1983

STRATIGRAPHY AND SEDIMENTATION OF THE PRECAMBRIAN REVETT FORMATION, NORTHWEST MONTANA AND NORTHERN IDAHO

David G. Alleman

103p.

STRATIGRAPHY AND SEDIMENTATION OF THE
PRECAMBRIAN REVETT FORMATION,
NORTHWEST MONTANA AND NORTHERN IDAHO

by

David G. Alleman

B.S., Central Missouri State University, 1980

Presented in partial fulfillment of the
requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1983

Approved by:

Don Winst
Chairman, Board of Examiners

[signature]
Dean, Graduate School

3-15-83
Date

3-1-83

ABSTRACT

Alleman, David G., Winter, 1983 Geology

Stratigraphy and Sedimentation of the Precambrian Revett Formation, Northwest Montana and Northern Idaho

Director: Don Winston DW

The Revett Formation of the Middle Proterozoic Belt Supergroup can be usefully divided into informal lower, middle, and upper members which can be correlated throughout the study area. The lower Revett is dominated by thick beds of clean, fine-grained quartzite which is most commonly flat-laminated or cross-stratified. The middle Revett is composed of thinly-laminated siltite and argillite with only occasional thin interbeds of clean quartzite. Laminae in the siltite are characteristically wavy and laterally discontinuous. The upper Revett comprises interstratified intervals tens of meters thick of both clean, fine-grained quartzite and thinly-laminated siltite-argillite.

Quartzite beds in the Revett Formation are tabular and laterally persistent, and lack channels or lateral accretion surfaces. Unchannelized, laterally unconfined sheet-floods are interpreted as the major depositional mechanism. Paleocurrent trends indicate dominantly north-northeastward sediment transport. Regional stratigraphic trends support this interpretation. Lateral and distal variation in sheet-flood deposits are represented in stratigraphic sections by changing ratios of clean quartzite to siltite. Vertical sequences of thickening, thinning, or thickening then thinning of quartzite beds represent abandonment, progradation, or shifting of depositional lobes.

Southward stratigraphic thickening in the upper Revett across the Jocko line, a proposed down-to-the-south syndepositional growth fault (Winston, 1982), is not abrupt enough to be clearly related to active faulting during deposition. A southward-thickening sediment wedge or structural displacement of thick next to thin stratigraphic sections may be better explanations of the observed thickness changes.

DEDICATION

I dedicate this work to my parents, and to my siblings.

ACKNOWLEDGMENTS

Special thanks to Don Winston for invaluable guidance, both geological and ontological, over the past two years; his inspiring insight will brighten my path for many more.

Thanks also to Johnnie N. Moore for his encouragement in the face of adversity and his careful criticism of the thesis. Keith Osterheld kindly served as a committee member with exceedingly short notice.

Thanks to Mac Donofrio and Bill Hoyerman for their proficient, inventive approaches to field geology, and for intrepidly accompanying me through treacherous, tedious, and memorable times. Special thanks to Patricia D'Arcy for her love, adaptability, and support.

This thesis was funded by a Research Assistantship from National Science Foundation/Montana University System MONTS Grant # PRM-801149. U.S. Borax graciously provided additional funding to help cover field expenses. Chevron Resources Company generously permitted the use of data from the West Twin Creek section.

Finally, thanks to John Nold for early inspiration in geology, to Laurie Emmart for drafting figures, and to the countless other people who contributed ideas and warm friendship.

TABLE OF CONTENTS

CHAPTER | Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Fine-grained terrigenous and carbonate rocks of the Belt-Purcell Supergroup of northwest Montana, northern Idaho, northwest Washington, and southern British Columbia were deposited during the Middle Proterozoic in a broad northwesterly-trending basin (Fig. 1). Four major stratigraphic divisions recognized across most of the Belt basin are the Prichard Formation, the Ravalli Group, the middle Belt carbonate interval, and the Missoula Group (Harrison, 1972). The Revett Quartzite, first described and named for exposure around Revett Lake by Ransome (1905) and formally designated the Revett Formation in 1963 by Harrison and Jobin, lies in the middle Ravalli Group, stratigraphically above the siltite and quartzite of the Burke Formation and below the argillite of the St. Regis Formation (Fig. 2). Harrison (1972) summarizes many important aspects of Belt geology and discusses Revett distribution and correlation. Harrison and others (1974b, 1980) and Winston (1982) provide excellent summaries of the details and problems of Belt structural geology. Winston (1982) proposes that during the Middle Proterozoic the continental crust of the Belt basin was cut into blocks by three nearly east-west-trending vertical fault zones and at least one northwest trending fault zone (Fig. 3). Bounding the northernmost Charlo block on the south is the Jocko line which moved down-to-the-south

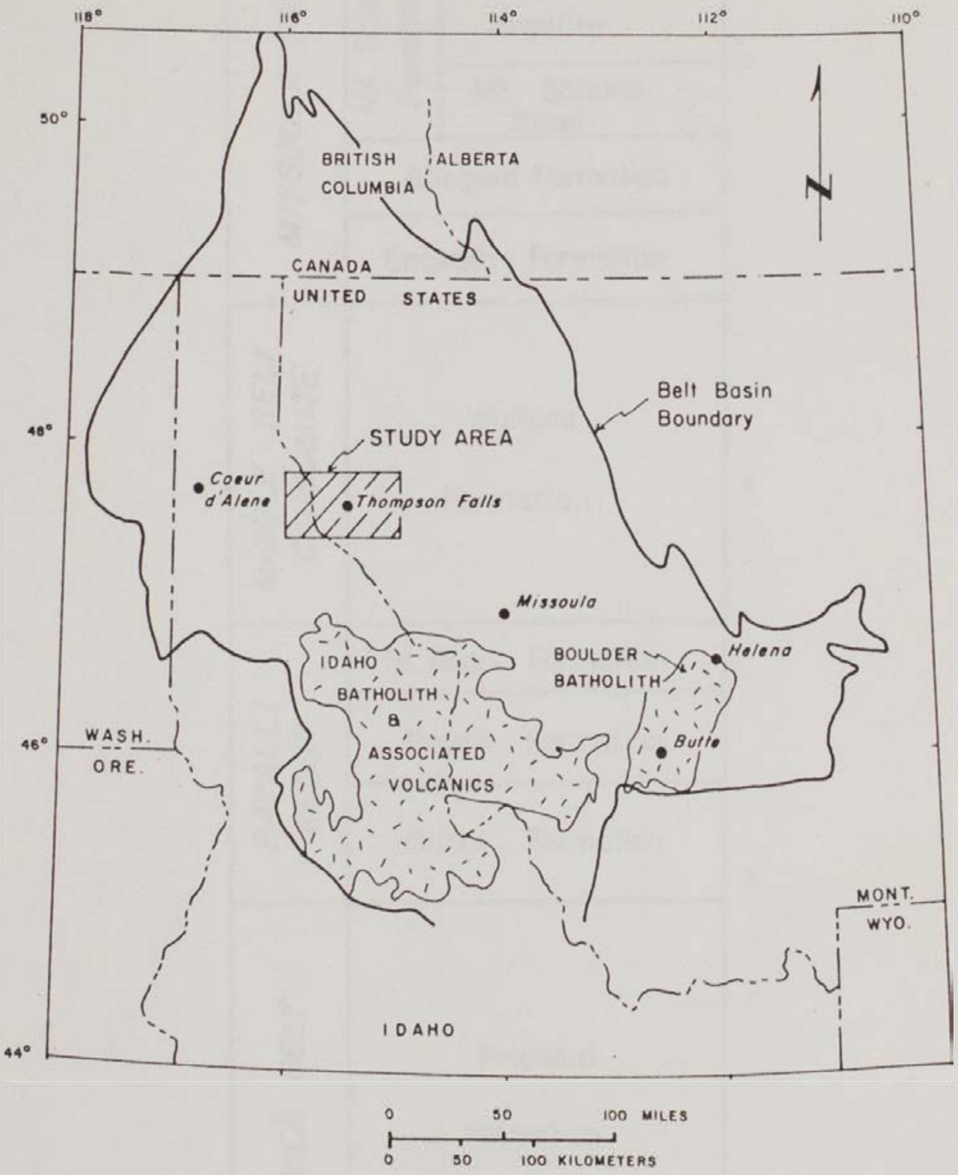


Figure 1. Belt basin and study area location map. Modified from Winston, 1978.

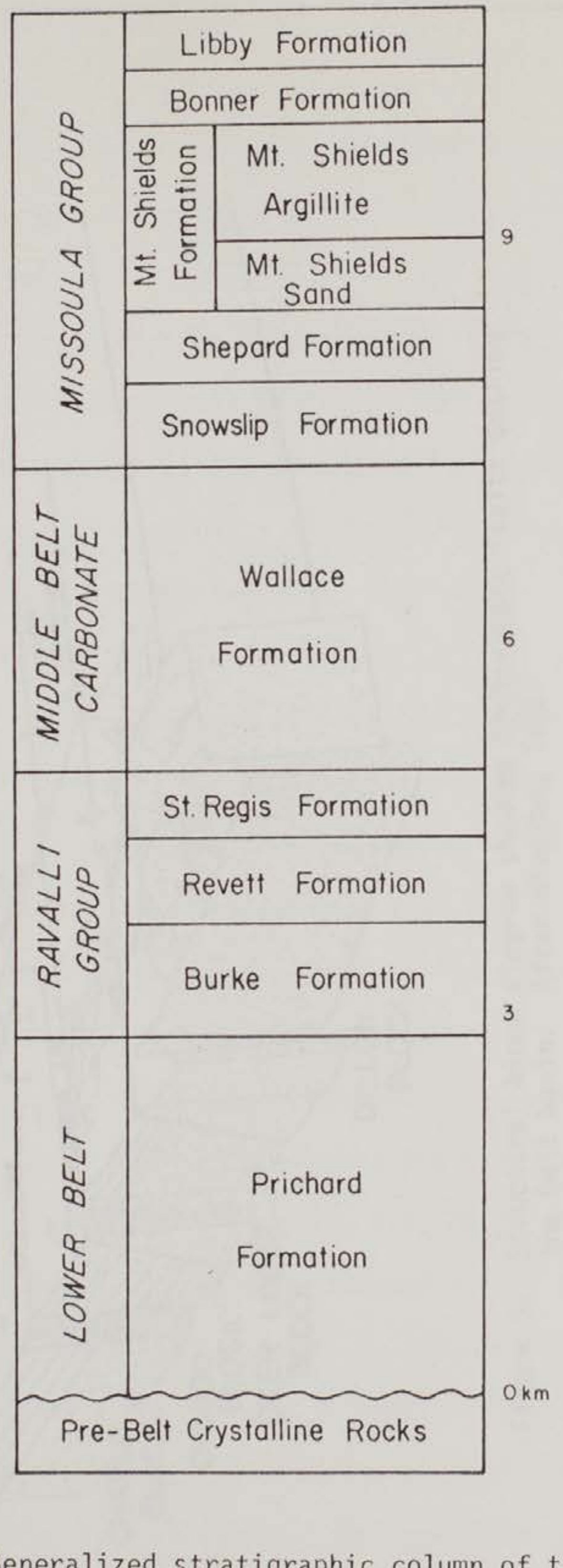


Figure 2. Generalized stratigraphic column of the Belt Supergroup.

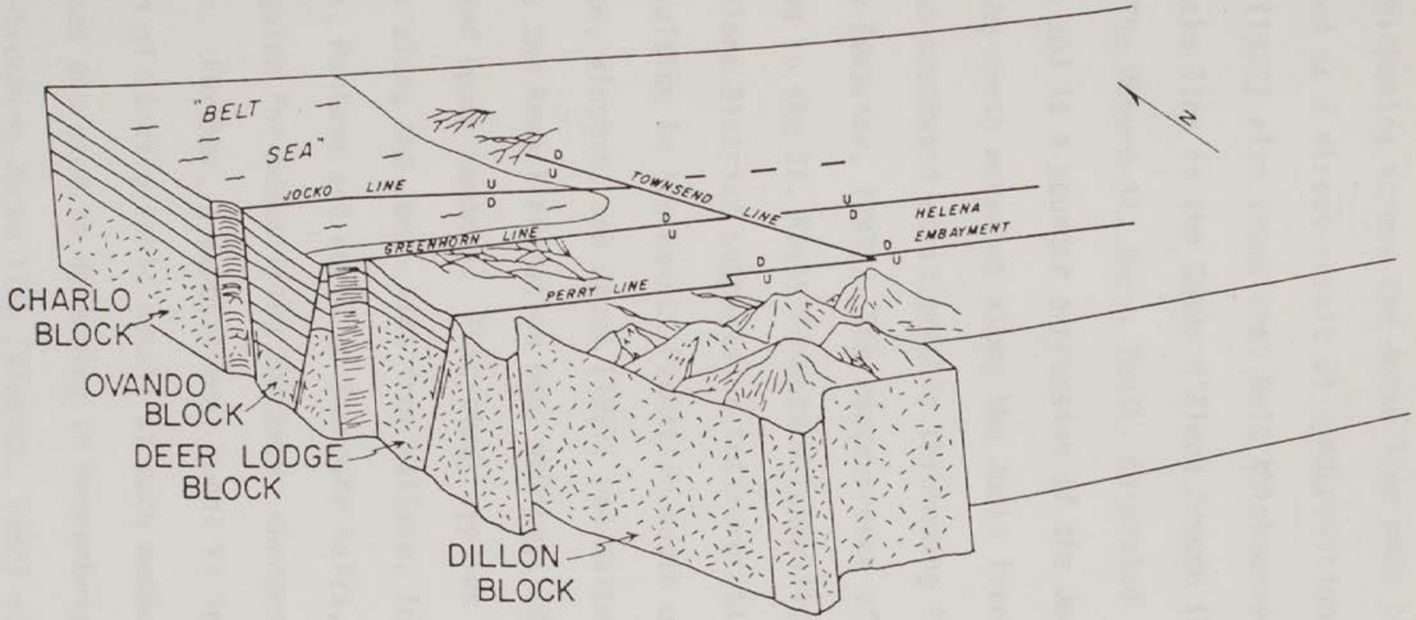


Figure 3. Structural block diagram showing Proterozoic faults cutting the Belt basin. After Winston, 1982.

during Belt deposition. Winston contends that southward stratigraphic thickening across the Jocko line onto the Ovando block can be interpreted as a direct result of syndepositional growth-faulting. Harrison (1972) also shows that Belt thicknesses are greatest south of the Jocko line in the Coeur d'Alene Trough (Harrison and others, 1974b). The Osburn-St. Marys fault, generated by Cenozoic extension, parallels and is a younger expression of the Jocko line. Precambrian down-to-the-south movement along the Jocko line caused soft-sediment slumps and southward stratigraphic thickening in the lower Prichard Formation (Webster, 1981). The reoccurrence of slumps and southward thickening in the St. Regis Formation (Chevillon, 1977) in the Coeur d'Alene District supports an interpretation of syndepositional growth faulting in the Revett Formation south of the Jocko line.

