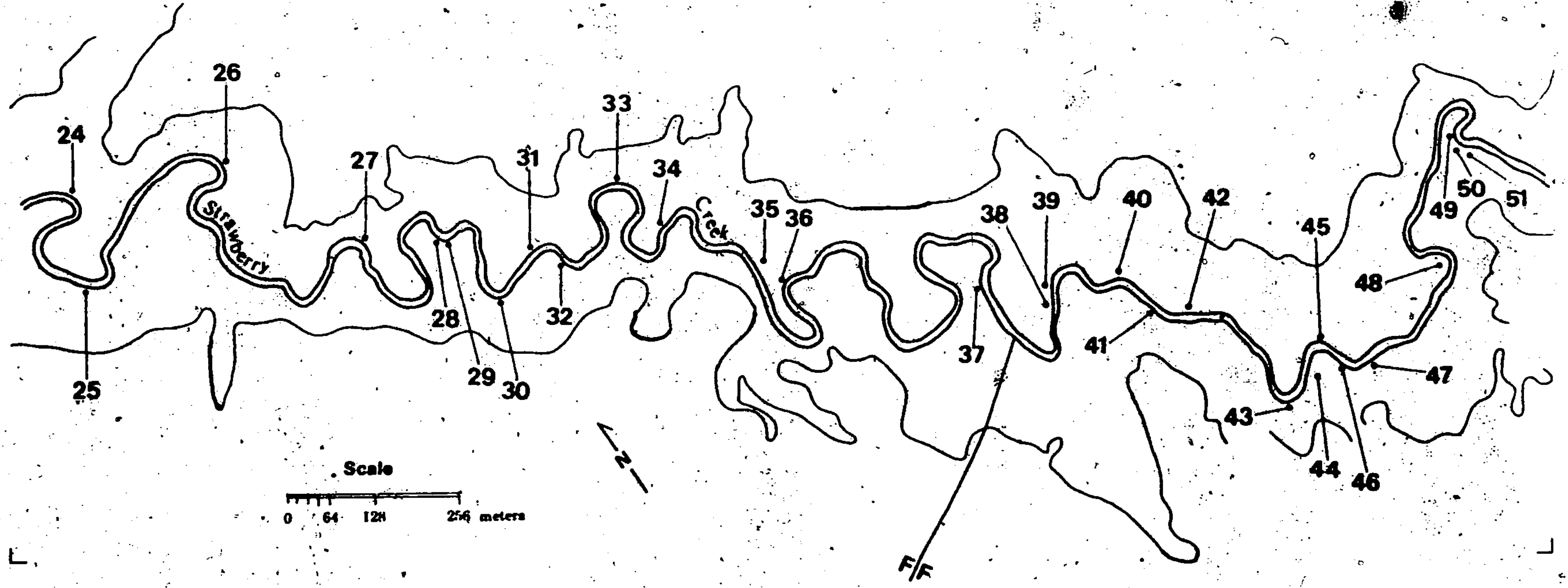
Appendix A

SECTION LOCATIONS



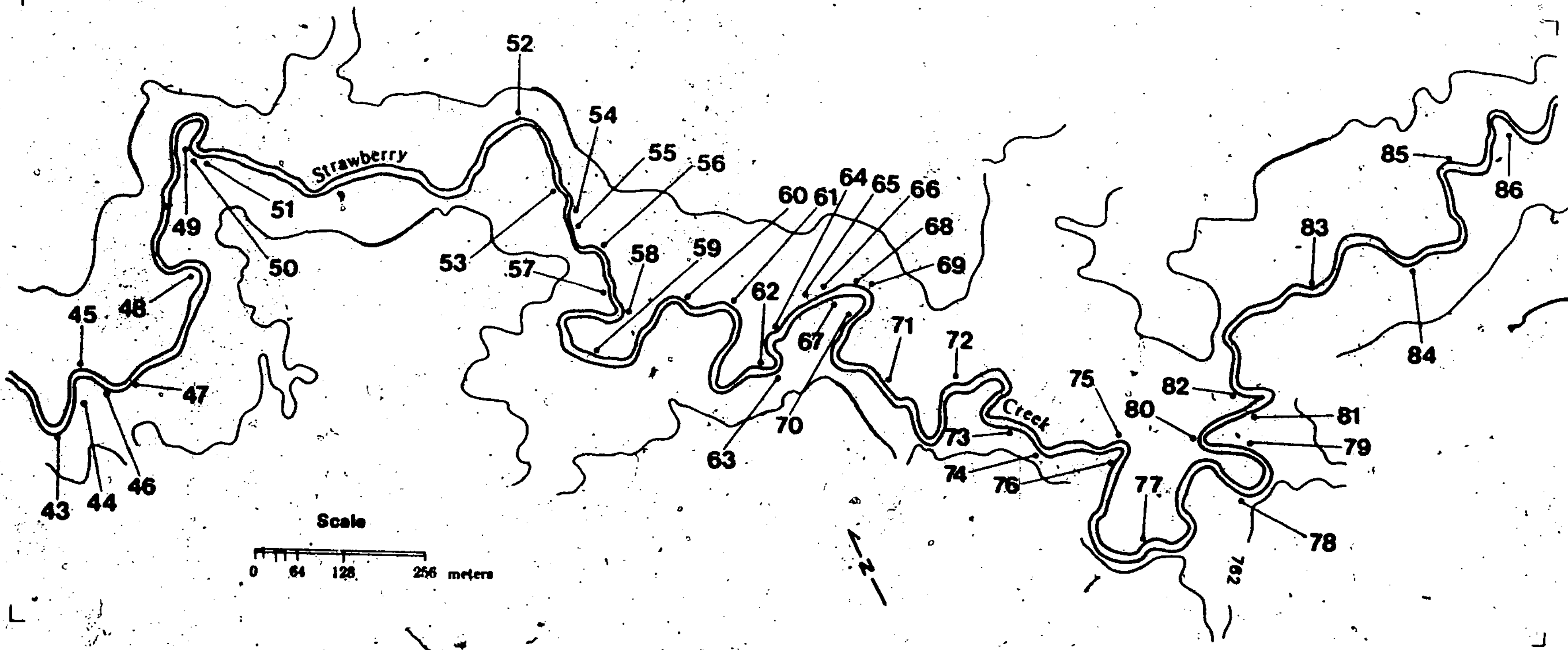
Appendix A

SECTION LOCATIONS



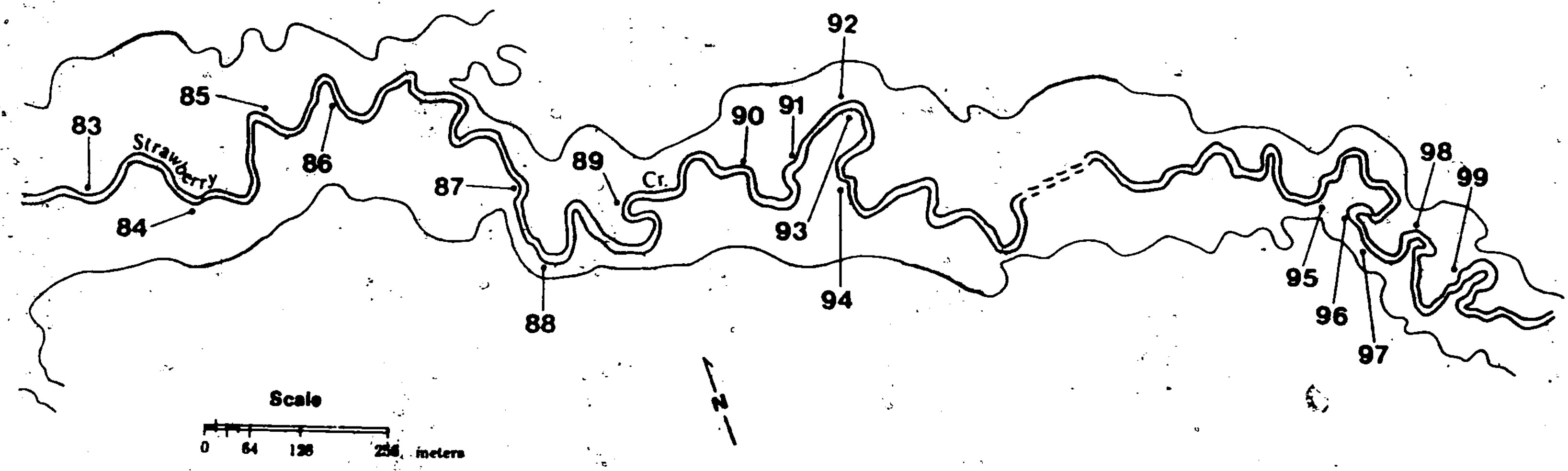
Appendix A

SECTION LOCATIONS



Appendix A

SECTION LOCATIONS



9. Appendix B

Data relevant to radiocarbon dated alluvial terrace sections; Strawberry Creek valley.