White, Winston, and Jacob (1977) and White and Winston (1982) subdivide the Revett Formation near Kellogg, Idaho into lower, middle, and upper members. This study applies their stratigraphic framework along the Jocko line from Wallace, Idaho as far east as St. Regis, Montana and north to Thompson Falls, Montana and utilizes it as a guide for identifying thickness changes within the Revett Formation. Further, a depositional model is interpreted from description of stratigraphic detail of each member. Measured section thicknesses are used to determine if Precambrian growth-faulting along the N82W-trending Jocko line (Winston, 1982) could be responsible for stratigraphic thickening to the south. Geographic distribution of thick and thin measured sections helps place limits on the orientation of the proposed growth-fault. In effect, does the proposed

Jocko line separate thin and thick sections? What other orientations could such a fault assume and still account for the observed thickness changes?

In order to document the presence and magnitude of thickness changes in the Revett Formation, stratigraphic sections were measured with a Jacob's staff and Brunton compass and described at a scale of 1" = 10' in the field. Figure 4 shows the location of these sections and their proximity to the Jocko line.

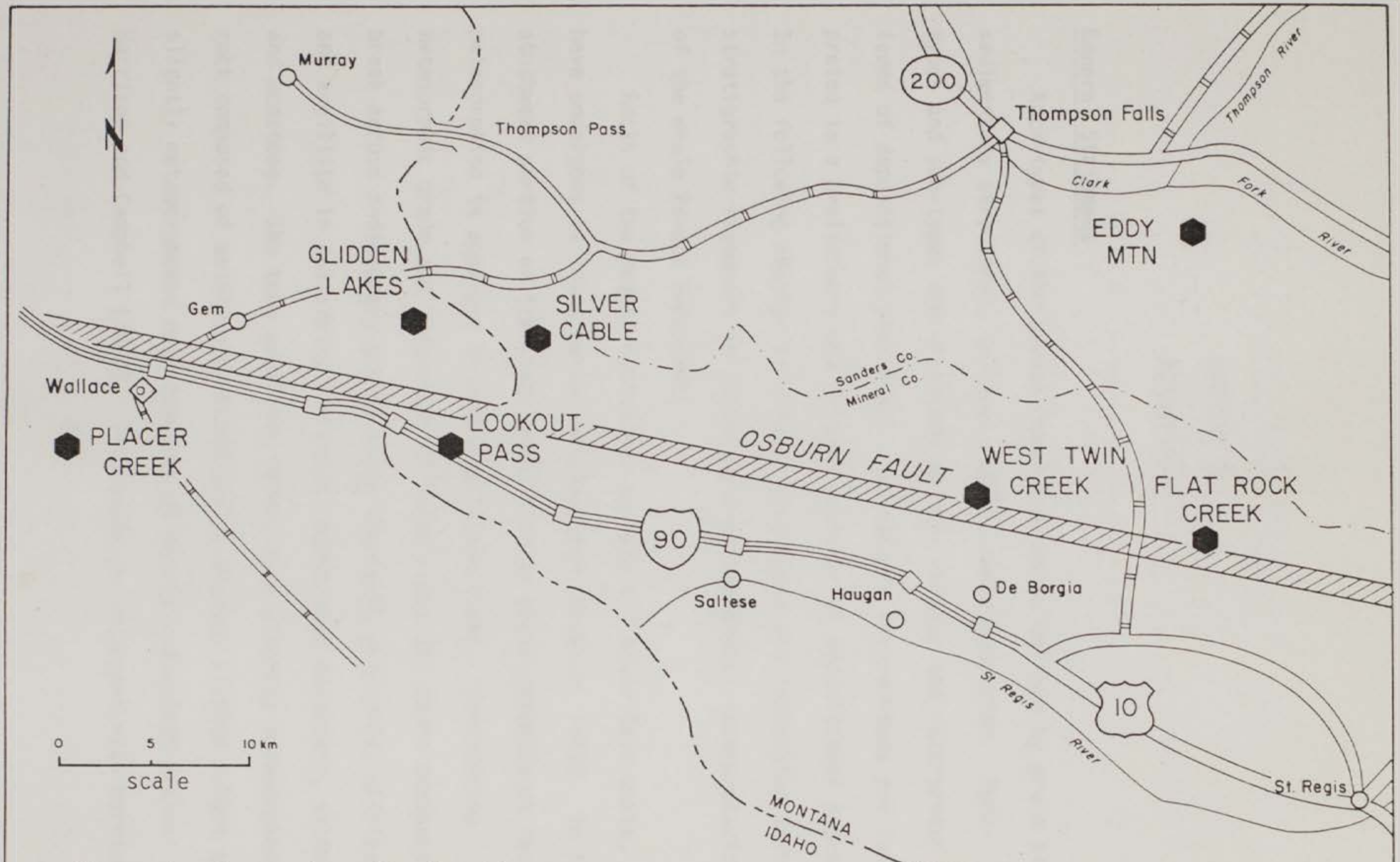


Figure 4. Measured section location map.

CHAPTER II

ROCK-TYPES

General Statement

Rock-types of the Revett Formation can be defined by grain size, sedimentary structures, textures, color, and composition. Rock-types and sub-types are described in this chapter and interpreted in terms of depositional processes. Sedimentary environments are interpreted in a preliminary way through analysis of depositional processes. In the following chapter individual rock-types are integrated into a stratigraphic framework to refine paleoenvironmental interpretation of the whole Revett Formation.

Rocks of the Revett Formation, as have all lower Belt units, have undergone at least burial metamorphism (Norwick, 1972). In the southwest portion of the study area, biotite grade greenschist facies metamorphism is apparent in more argillitic rocks. Considering metamorphic grade and induration of these rocks and their tendency to break across sedimentary grains I use the terms quartzite, siltite, and argillite in describing the rocks rather than sandstone, siltstone, and mudstone. The term argillite refers to a slightly metamorphosed rock composed of mainly clay-sized grains whereas siltite refers to a slightly metamorphosed rock composed of mainly silt-sized grains . Harrison and Campbell (1963). This usage is in accord with Harrison and Jobin (1963) and also with terminology used in publications concerning Belt rocks.

The three rock-types of the Revett Formation as identified here are 1) the vitreous white quartzite rock-type; 2) the silty quartzite rock type; and 3) the thinly-laminated siltite-argillite rock-type. The vitreous white quartzite rock-type is divided into a flat laminated sub-type, a cross-stratified sub-type, and a ripple cross-laminated sub-type. The silty quartzite rock-type includes a continuum of rock-types ranging from silty quartzite to sandy siltite which is most commonly massive. The most common sedimentary structures are ripple cross-lamination and flat lamination. The thinly-laminated siltite-argillite rock-type is composed of siltite, argillite, and intricate mixtures of these two size grades as laminae and as grains.

Interbeds of the vitreous white quartzite and silty quartzite rock-types form the lower Revett and intervals of the upper Revett. The thinly-laminated siltite-argillite rock-type dominates the middle Revett and composes intervals in the upper Revett.

Vitreous White Quartzite Rock-Type

General Description

The vitreous white quartzite rock-type is composed of well-sorted, subrounded, coarse-silt to medium-grained quartz and feldspar sand grains. It is white, very light green, or light grey on both weathered and fresh surfaces. Individual beds and sets of beds range from 5 to 300 cm thick and average 30 to 80 cm thick. Upper and lower surfaces are remarkably parallel and nearly flat, forming very tabular beds that can be traced along outcrop for more than 100 m where exposure permits. Flat bases of some beds are erosional whereas most are depositional surfaces. The top 3 to 10 cm of some beds subtly fines upward by an increase in the silt and clay matrix between the sand grains. Since the original clay is now phengite or sericite (Steve Herndon, pers. comm.), the fining upward sequences are reflected by a slight darkening in color which corresponds to the increase of iron contained within the finer sediment. A discrete thin argillite layer ranging from a veneer to a layer 0.5 cm thick commonly caps these graded sequences. Rounded argillite chips 0.1 to 0.5 cm thick and 0.3 to 2.0 cm long are incorporated in some quartzite beds as scattered matrix-supported clasts with long axes oriented parallel to bedding. Argillite clasts occur more commonly as isolated grains than concentrated in layers. Three sub-types of the vitreous white quartzite rock-type can be recognized and are described below.

Flat-Laminated Quartzite Sub-type

Description

The flat-laminated quartzite sub-type is the most common lithology of the Revett as well as the most common sub-type of the vitreous white quartzite, forming well over half of the fine-grained quartzite in the formation. This sub-type is characterized by tabular, laterally continuous beds with even horizontal laminae from 1.0 to 2.0 mm thick which are laterally continuous over tens of meters. Dark laminae only several grain diameters thick which reflect small magnetite and ilmenite concentrations alternate with magnetite-free light laminae. The bases of most beds, although sharp, are planar depositional surfaces and only occasional beds have scoured bases. Some beds fine upward by incorporating clay and are occasionally capped by thin desiccation-cracked argillite layers (Fig. 5a) sharply overlain by the succeeding bed, most commonly a bed of the silty quartzite rock-type less than one to ten cm thick. Generally, beds of flat-laminated quartzite are sharply overlain by beds of silty quartzite with little evidence of a gradation separating them (Fig. 5b). Bed boundaries within sets of flat-laminated quartzite beds are occasionally marked by argillite veneers less than several mm thick. Bedding surfaces infrequently exhibit parting lineation which parallels dip direction of cross strata of the cross-stratified sub-type.

Interpretation

The flat-laminated quartzite sub-type represents upper flow regime, plane bed deposition of traction load sediment on broad flat surfaces. Since the grain size is medium to very fine, much of the sand may have been carried in suspension as well as in traction. Lack of irregularities on plane beds imparted great lateral continuity, sharp planar boundaries, and parallel-horizontal orientation to individual lamina. Hydrologic segregation of bed load into magnetite/ilmenite-rich and poor laminae formed flat horizontal laminae and orientation of long grain axes parallel to flow direction formed parting lineation (Allen, 1964).

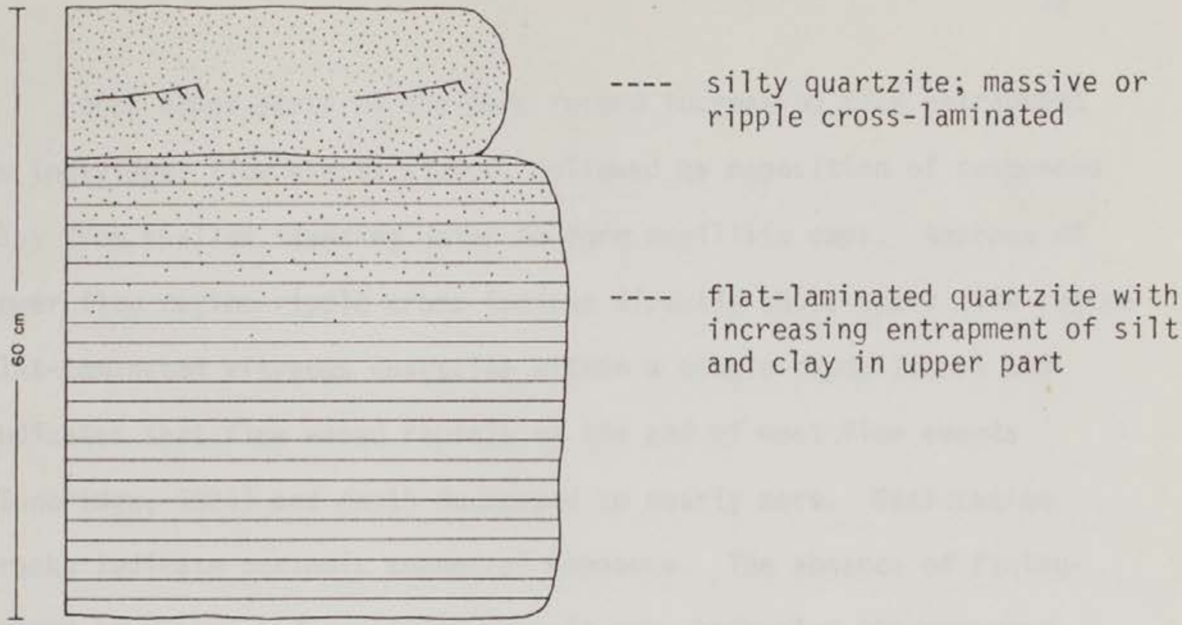


Figure 5a. Flat-laminated quartzite with increasing silt and clay in upper part sharply overlain by silty quartzite.

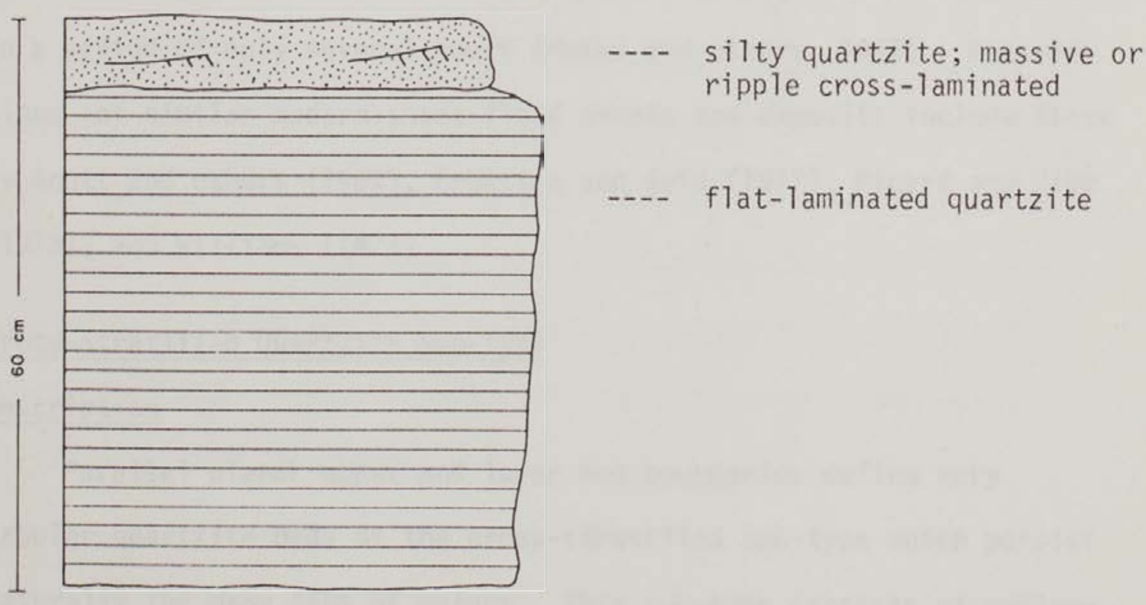


Figure 5b. Flat-laminated quartzite sharply overlain by silty quartzite.

Finer upper parts of the beds record increasing clay entrapment as individual flow events slowed, followed by deposition of suspended clay from shallow standing water to form argillite caps. Absence of lower flow regime ripple cross-laminae directly above upper flow regime flat-laminated vitreous quartzite within a single depositional bed indicates that flow waned rapidly at the end of most flow events (Tunbridge, 1981) and depth decreased to nearly zero. Desiccation cracks indicate periodic subaerial exposure. The absence of fining-upward sequences and argillite caps in some beds plus the presence of rounded argillite clasts in other beds reflect minor scour and reworking, although reactivation surfaces are difficult to pinpoint due to their planar horizontal configuration parallel to bedding and lamination. Extensive flat-laminated sand beds very similar to this Revett sub-type were deposited by a large flood at Bijou Creek, Colorado in a period of only several hours (McKee and others, 1967). Descriptions of similar modern sheet flood events and deposits include those by Scott and others (1969), Frostick and Reid (1977), Picard and High (1973), and Williams (1971).

Cross-Stratified Quartzite Sub-type

Description

Parallel planar upper and lower bed boundaries define very tabular quartzite beds of the cross-stratified sub-type which persist laterally for many tens of meters. This sub-type consists of medium- to very fine-grained sand and composes 15 to 35 percent of the vitreous white quartzite rock-type. It is the most distinctive and commonly-mentioned lithology of the Revett Formation. Both solitary sets and individual sets of cross-strata within cosets range from 15 to 100 cm and average 25 to 40 cm thick. Vertical stacking of two or more cross strata sets is common and forms planar cross stratification cosets varying from 50 to 300 cm and averaging 100 cm thick (Fig. 6a). Lower boundaries of cosets of planar cross-strata are planar, essentially non-erosional surraces laterally continuous for at least many tens of meters. Contacts between vertically-stacked planar cross-strata sets are sharp surfaces which horizontally truncate underlying foreset beds. Grouped cosets commonly form complete quartzite beds exclusive of any other rock-type (Fig. 6a). Solitary sets of simple cross-strata commonly occur at the base of and within thicker sequences of flat-laminated quartzite (Fig. 6b). Tangential cross-strata foresets dip 15 to 25 degrees with respect to bedding. Cross strata dips are unimodal and indicate generally north-northeastward sediment transport (Hrabar, 1971; Bowden, 1977). Bimodal or herringbone cross-strata are not apparent from field observation. Vertical gradation from the planar cross-stratified to the flat-laminated rock-type overlain by silty quartzite forms a large proportion of the lower Revett and quartzite intervals of the upper Revett.

Interpretation

Down-current migration of straight- to slightly sinuous - crested sand waves characteristic of the upper part of the lower flow regime

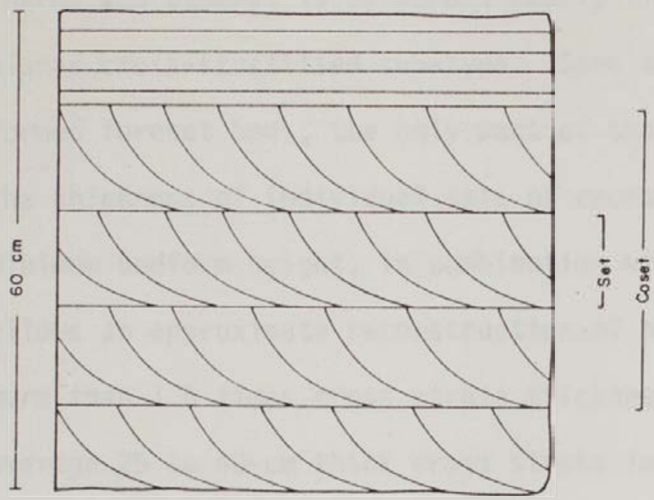


Figure 6a. Planar cross-strata with tangential foresets in tabular beds. Set and coset terminology after McKee and Weir (1953).

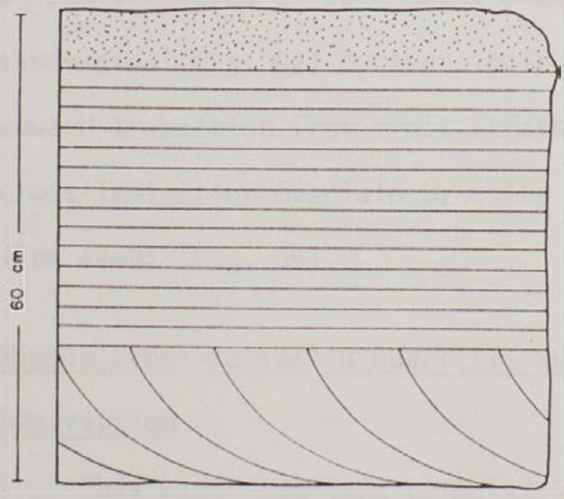


Figure 6b. Simple cross-strata with tangential foresets in a tabular bed overlain by flat-laminated quartzite.

(Harms and others, 1975) across nearly flat surfaces deposited the planar cross-stratified sub-type. Sand avalanches down slipfaces formed foreset beds, the only part of the bedform commonly preserved. The thickness of individual sets of cross strata, which reflect the minimum bedform height, in combination with several other parameters, allows an approximate reconstruction of paleoflow depths probably more than 1.5 times cross strata thickness (Jopling, 1966). Thus the average 25 to 40-cm thick cross strata indicate paleo flow depths of approximately 35 to 60 cm or more. Tangential foreset beds are due to buildup of lower foreset slopes by sediment falling from suspension more rapidly than sediment avalanching down the slipface, and may indicate a large amount of sediment in suspension (Jopling, 1965). Foreset dips of 15 to 25 degrees common in the Revett are indicative of relatively high velocities (Jopling, 1966). Stacked sets of unimodal cross strata not separated by argillaceous laminae record downstream migration of sand waves over foresets of adjacent preceeding sand waves (Fig. 6a) during single major flood events. Conversely, upward transition from cross strata to flat lamination and/or ripple cross-lamination overlain by silty quartzite records waning of one flow event (Fig. 6b).

Ripple Cross-Laminated Quartzite Sub-type

Description

This minor sub-type comprises clean quartzite containing either asymmetrical ripple cross-laminae or ripple drift laminae. Ripple drift laminae build perceptibly upward from depositional horizontal at varying angles, whereas ripple cross-laminae build upward at very low angles or do not build upward at all. Foreset laminae 1.0 to 3.0 cm high with 3.0 to 10.0 cm wavelengths dip 15 to 25 degrees to overall bedding. Ripple drift cross-laminae are type A of Jopling and Walker (1968), without stoss-side laminae with laterally-climbing ripple crests (Fig. 7). The ripple cross laminated sub-type occurs as 5 to 35 cm thick beds only within thicker vitreous white quartzite and most commonly transitionally overlies a sequence of the flat-laminated sub-type. The ripple cross-laminated sub-type is most commonly overlain by the silty quartzite rock-type.

Interpretation

Downstream migration of small current ripples of the lower part of the lower flow regime formed ripple cross-lamination. Simple cross-laminae result from foreset avalanche accumulation on only the lee side of migrating ripples whereas type A ripple drift cross-laminae form as rate of accumulation of suspended sediment on the lee side of current ripples approaches the rate of down-current migration (Jopling and Walker, 1968) causing ripple crests to build upward obliquely (Fig. 7). Ripple drift cross-laminae thus indicate fairly rapid accumulation of sediment from suspension and commonly form where velocity slows abruptly (McKee and others, 1967). Beds of the ripple cross-laminated sub-type gradationally overlying the flat-laminated sub-type record a shift from upper to lower flow regime as individual flood events wane, further evidence of the episodic, rapid complexion of Revett deposition.

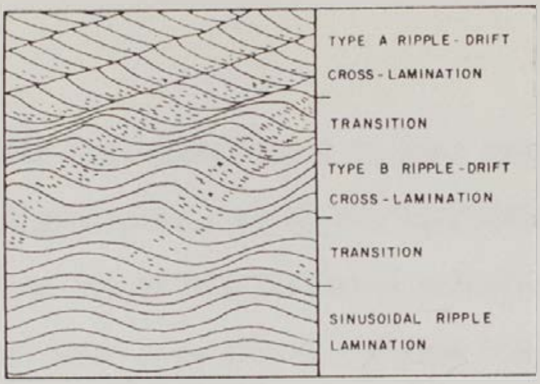


Figure 7. Diagrammatic representation of the gradation from sinusoidal ripple lamination to type A ripple-drift cross-lamination. This gradation represents increasing bed load movement relative to suspended load fallout. After Jopling and Walker, 1966.

Silty Quartzite Rock-Type

Description

The silty quartzite rock-type ranges from silty, very fine-grained quartzite to sandy siltite to argillitic siltite composed mainly of quartz and feldspar. Silt- and argillite-sized grains also consist of muscovite, phengite sericite, illite, and chlorite produced by burial metamorphism of original clay (Hoffman and Hower, 1979). Fresh and weathered surfaces range from light to very dark green and brownish green, reflecting the poorly sorted composition of this rock-type. Weathered outcrop faces appear very thinly-bedded and bedding surfaces commonly have a dull phyllitic sheen.

The silty quartzite rock-type occurs in beds ranging from less than 1.0 to 60 cm thick and averaging 3 to 20 cm interbedded with both the vitreous white quartzite and thinly-laminated siltite-argillite rock-types. Individual beds have parallel planar bounding surfaces and are continuous laterally as far as most exposures extend, up to many tens of meters. This rock-type is most commonly massive or penetratively cleaved, making its sedimentary structures difficult to discern. Infrequent sedimentary structures in decreasing order of abundance are current ripple cross-lamination, flat lamination, ripple drift cross-lamination, and occasional graded siltite to argillite couplets 0.5 to 2.0 cm thick. Occasional argillite surfaces are mud-cracked. Matrix supported argillite clasts, ranging from rounded to angular, averaging 0.3 cm thick by 1.5 cm long lie parallel to bedding.

Interpretation

Episodic flows deposited sand and silt on flat, gently sloping surfaces. The abundant massive bedding in the silty quartzite rock-type may have formed in several ways. Very rapid deposition from suspension (Blatt and others, 1980; p. 136; Reineck and Singh, 1980; p. 113) or deposition from highly concentrated sediment dispersions (Blatt and others, 1980; p. 136) can form massive, homogeneous bedding, and dewatering during compaction (Reineck and Singh, 1980; p. 113) or liquefaction soon after deposition (Blatt and others, 1980; p. 136) can destroy primary sedimentary lamination.

Migration of lower flow regime small current ripples with varying proportions of suspended and traction deposition formed ripple cross-lamination and ripple drift lamination. Upper flow regime plane beds formed flat lamination. The dirtier and less well-sorted quality of the silty quartzite rock-type resulted from rapid deposition from suspension and from deposition by lower flow regime small current ripples which deposited larger proportions of interstitial silt and clay than plane beds and large-scale sand waves (Wilson and Pitman, 1977) which deposited most of the vitreous quartzite rock-type. Graded siltite to argillite couplets record waning of discrete flow events followed by periods of standing water deposition of suspended clay and mud. Subaerial shrinkage cracks record drying of exposed mud surfaces. Mudcracked polygons were reworked into rounded mud clasts by subsequent sediment influx. Intermittent subaerial exposure, in combination with unidirectional cross-strata dips, repeated shallowing and waning flow events, and abundant upper flow regime plane bed deposition, is strong evidence for a fluvial rather than marine depositional environment.