Radiocarbon date: 8660 ±125 yrs. B.P.

Lab number: S-1926

Terrace: T-1

Alluvial stratigraphic section: Section 12, Figure 5.19a.

Radiocarbon dated material: Charcoal fragments of organic paleosol.

Stratigraphic Position: Dated paleosol was observed at 2.5m above the alluvial gravel/bedrock contact and was directly preceded by 1.6m fining-upward sequence of sands and silts. Radiocarbon dated charcoal was extracted from the 15 cm thick organic paleosol. Above the paleosol was 9 cm of silt and fine sand which in turn was followed by 6 cm of volcanic ash. The volcanic ash was identified by electron probe analysis as Mazama Ash, approximately dated at 6600 years B.P. The ash horizon was succeeded by 30 cm of overbank fines which in turn was followed by colluvium.

Radiocarbon date: 8015 ± 135 yrs. B.P.

Lab number: S-1787

Terrace: T-1

Alluvial stratigraphic section: Section 39, Figure 5.19b.

Radiocarbon dated material; Bi-valve mollusc shells.

Stratigraphic position: The shells were extracted from well to moderately bedded sands and grits associated with the basal gravels of the T-1 alluvial section. At this section T-1 alluvium overlies preglacial gravels and sands.

Radiocarbon date: 5865 ± 135 yrs. B.P.
Lab number: S-1789
Terrace: T-1
Alluvial stratigraphic section: Section 27, Figure 5.19a.
Radiocarbon dated material: Bone; bison, phalanx of hind foot.
Stratigraphic position: Bone was extracted from the contact plane between 1.35m of overbank fines and overlying banded slump material.

Radiocarbon date: 5640±130 yrs. B.P.
Lab number: S-1788
Terrace: T-1.
Alluvial stratigraphic section: Section 39, Figure 5.19b.
Radiocarbon dated material: Bone; right mandible of <u>Canis lupus</u>.
Stratigraphic position: Bone was found on the terrace scarp surface well above the contemporary floodplain. The original emplacement of the bone appears to have been in either the T-1 terrace alluvium or the overlying soil

profile.

Radiocarbon date: 4685± yrs. B.P.
Lab number: S-1800
Terrace: T-2
Alluvial stratigraphic section: Section 34, Figure 5.20b.
Radiocarbon dated material: Bone; small unidentifiable fragment.
Stratigraphic position: bone was extracted from point bar sands, 1m below terrace tread surface.

Radiocarbon date: 1965±75 yrs. B.P.
Lab number: S-1783
Terrace: T-4
Alluvial stratigraphic section: Section 79, Figure 5.22.
Radiocarbon dated material: Bone; bison ribs and vertebra.
Stratigraphic position: Bones were extracted from overbank fines, 50 cm below terrace tread surface.

Radiocarbon date: 1625± 80 yrs. B.P.
Lab number: S-1785
Terrace: T-3
Alluvial stratigraphic section: Section 99, Figure 5.21c
Radiocarbon dated material: bone; top portion of bison

skull.

Stratigraphic position: Bison skull was extracted
from basal gravels and sands, 1.4m beneath terrace tread surface.

Radiocarbon date: 1135±80 yrs. B.P.

Lab number: S-1786

Terrace: T-2

Alluvial stratigraphic section: Section 89, Figure 5.20d.

Radiocarbon dated material: Bone; bison skull, top portion and atlas.

Stratigraphic position: Bison skull was extracted
from overbank fines, 55 cm beneath terrace tread surface.

Radiocarbon date: 760±85 yrs. B.P.

Lab number: S-1784

Terrace: T-3

Alluvial stratigraphic section: Section 76, Figure 5.21c.

Radiocarbon dated material: Bone; bison (juvenile) lumbar vertebra.

Stratigraphic position: Bone was extracted from
point bar sands, 1.84m below terrace tread surface.