Thinly-Laminated Siltite-Argillite Rock-Type

Description

The thinly-laminated siltite-argillite rock-type occurs in the middle and upper Revett and is characterized by irregularly alternating slightly wavy laminae of light to medium green massive siltite and argillite 0.1 to 5.0 mm thick. Individual laminae pinch out laterally over distances of less than 10 cm. Boundaries between siltite and argillite laminae are generally quite sharp. Siltite bases commonly cut and truncate underlying argillite laminae. This rock-type differs from the silty quartzite rock-type in its overall finer grain size and the wavy discontinuity of its thin laminae. Of secondary importance are more continuous sedimentary couplets which grade upward from siltite into argillite and are commonly interbedded with intervals of the thinly-laminated argillitic siltite. They most commonly occur as stacks of several couplets, each averaging 2.0 cm thick. Unlike the wavy siltite and argillite laminae, they extend laterally for several meters. These couplets are commonly truncated at low angles from above by thinly-laminated argillitic siltite beds. Siltite in couplets and thinly-laminated rocks is most commonly massive but occasionally ripple cross-laminated to indistinctly horizontally laminated. Oscillation ripples occur occasionally. Rounded argillite clasts 0.1 to 5.0 mm thick by 1.0 cm long occur in this rock-type but are less common than in vitreous white quartzite or silty quartzite.

Interpretation

Thinly interlaminated siltite and argillite record alternation of upper and lower regime flow in very shallow, narrow scours and suspended deposition from standing water, respectively. Laterally discontinuous thin interlaminae reflect the temporal continuity of these processes and the irregular lateral migration of small scours millimeters deep by centimeters wide across flat low relief surfaces. Concentration of flow in small scours and lack of high suspended sediment loads enabled these more continuous processes to rework sediment and truncate underlying laminae, rendering individual depositional events difficult to discern. Occasional oscillation ripples are evidence for wave reworking in standing water. Rounded argillite clasts are smaller and less common than in the silty quartzite rock-type indicating longer periods of water-saturated conditions with less drying of muddy surfaces. Reworking by subsequent flow events is facilitated by moist, poorly-consolidated sediment. Graded siltite to argillite couplets record accumulation first of traction and suspended silt followed by deposition of suspended clay during waning flow of individual depositional events. Subsequent flow events reworked underlying mud layers into rounded mud clasts.

CHAPTER III

STRATIGRAPHY, CORRELATION AND FURTHER INTERPRETATIONS

General Statement

In the foregoing chapter rock-types were described and provisionally interpreted on the basis of local depositional processes. Depositional environments can be more thoroughly interpreted through integrated analysis of rock-types within their stratigraphic framework. Vertical sequences in measured and described sections of Revett exposure (Appendix B) add much information that simple rock descriptions cannot, and the correlation based on the sequences provides the stratigraphic and sedimentologic framework. Vertical exposure in the study area is generally quite good but exposure along strike varies from poor in some areas to excellent in cirque walls at higher elevations, where great lateral continuity of individual beds is most apparent.

Lithic Correlation

Correlation of measured sections in the study area (Fig. 8) is based on lithologic sequence rather than specific marker beds. The lower, middle, and upper informal members of the Revett Formation defined near Kellog, Idaho (White, Winston, and Jacob, 1977; White and Winston, 1977, 1982) can be correlated throughout the study area to the east. Lithologically, the lower Revett is dominated by

Horizontal Scale

For N-S and E-W distance between sections

1cm = 3 km

Lithologic Key

- vitreous white quartzite
- thinly-laminated siltite-argillite
- silty quartzite
- red argillite
- covered section

BELT UNITS

Yw = Wallace Formation
Ysr = St. Regis Formation
Yru = upper Revett Formation
Yrm = middle Revett Formation
Yrl = lower Revett Formation
Yb = Burke Formation

MEASURED SECTIONS

PC = Placer Creek
GL = Glidden Lakes
LP = Lookout Pass
SC = Silver Cable
WT = West Twin Creek
FR = Flat Rock Creek
EM = Eddy Mountain

Figure 8. Stratigraphic correlation of the Revett Fm. in the study area and key to correlation diagram.

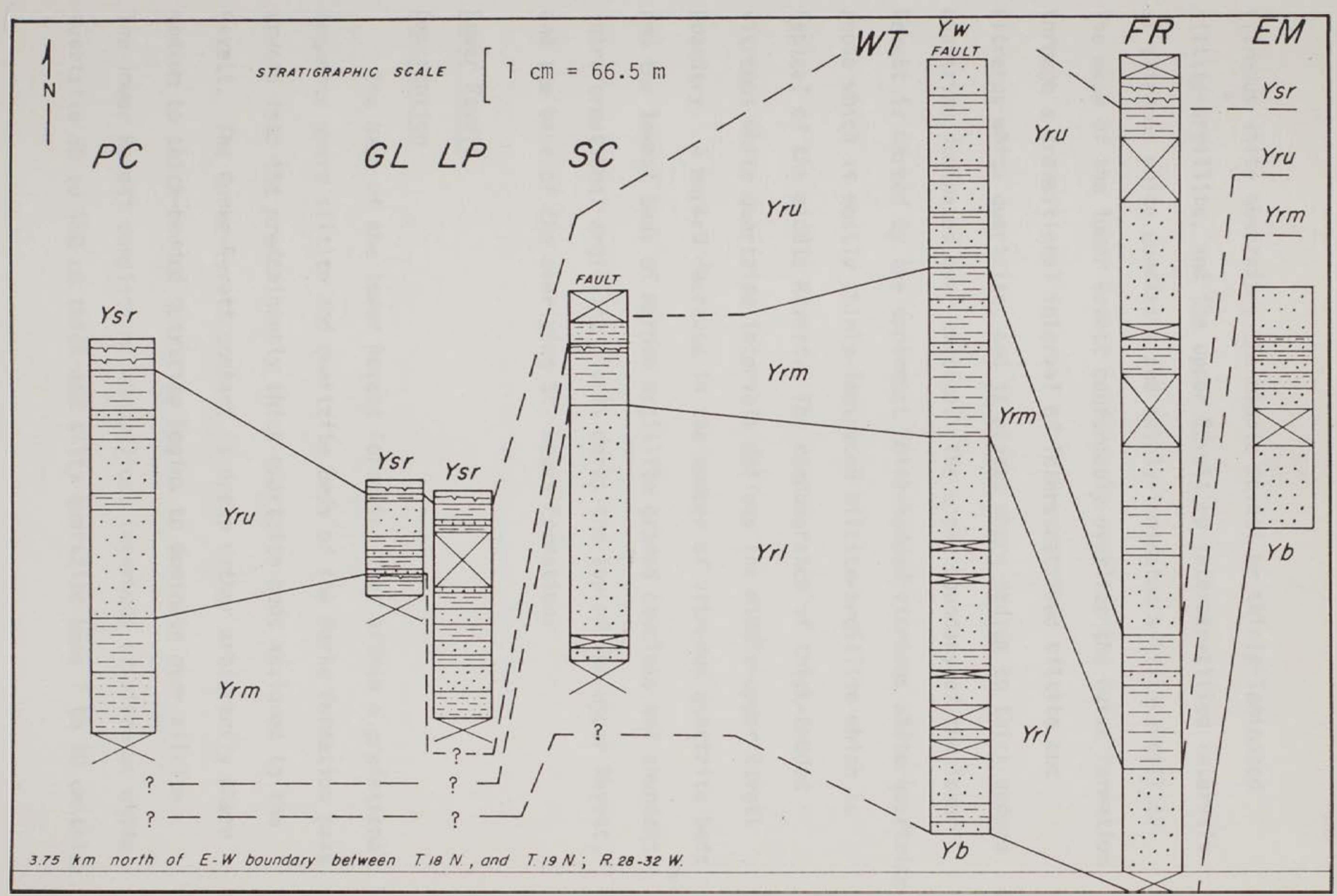


Figure 8. Correlation Diagram

vitreous white quartzite, the middle Revett by thinly-laminated siltite-argillite, and the upper Revett by interstratified intervals of vitreous white quartzite and thinly-laminated siltite-argillite. The base of the lower Revett conformably overlies the Burke Formation through a transitional interval of interstratified siltite and vitreous white quartzite, and is placed where medium to thick-bedded quartzite dominates over siltite. The upper boundary of the lower Revett is marked by the uppermost thick-bedded vitreous white quartzite above which is mostly thinly-laminated siltite-argillite which is typical of the middle Revett. The reappearance of thick-bedded vitreous white quartzite intervals defines the middle-upper Revett boundary. A marked decrease in the number of vitreous quartzite beds and the lowest beds of maroon argillite graded couplets and abundant intraformational argillite clasts marks the top of the upper Revett, and the base of the overlying St. Regis Formation.

Lower Revett

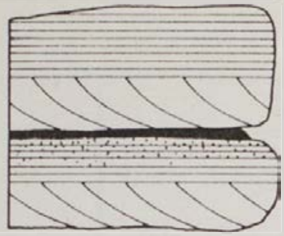
Description

The base of the lower Revett Formation lies within a gradational sequence where siltite and quartzite beds of the Burke Formation pass upward into the predominantly thick quartzite beds assigned to the Revett. The Burke-Revett contact is drawn rather arbitrarily where medium to thick-bedded quartzite begins to dominate over siltite. The lower Revett consists of noncyclical interbeds of vitreous white quartzite 50 to 150 cm thick and silty quartzite beds 1 to 20 cm thick.

Upper portions of vitreous white quartzite beds are in nearly every case overlain directly by silty quartzite with a sharp to slightly gradational boundary between the two rock-types. Upper portions of some quartzite beds are graded through increase in interstitial clay and capped by an argillite veneer. Where vitreous white quartzite beds are greater than 50 cm thick, overlying silty quartzite beds range from less than 1.0 to 15 cm thick. Where vitreous white quartzite beds average 5 to 30 cm thick, overlying silty quartzite beds range from 5 to 35 cm thick. Vitreous white quartzite beds are commonly composed completely of flat-laminated quartzite but are also commonly formed by an upward transition from cross-stratified quartzite to flat-laminated quartzite. Figure 9 illustrates typical stratigraphic sequences abstracted from measured and described sections of the Revett Formation (Appendix B). The lower sharp boundaries of the vitreous white quartzite beds have only several cm of erosional relief into underlying beds, thus are remarkably persistent along strike distances of many tens to hundreds of meters.

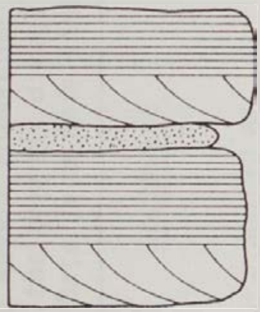
Across the study area, the average thickness of vitreous white quartzite beds, thickness of cross-strata sets, average grain size of vitreous white quartzite, and proportion of sand-size to silt-size rocks all decrease to the northeast. Conversely, the proportion of flat-laminated rocks and ripple cross-laminated rocks to cross-stratified rocks increases to the northeast (Table I). These general trends in the Revett Formation are also observed by Bowden (1977).

A)



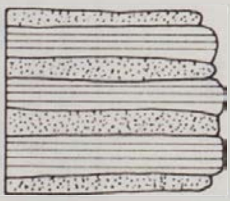
Interpretation - waning and shallowing of a single flow event

B)



Interpretation - waning and shallowing of a single flow event
- more proximal, central part of flow

C)



Interpretation - waning of individual flow events
- more distal, lateral part of flow than (B) reflected by thinner beds and higher ratio of siltite to quartzite

D)

Interpretation - waning of a single flow event

Figure 9. Typical stratigraphic sequences abstracted from measured sections (Appendix B), all exhibiting evidence of rapid, episodic deposition.

Table I. Lateral variation in the Revett Formation from southwest to northeast, the general direction of sediment transport. Data from this study only.

	Southwest	Northeast
Maximum/Average thickness of vitreous white quartzite beds	300/90 cm	200/60 cm
Maximum/Average thickness of cross-strata sets	100/60 cm	80/30 cm
Maximum/Average grain size of vitreous white quartzite	med. sand/ fine sand	fine sand/ v. fine sand
Proportion of sandy to silty rocks	higher (approx. 10:1)	lower (approx. 7:1 or less)
Proportion of flat-laminated and ripple cross-laminated to cross-stratified rocks	lower (approx. 4:1)	higher (approx. 10:1)

Interpretation

Laterally continuous stratification indicates that sediment was deposited on flat surfaces. Paleocurrent data (Appendix C) indicate that transport was north-northeastward (Bowden, 1977; Hrabar, 1971). Regional sedimentologic trends (Table I) are compatible with a north-northeastward transport direction. Intimate interbedding of the vitreous white quartzite and silty quartzite rock-types on a scale of decimenters, and their persistence along strike for many tens of meters with no significant channeling or change in thickness can best be explained by large episodic sheet floods that crossed broad flat surfaces (Tunbridge, 1981; Rahn, 1967; Williams, 1971; Scott and others, 1969). Upward transition within single beds from flat-laminated vitreous white quartzite to massive or current rippled silty quartzite to thin, occasionally mud-cracked argillite caps indicates rapid fluvial sedimentation punctuated by subaerial exposure with local ponding. These processes are most closely analogous to those in modern internally-drained intermontane basins or bolsons where material is transported in sheet floods from the lower segment of an alluvial fan across a broad flat alluvial plain (Peterson, 1981). Bolsons are divided by Peterson into two major physiographic parts, the piedmont slope and the bolson floor. At the base of the piedmont slope lies the fan skirt which is built from sediment reworked from coalescing alluvial fans upslope. The fan skirt is characterized by a lack of dissection and a distinctly smooth topographic surface. Single floods deposit sheets of sediment along broad swales in the gentle slope. Denny (1965, p. 39) also describes in bolsons of the southwestern U.S. very broad flat-floored troughs with no distinct banks, which he terms desert washes. Modern sheet flood deposits described briefly by Bull (1963), McKee and others (1967), McGee (1897), Williams (1970), and Wasson (1977) bear marked similarity to the lower Revett in that they are broad, laterally extensive sediment sheets with sharp planar bases without scouring and well-defined channels.

Lateral persistence and interbedding of rock-types as well as the scarcity of channeling and scouring in the Revett Formation can be explained by deposition by similar sheet flood processes but in environments of a greatly expanded scale. Simultaneous formation of two distinct rock-types within one sheet flood can be explained by observing how flow regime affects sorting in fluvial sands. Wilson and Pitman (1977) demonstrate that interstitial clay and silt are low or absent in sand deposited by upper lower flow regime large ripples (including sand waves) and upper flow stage (plane beds) whereas clay and silt content can be quite high in sand deposited by bedforms of the lower part of the lower flow regime. During the main pulse of a flood event, plane beds and sand waves deposit clean well-sorted sand. As the flood wanes, velocity and depth decrease causing deposition of silty impure sand rapidly from suspension and from small-scale current ripples. Scott and others (1969) determined that deposits at lateral margins of sheet floods thin and consist of interlayered sandy and silty sediment (Fig. 10), thus the ratio of vitreous white quartzite to silty quartzite thickness at a specific stratigraphic level can serve as a guide to relative proximity within a depositional sheet. In the Revett Formation, the highest vitreous : silty thickness ratios of greater than 100:1 represent the most proximal central portion of a flood where plane beds and sand waves deposited greater thicknesses of clean sand than at more lateral and distal parts of the flood sheet. Sections of the lower Revett with the lowest vitreous : silty thickness ratios of about 1:1 represent the more lateral and distal edges of depositional sheets where flow conditions formed plane beds and sand waves less commonly (Fig. 11). Here higher proportions of silty quartzite were deposited from single flood events, mainly from rapid suspension deposition and from small-scale current ripples. Relatively thinner beds nearer flood margins reflect deposition where less sediment was transported per event farther from the central flood pulse.

Lack of irregular scoured surfaces at the base of vitreous white quartzite units can be in part explained by high sediment loads during flow events indicated by ripple drift cross-lamination and tangential foresets on cross-strata. High sediment loads are also characteristic of plane bed flow conditions. Relatively little scour can occur during flooding where much sediment falls from suspension, and as much sediment is delivered from upstream as is transported downstream (Laursen, 1953). Before the advent of land vegetation in the late

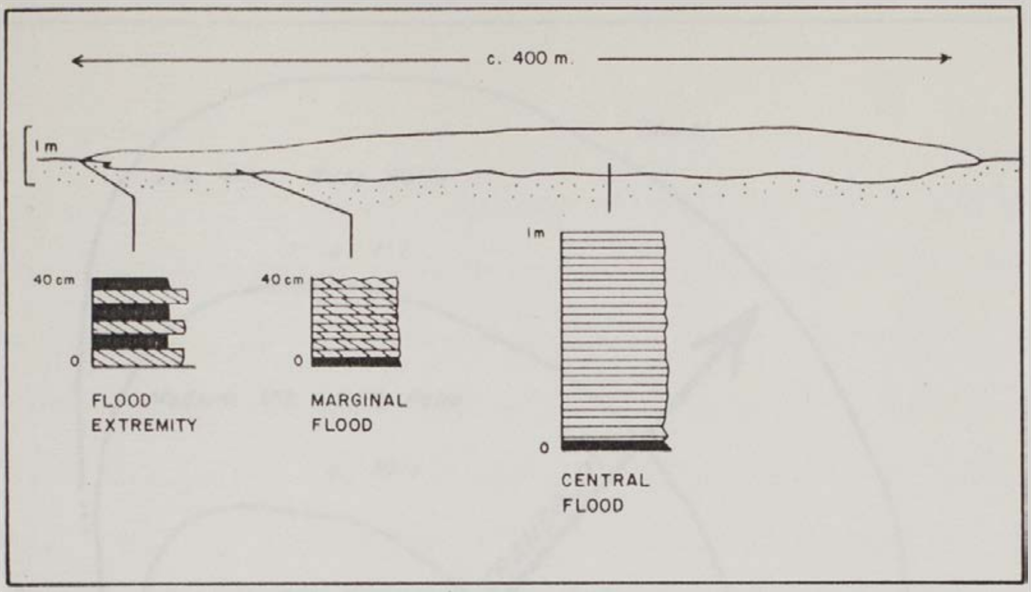


Figure 10. Lateral facies variation in a sheetflood deposit. After Scott and others, 1969; Tunbridge, 1981.

Paleozoic, fluvial sedimentation commonly occurred as identifiable individual flood events in the form of broad sheets (Schumm, 1968). Aggradation in locally lower areas fills irregularities and greatly increases width:depth ratios (Schumm, 1961), effectively minimizing channeling at any scale and forming flat planar upper and lower bed surfaces. Another factor in preventing scour and channel edges from forming is the noncohesive character of uniform sands low in clay (Long, 1978; Schumm, 1961) compounded by lack of stabilizing vegetation in pre-late Paleozoic time (Schumm, 1968; Pearce, 1976). Lack of evidence of channel incision in ancient fluvial systems has also been attributed to steadier regimes of river grade and climate in combination with steadier and/or higher sediment supply rates (Friend, 1978).

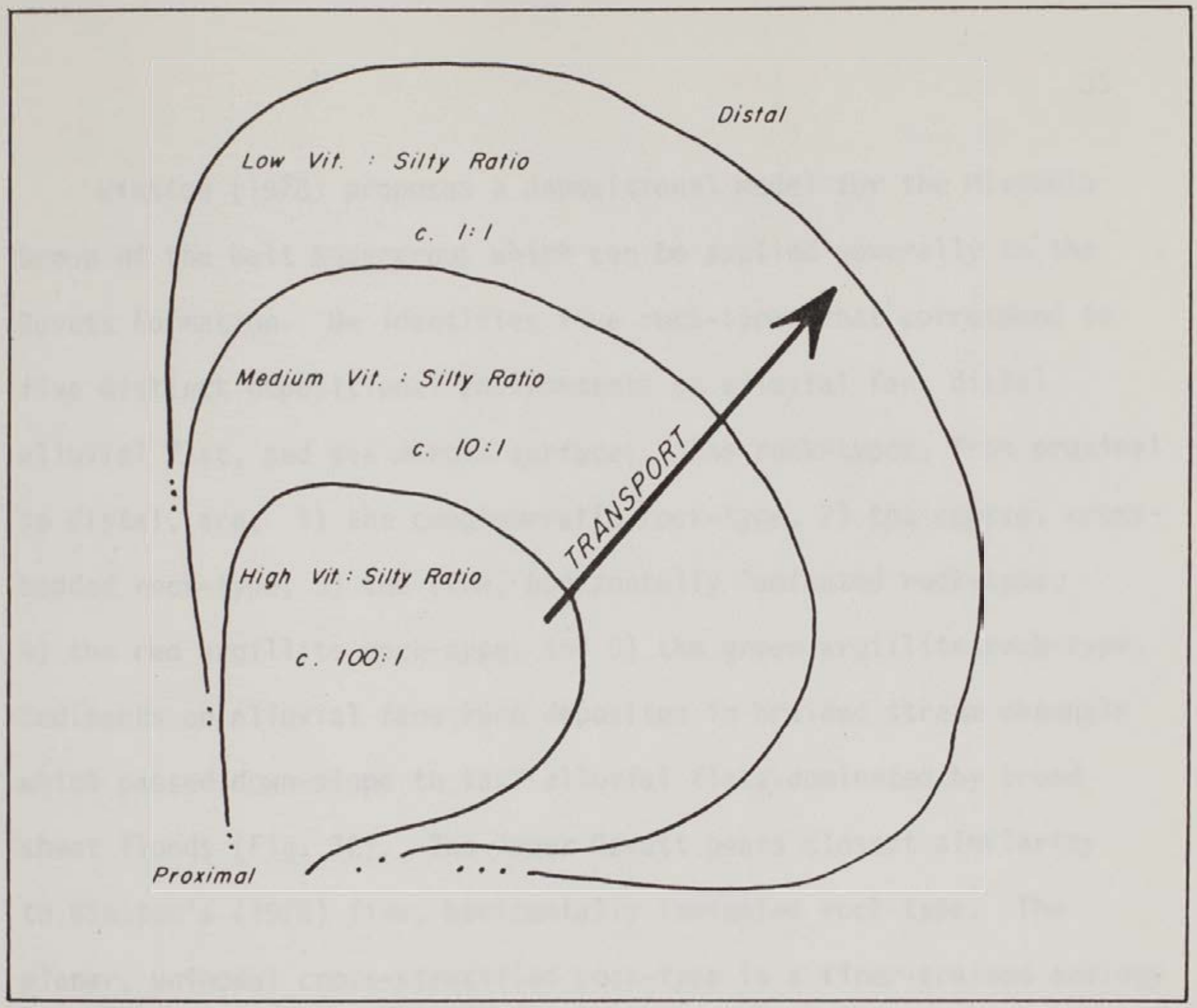


Figure 11. Plan view of proximal/distal and central/marginal variation in the ratio of vitreous white quartzite to silty quartzite rock-type in a sheetflood deposit.

Winston (1978) proposes a depositional model for the Missoula Group of the Belt Supergroup which can be applied generally to the Revett Formation. He identifies five rock-types that correspond to five distinct depositional environments on alluvial fan, distal alluvial flat, and sea margin surfaces. The rock-types, from proximal to distal, are: 1) the conglomeratic rock-type, 2) the coarse, cross-bedded rock-type, 3) the fine, horizontally laminated rock-type, 4) the red argillite rock-type, and 5) the green argillite rock-type. Sediments on alluvial fans were deposited in braided stream channels which passed down-slope to vast alluvial flats dominated by broad sheet floods (Fig. 12). The lower Revett bears closest similarity to Winston's (1978) fine, horizontally laminated rock-type. The planar, unimodal cross-stratified rock-type is a finer-grained analogy of the coarse, crossbedded rock-type. The lower Revett most probably represents a sheet wash environment on the alluvial fan skirt distal to braided streams of alluvial fan and at the most proximal part of the alluvial plain depositional environment. Steel and others (1977, 1978) describe a proximal alluvial plain sequence similar to the lower Revett in that it is characterized by tabular sand bodies with abundant flat lamination, planar cross-strata, and current ripples. Devonian fluvial sandstones studied by Friend (1978) show the following characteristics: 1) unimodal paleocurrent trends, 2) downstream decrease in grain size and thickness of quartzite beds, 3) downstream decrease in cross-strata thickness, 4) downstream increase in proportion of siltstone, small-scale stratification, and flat bedding,

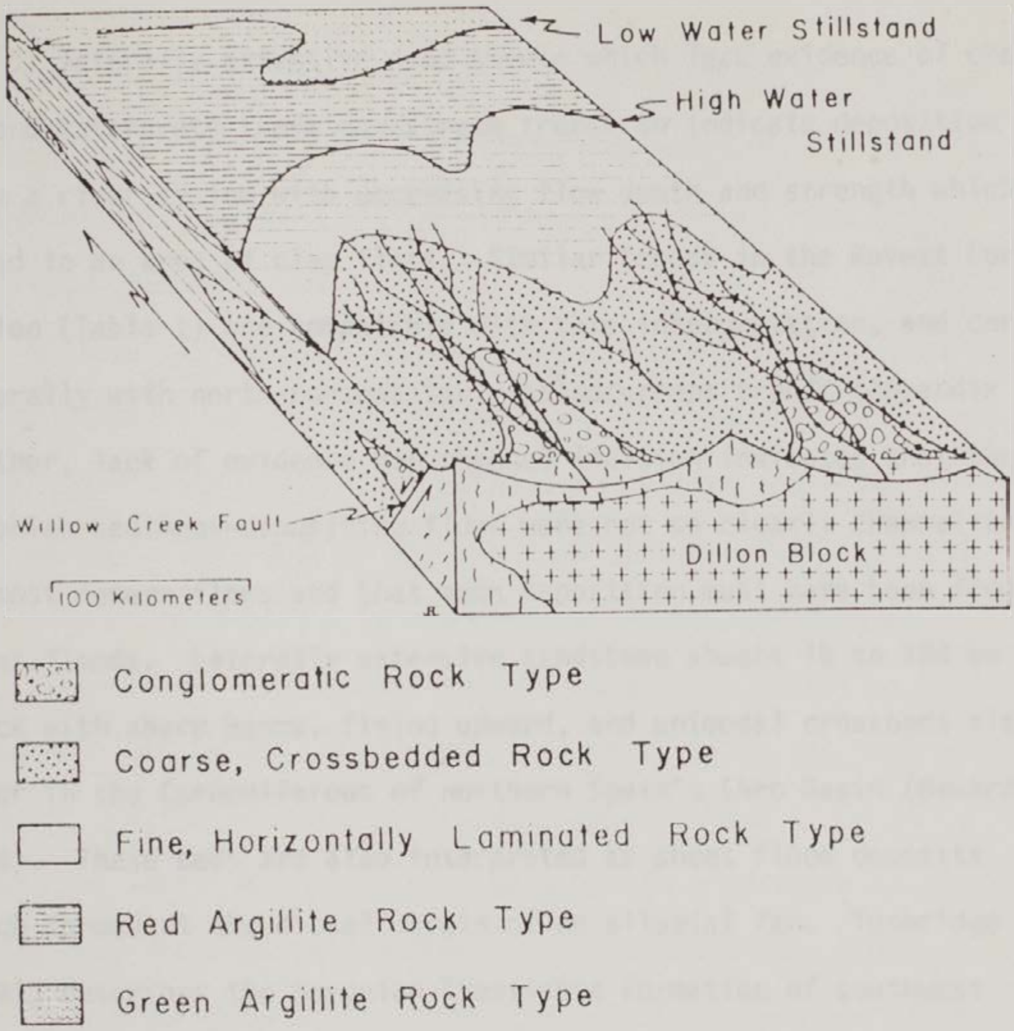


Figure 12. Schematic block diagram of Winston's (1978) fluvial facies model showing braided streams flowing from the Dillon block northward to the Belt Sea. After Winston, 1978.

and 5) laterally extensive sand sheets which lack evidence of channeling. Friend interprets these downstream trends to indicate deposition from a river system with decreasing flow depth and strength which ended in an area of clay flats. Similar trends in the Revett Formation (Table I) are compatible with this interpretation, and correspond generally with north-northeasterly paleocurrent trends (Appendix C). Further, lack of evidence for channel incision indicates that the Devonian sediment-depositing flows were not so clearly channelized as most modern flows and that much deposition must have been from sheet floods. Laterally extensive sandstone sheets 10 to 150 cm thick with sharp bases, fining upward, and unimodal crossbeds also occur in the Carboniferous of northern Spain's Ebro Basin (Heward, 1978). These beds are also interpreted as sheet flood deposits which formed at the distal margin of an alluvial fan. Tunbridge (1981) describes the Devonian Trentishoe Formation of southwest England, remarkably similar to the Revett in that it also is composed of laterally-extensive tabular beds of flat laminated sandstone. Further similarities include 1) upward transition within individual beds from flat-bedded sand to silty sand with no ripple cross-laminae between, 2) absence of channel forms with no evidence that sand sheets are merged channel fills or laterally accreted, 3) unidirectional paleocurrent trends, and 4) thickness of deposits from single flood events. Tunbridge interprets sheet flooding as the mechanism of their formation. Other sheet flood deposits described briefly in the literature include parts of the New Red Sandstone, Permo-Triassic of

England (Laming, 1966) and the Late Silurian Ringerike Group of Norway (Turner, 1974). Both of these deposits have significant proportions of dominantly flat-laminated sandstone in tabular, laterally extensive beds.

Although not legion, it is clear that there are a number of ancient sheet flood deposits with which the Revett Formation shares important similarities. Lack of numerous modern analogies can be attributed to the powerful influence of land vegetation in the Phanerozoic and possibly to substantial climatic differences.

Bowden's (1977) interpretation of the lower Revett as a distal braided stream deposit seems untenable considering the lack of scouring and channeling and the great lateral continuity of individual beds. A survey of braided stream literature (c.f. Miall, 1977, 1978; Boothroyd and Nummedal, 1978; Rust, 1978; Steel and Aasheim, 1978; Moody-Stuart, 1966; Smith, 1970; Cant and Walker, 1976; Coleman, 1969; Doeglas, 1962; Kessler, 1971) reveals no modern or ancient braided stream deposits whose beds rival the lateral persistence of the Revett. Cotter (1978) recognizes a sheet-braided model in Ordovician-silurian rocks characterized by laterally extensive beds with width:thickness ratios greater than 20:1 but even these deposits differ markedly from lower Revett strata in that they commonly have abandoned channel mudstones, truncated beds, and very apparent pinching and swelling of individual sheet-like units across only 10 to 20 m of outcrop.

Regional sand body geometry (e.g. sheet vs. shoestring) is a powerful interpretive tool whose importance should also be recognized. In sheet sands like the Revett which crop out over 1000's of square kilometers, which lack channel margins and point bar deposits, deposition by waning sheet floods seems the most logical interpretation (Collinson, 1978).

Middle Revett

Description

The base of the middle Revett is placed where vitreous white quartzite of the lower Revett passes upward to meters-thick intervals of thinly-laminated siltite-argillite rock-type separated by vitreous white quartzite beds centimeters thick. This transition is quite obvious in outcrop and commonly occurs through 10 to 30 meters of vertical section. Proportions of rock-types in the middle Revett are approximately 70% thinly-laminated siltite-argillite, 20% silty quartzite, and 10% vitreous white quartzite. Identifying individual depositional events is hampered by the discontinuous bedding and poor exposure characteristic of these very fine-grained rocks. Only in graded siltite to argillite couplets 3 to 15 cm thick can single depositional events be recognized. Vitreous white quartzite beds within siltite-argillite intervals are flat laminated, average 5 to 15 cm thick and are solitary or grouped together in 3 to 10 m packages interbedded with silty quartzite and siltite-argillite rock-types. Minor red argillite and red argillite mud chip intervals occur in the

Glidden Lakes and Silver Cable sections, as well as at several other locations north of the Jocko line (Winston, unpub. data; Jeff Mauk, pers. comm.; Brian White, pers. comm.).

Interpretation

Formation of the thinly-laminated siltite-argillite rock-type can be explained by more constant water saturation near the Belt Sea margin which prevented rapid induration and allowed both subsequent flood influxes and wave energy in standing water to rework this sediment extensively.

That flat-laminated subaerial quartzite of the lower Revett passes down-slope to middle Revett lithologies deposited and reworked along the Belt Sea margin requires some modification of Winston's (1978) facies model. Vitreous white quartzite in the middle Revett represents distal fan skirt flat-laminated sand deposited by sheet floods directly onto the thinly-laminated siltite-argillite facies tract along the Belt Sea margin, thereby effectively eliminating the broad red argillite mud flats during much of Revett deposition (Fig. 13). Intervals of red argillite less than 5 m thick in the middle Revett in the Thompson River (Winston, unpub.), Glidden Lakes, and Silver Cable sections (Appendix B) and intervals of red argillite greater than 5 m thick in the middle Revett near Plains, Montana (Jeff Mauk, pers. comm.) are interpreted as lateral facies equivalents of the thinly-laminated siltite-argillite rock-type. Figure 12 demonstrates in plan view a larger, more active depositional lobe with flat-laminated rock-type deposition farther "seaward" than adjacent smaller, less active depositional lobes. The smaller lobes have Winston's (1978) proximal-distal facies succession (flat-laminated to red argillite to green argillite) whereas the larger lobes pass distally from flat-laminated to thinly-laminated siltite-argillite to green argillite. Lateral shifting or sourceward retreat of the larger depositional lobe, seaward progradation of smaller lobes, and rise or fall in sea level can cause lateral and distal shifting of depositional environments, forming vertical sequences with red argillite interbedded with thinly-laminated siltite-argillite.

The thinly-laminated siltite-argillite rock-type of the middle Revett differs from Winston's (1978) green argillite rock-type in that the laminae are wavy and discontinuous and couplets are commonly not well-defined, reflecting that it has been thoroughly reworked or that it was never coupleted. Both differences are attributed to the closer proximity of the thinly-laminated siltite-argillite to the higher energy area of major flood events (see description of siltite-argillite rock-type). Winston visualizes the green argillite rock-type to have been deposited mainly from suspension at the distal end of flood influxes beyond broad red argillite flats. The thinly-laminated siltite-argillite rock-type of the middle Revett was deposited just basinward of sheet flood sand and was therefore subject to more competent traction currents and more reworking during subsequent flood events.

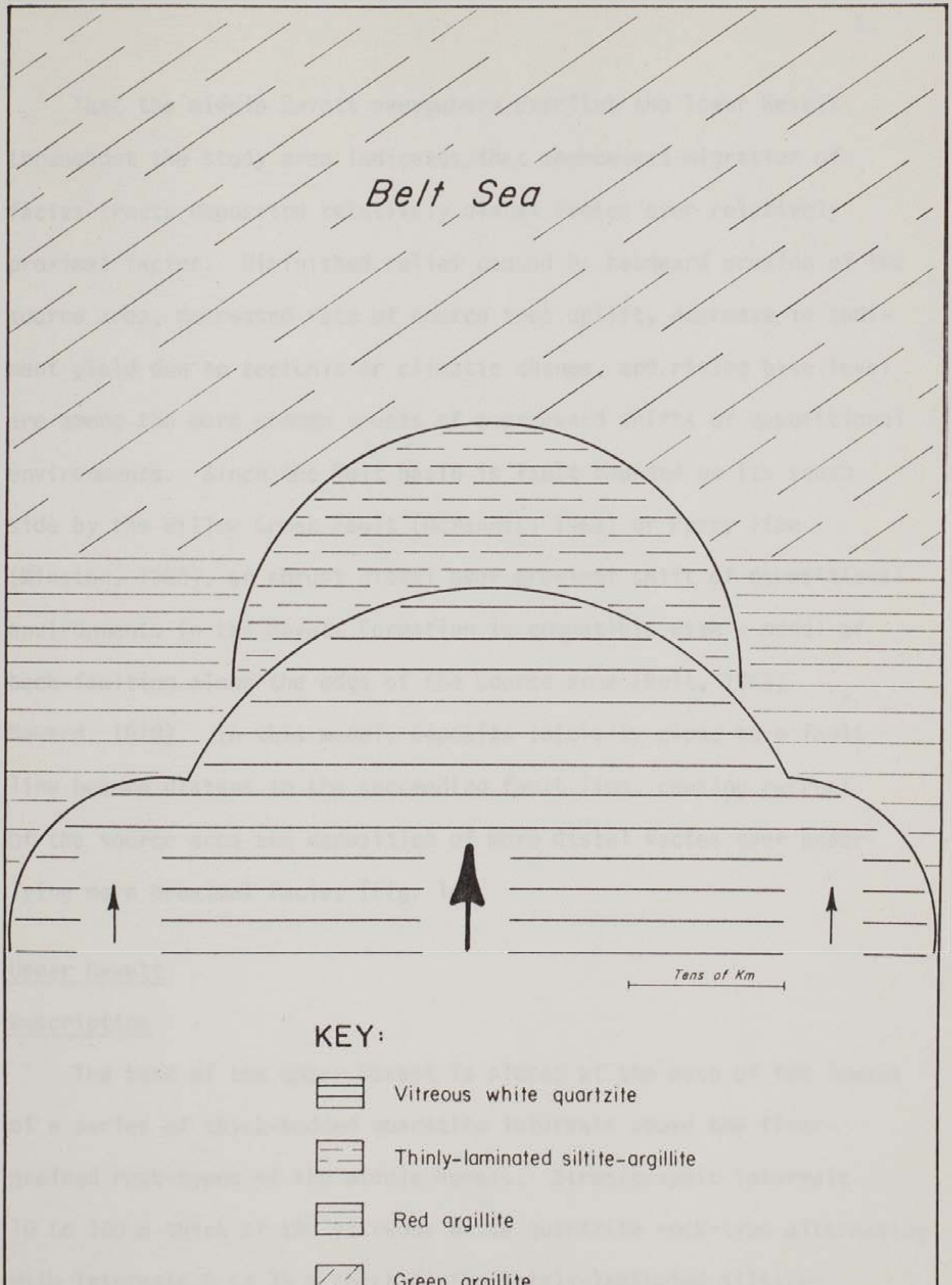


Figure 13. Generalized facies distribution during Revett deposition showing red argillite tracts as lateral equivalents of thinly-laminated siltite-argillite.

That the middle Revett everywhere overlies the lower Revett throughout the study area indicates that sourceward migration of facies tracts deposited relatively distal facies over relatively proximal facies. Diminished relief caused by headward erosion of the source area, decreased rate of source area uplift, decrease in sediment yield due to tectonic or climatic change, and rising base level are among the more common causes of sourceward shifts of depositional environments. Since the Belt basin is fault-bounded on its south side by the Willow Creek Fault (McMannis, 1963) or Perry line (Winston, 1982), an abrupt distal over proximal shift of depositional environments in the Revett Formation is compatible with a model of back-faulting along the edge of the source area (Belt, 1968; Heward, 1978). In this model, deposits initially close to a fault line become distant to the succeeding fault line, causing retreat of the source area and deposition of more distal facies over underlying more proximal facies (Fig. 14).

Upper Revett

Description

The base of the upper Revett is placed at the base of the lowest of a series of thick-bedded quartzite intervals above the finer-grained rock-types of the middle Revett. Stratigraphic intervals 10 to 100 m thick of the vitreous white quartzite rock-type alternating with intervals 5 to 75 m thick of the thinly-laminated siltite-argillite rock-type constitute the upper Revett. White and Winston (1977) identify four quartzite intervals alternating with three

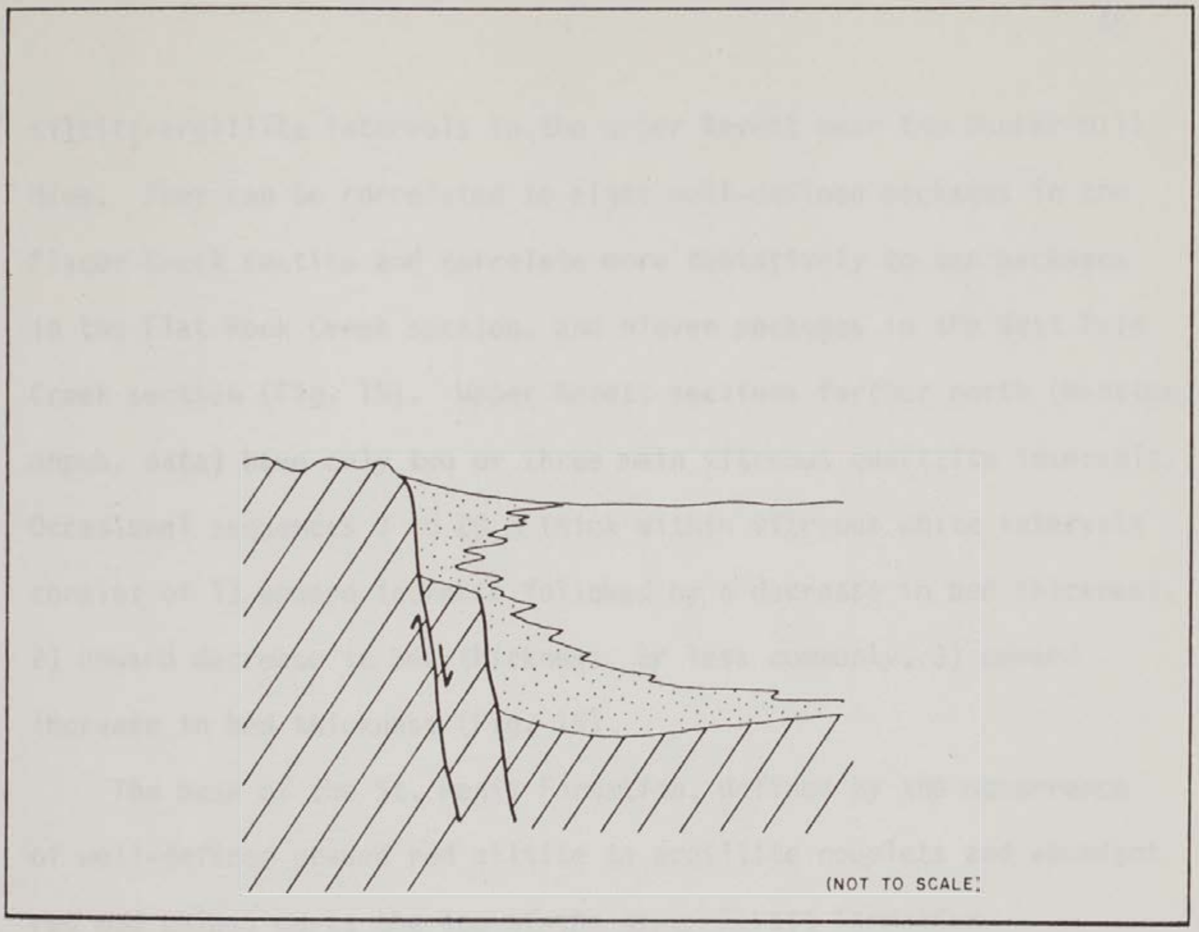


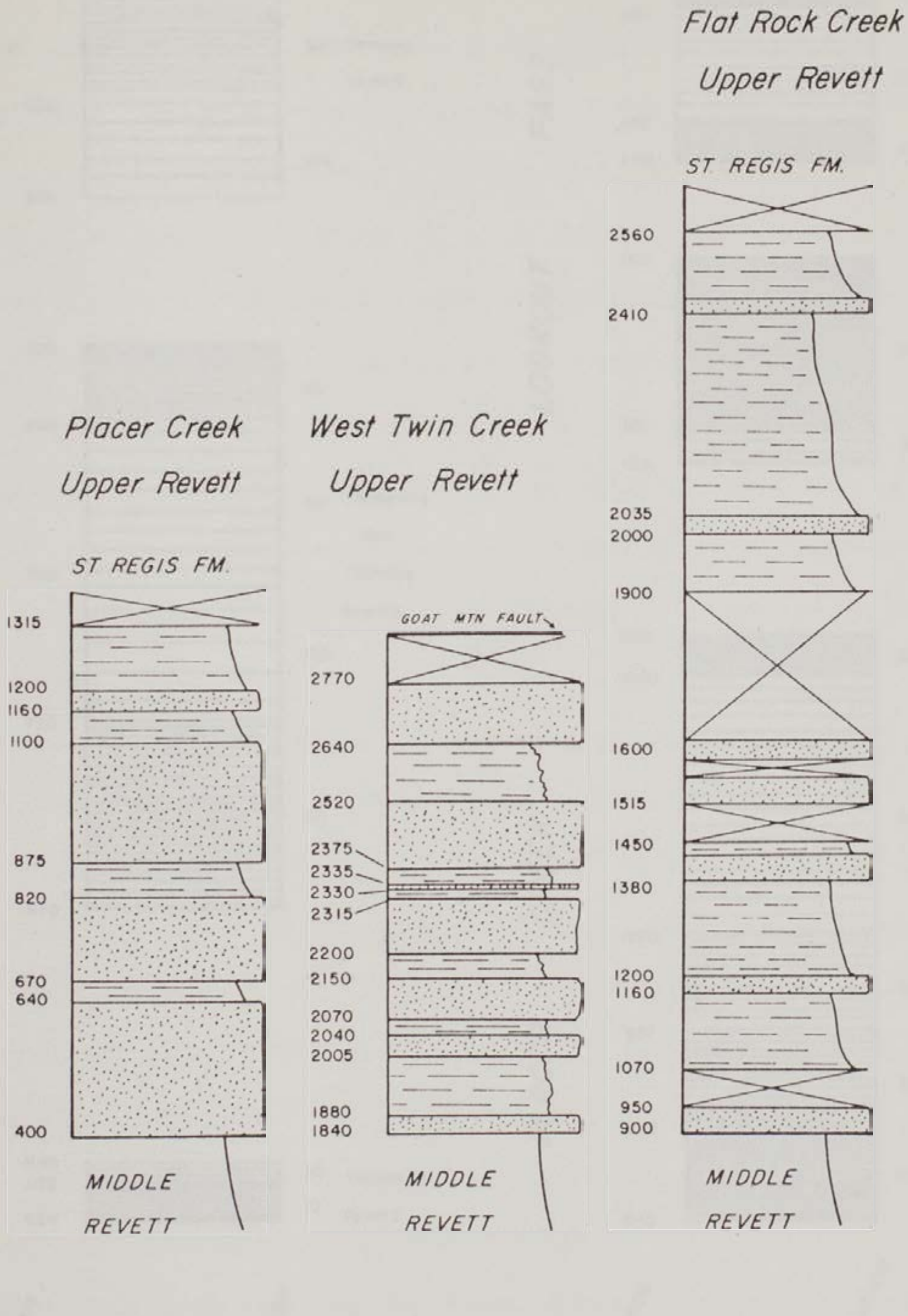
Figure 14. Sketch showing sourceward shift of facies due to back-faulting along a basin margin. After Belt, 1968 and Heward, 1977.

siltite-argillite intervals in the upper Revett near the Bunker Hill Mine. They can be correlated to eight well-defined packages in the Placer Creek section and correlate more tentatively to ten packages in the Flat Rock Creek section, and eleven packages in the West Twin Creek section (Fig. 15). Upper Revett sections farther north (Winston, unpub. data) have only two or three main vitreous quartzite intervals. Occasional sequences 3 to 20 m thick within vitreous white intervals consist of 1) upward increase followed by a decrease in bed thickness, 2) upward decrease in bed thickness, or less commonly, 3) upward increase in bed thickness (Fig. 16).

The base of the St. Regis Formation, defined by the occurrence of well-defined graded red siltite to argillite couplets and abundant red mud chips, marks the top of the upper Revett Formation.

Interpretation

Distal lobes of sheet flood sand built out locally over extensively reworked silt and clay of the upper Revett and formed interstratified intervals tens of meters thick of the vitreous white quartzite and the thinly-laminated siltite-argillite rock-type. Progradation of distributary lobes of sheetwash sand formed upward-thickening bed sequences. Abrupt abandonment of distributary lobes and progradation into new areas formed upward-thickening bed sequences in new prograding areas and ended formation of either thinning or thickening upward sequences on and below the abandoned lobe. Complete sequences of thickening then thinning of beds upward record steady



Scale 1" = 400'

Figure 15. Upper Revett stratigraphic sections showing interbedded intervals of quartzite and siltite-argillite.

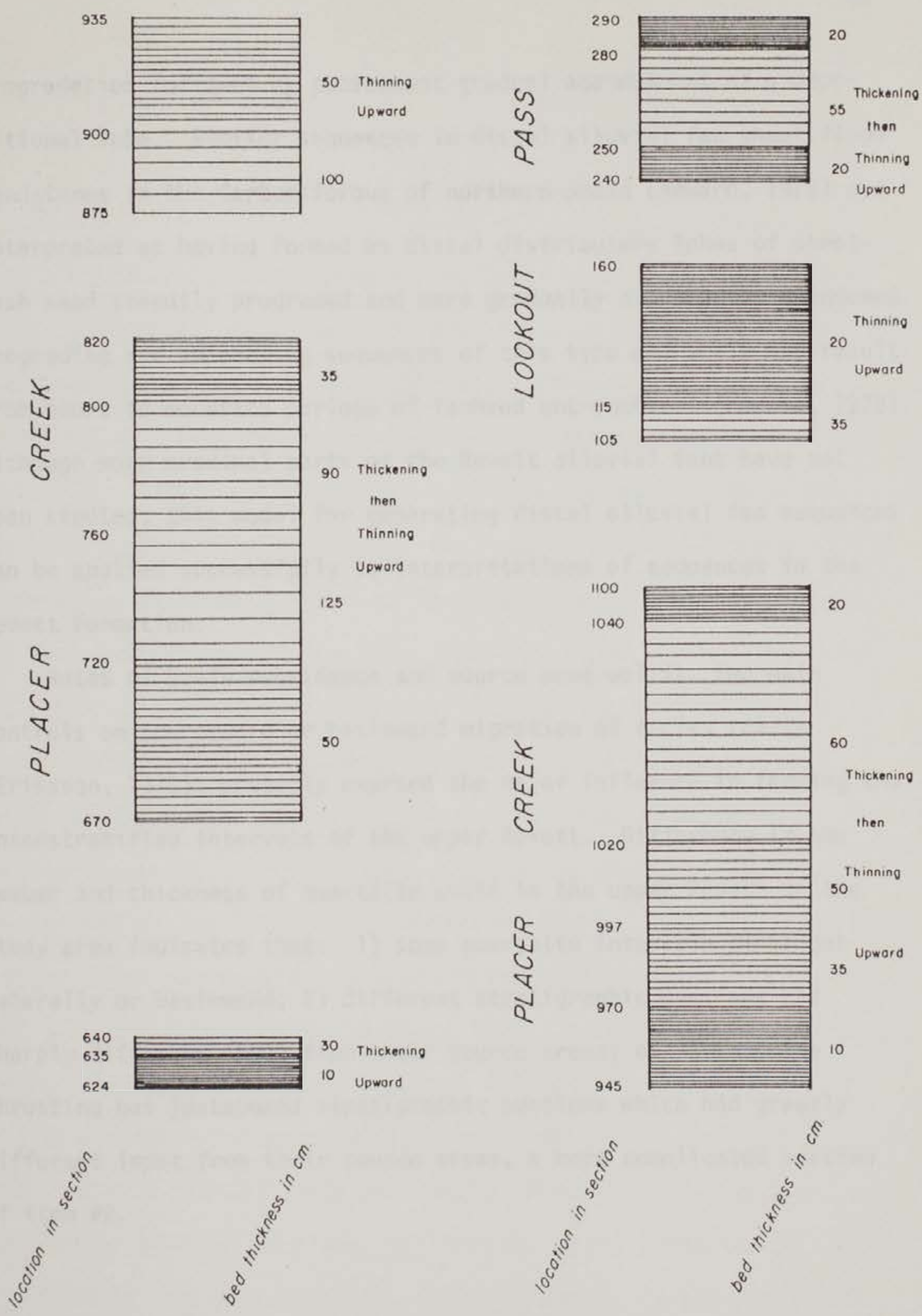


Figure 16. Vertical thickening and thinning of beds.

progradation followed by subsequent gradual abandonment of a depositional lobe. Similar sequences in distal alluvial fan sheet flood sandstones in the Carboniferous of northern Spain (Heward, 1978) are interpreted as having formed as distal distributary lobes of sheetwash sand steadily prograded and were gradually or abruptly abandoned. Prograding and abandoning sequences of this type and scale may result from short to moderate periods of fanhead entrenchment (Heward, 1978). Although more proximal parts of the Revett alluvial fans have not been studied, this model for generating distal alluvial fan sequences can be applied successfully to interpretations of sequences in the Revett Formation.

Rates of basin subsidence and source area uplift, two main controls on sourceward or basinward migration of facies tracts (Eriksson, 1978), probably exerted the major influence in forming the interstratified intervals of the upper Revett. Difference in the number and thickness of quartzite units in the upper Revett in the study area indicates that: 1) some quartzite intervals pinch out laterally or basinward; 2) different stratigraphic sections had sharply different input from their source areas; or 3) Laramide thrusting has juxtaposed stratigraphic sections which had greatly different input from their source areas, a more complicated version of item #2.

CHAPTER IV

STRATIGRAPHIC THICKNESS CHANGES

Stratigraphic thicknesses of the upper Revett are two to three times greater in the southern portion of the study area near the Jocko line than to the north of it (Fig. 17). Although both the Flat Rock Creek and West Twin Creek sections now lie immediately north of the Jocko line, their location in the overturned southern limb of the Savenac Syncline (Fig. 18) allows the reconstruction of their pre-deformation position as south of the Jocko line. Thus, the Flat Rock and West Twin Creek sections were deposited south of the Jocko line and moved northward across the Jocko line as the Savenac Syncline formed. Folds and thrusts which carried thicker sections of rock northeastward across the Jocko line form a large southeastward-curving structural arc which truncates the northerly-trending folds and thrusts on the Charlo block (Winston, 1982). Since broad open upright folds characterize both the Ovando and Charlo blocks (Harrison and others, 1980; Winston, 1982), crumpling and compression against the rocks of the Charlo block during thrusting is proposed as a mechanism for generating tight overturned folds and thrusts along the Osburn fault (Winston, 1982). Given the proposed original position of measured sections, differences in thickness can be explained by tectonic transport, facies changes, or syndepositional growth faulting.

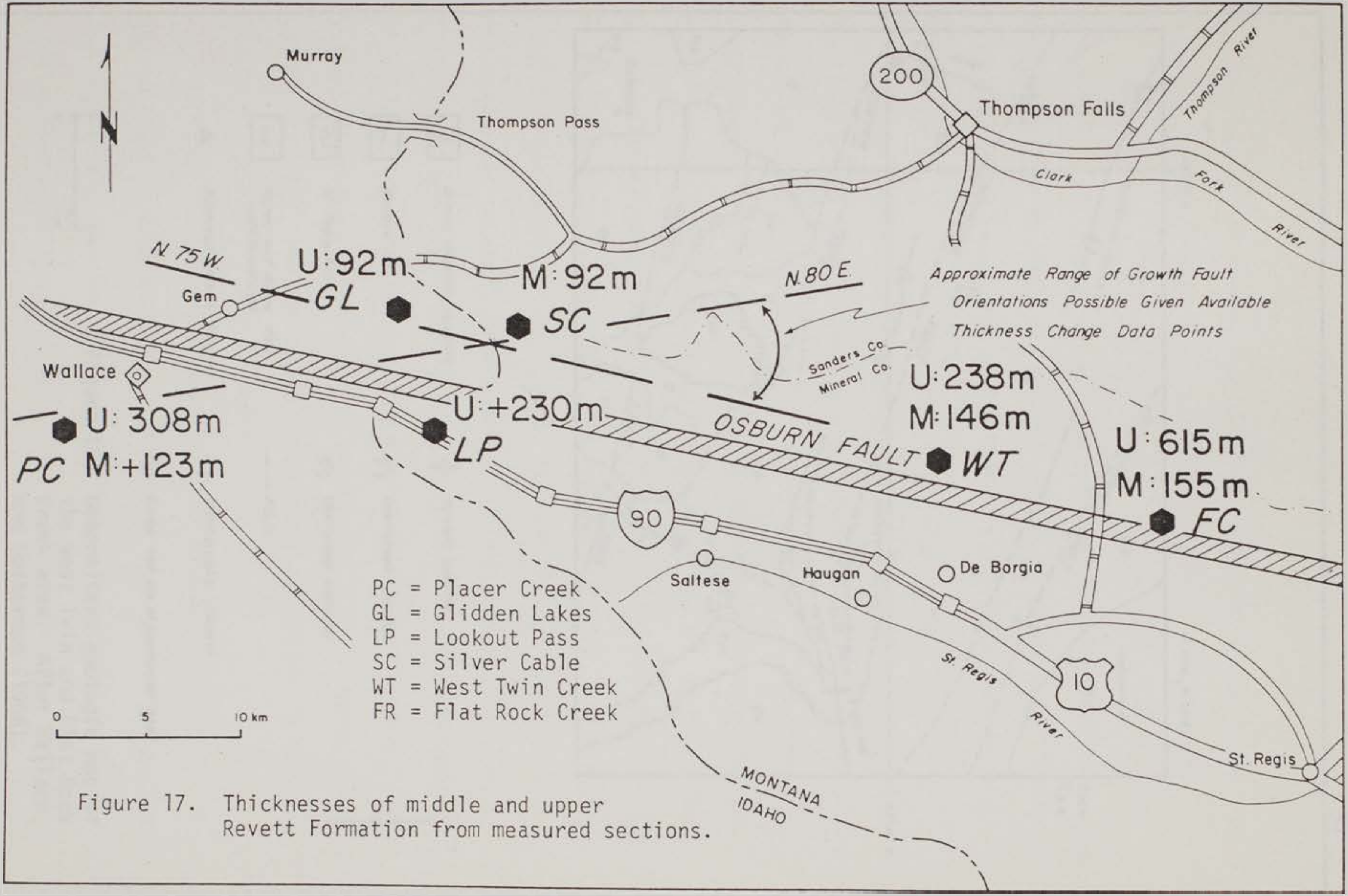


Figure 17. Thicknesses of middle and upper Revett Formation from measured sections.

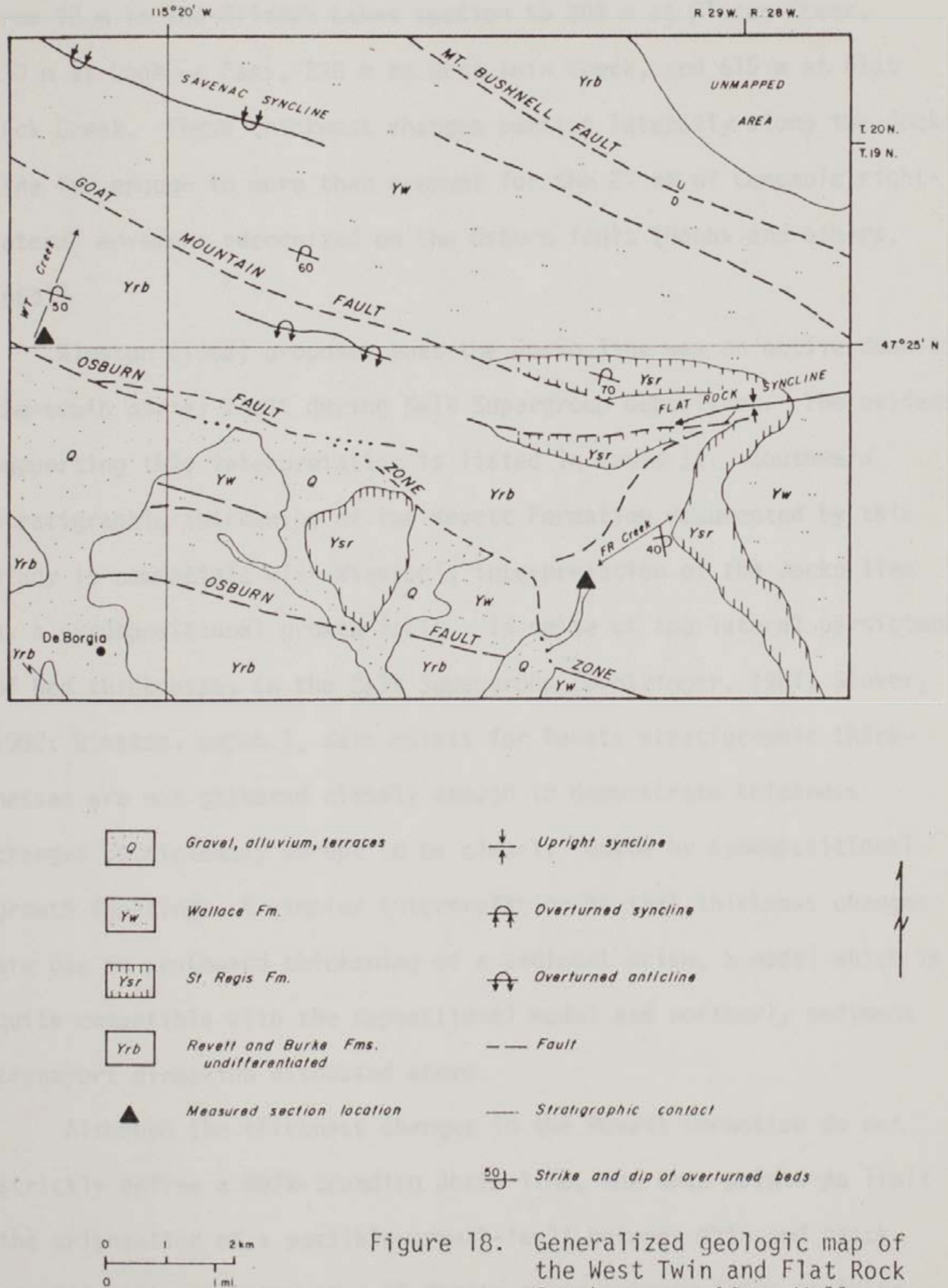


Figure 18. Generalized geologic map of the West Twin and Flat Rock Creek area. After Wallace and Hosterman (1956).

The upper Revett Formation thickens southward in the study area from 92 m in the Glidden Lakes section to 308 m at Placer Creek, 230 m at Lookout Pass, 238 m at West Twin Creek, and 615 m at Flat Rock Creek. These thickness changes persist laterally along the Jocko line far enough to more than account for the 27 km of Cenozoic right-lateral movement recognized on the Osburn fault (Hobbs and others, 1965).

Winston (1982) proposes that the Jocko line was an active down-to-the-south normal fault during Belt Supergroup deposition. The evidence supporting this interpretation is listed in Table II. Southward stratigraphic thickening of the Revett Formation documented by this study is compatible with Winston's interpretation of the Jocko line as a syndepositional growth fault. In spite of the lateral persistence of bed thicknesses in the Belt Supergroup (Grotzinger, 1981; Slover, 1982; Winston, unpub.), data points for Revett stratigraphic thicknesses are not gathered closely enough to demonstrate thickness changes sufficiently abrupt to be clearly caused by syndepositional growth faulting. A simpler interpretation is that thickness changes are due to southward thickening of a sediment prism, a model which is quite compatible with the depositional model and northerly sediment transport direction discussed above.

Although the thickness changes in the Revett Formation do not strictly define a N82W-trending Jocko line, the data points do limit the orientation of a possible growth-fault between thin and thick stratigraphic sections to a 25 degree range between lines striking

Table II. Evidence for Middle Proterozoic movement along the Jocko and Greenhorn lines.

<u>JOCKO LINE</u>	
Webster (1981) . .	Soft-sediment folds and slumps indicate southwestward paleoslope during lower Prichard Fm. deposition along the Jocko line near the junction of the Clark Fork and Flathead Rivers; stratigraphic intervals in the lower Prichard thicken 427 m southward across the Jocko line.
Chevillon (1977) .	An 800 m-thick zone of quickstone breccia and other well-developed soft-sediment deformation features occurs in the St. Regis Fm. in the Atlas Mine just south of the Osburn fault.
Winston (1982) . .	The Revett Fm. thickens southward across the Jocko line from 336 m on the north (Hobbs and others, 1965) to 1160 m on the south (White, Winston, and Jacob, 1977) near the Coeur d'Alene district.
- - - - (1982) . .	The St. Regis Fm. thickens southward across the Jocko line from 427 m (Hobbs and others, 1965) to 1525 m (Wallace and Hosterman, 1956) near Saltese, Montana.
- - - - (1982) . .	The Revett Fm. thickens nearly 116 m southward across the Jocko line near the junction of the Flathead River and the line.
- - - - (1982) . .	Soft-sediment deformation in the Wallace Fm. is more intense near the Jocko line than north or south of it.

Table II (Continued)

GREENHORN LINE	
Winston (1982) . .	Middle and upper Belt sediments of the Ovando block thin abruptly where they cross southward onto the Deerlodge block just north of Greenhorn Mountain.
- - - - (1982) . .	The Helena Fm. thins southward across the Greenhorn line from 2460 m (Bierwagen, 1964) to 1310 m (Knopf, 1963).
- - - - (1982) . .	The Snowslip Fm. thins southward from 1070 m (Bierwagen, 1964) to 233 m (Winston, unpub.) across the Greenhorn line.
- - - - (1982) . .	The Shepard Fm. thins southward from 3375 m (Bierwagen, 1964) to 88 m (Winston, unpub.) across the Greenhorn line.
- - - - (1982) . .	The Mount Shields Fm. thins slightly from 836 m to 781 m near the Greenhorn line.
- - - - (1982) . .	The Garnet Range and Pilcher Formations are significantly thinner near the Greenhorn line.
Wallace and others (1976) .	Soft-sediment slump breccias in the Wallace Fm. are projected as originating along the Greenhorn line.

approximately N75W and N80E (Fig. 17). The N82W-trending Jocko line falls within this range.

Given the indirect supporting evidence for growth faulting along both the north and south margins of the Ovando block (Winston, 1982) summarized in Table II, growth faulting during deposition of the Revett Formation seems a possible explanation for stratigraphic thickening south of the Jocko line. Webster (1981) describes soft-sediment slumps and folds in the lower Prichard Formation which infer that fault-generated slopes along the Jocko line were present during early Belt deposition. Chevillon (1977) documents intrastratal quickstone breccias in the St. Regis Formation along the Jocko line which formed during slope-generated soft-sediment slumping. No slumping or soft-sediment folding coincides with Revett thickness changes. If growth-faulting is the cause of the thickness changes, this would suggest that sediments were draped over the Jocko line as it continued to move down to the south, preventing a topographic expression of the line at the surface (Winston, 1982). More rapid sedimentation rates during deposition of the sandier Burke and Revett Formations relative to the Prichard Formation could have effectively buried the earlier topographic relief created by growth faulting, allowing the Revett sedimentary prism to be shed northward across the Jocko line.

A third possible explanation of southward thickening across the Jocko line is tectonic juxtaposition of thick and thin stratigraphic sections from different parts of the original, undeformed basin. The magnitude of transport necessary to account for the thickness changes, given the lateral persistence of bed thicknesses in the Belt (Grotzinger, 1981; Slover, 1982; Winston, unpub. data) requires that a fault of mappable proportions separate thick and thin stratigraphic sections. Geologic mapping of this structurally complex area (Wallace and Hosterman, 1956; Harrison and others, 1974a, 1981) has identified numerous faults, of which the Osburn fault with 27 km of right lateral movement is the best known. As stated above, the thickness changes in the Revett Formation persist laterally far enough to eliminate the possibility that the Osburn fault juxtaposed the thick and thin stratigraphic sections. Translation on major thrusts just north of this area decreases southward to a minimum of a few tens of km near the Jocko line (Harrison and others, 1980). Movement along these and other faults in the area could be responsible for juxtaposition of thick and thin stratigraphic sections, although determination of how much movement and along what faults this movement occurred will be no simple task. Harrison and others (1980) comment on the complexity of the deformations which have folded and faulted the Belt basin and note that many of these events "are neither well-dated nor well understood." They warn that "the Belt terrane is cut by many thrusts of significant tectonic transport" and conclude that "much more data on facies of Belt rocks must be collected before palinspastic reconstruction of the sedimentary basin can be attempted."

The three explanations for southward thickening in the Revett Formation discussed above are syndepositional growth faulting, a southward-thickening sedimentary prism, and structural juxtaposition of thick next to thin stratigraphic sections. Each of the three explanations has its merit, although at this time no definite conclusion can be drawn as to which, if any, is directly responsible for the thickness changes. Adherence to the principle of simplicity favors a southward-thickening sedimentary prism as the most probable explanation, without excluding the other two as possible explanations.

CHAPTER V

SYNTHESIS

Episodic floods of high and variable discharge deposited sand and silt of the Revett Formation on a broad flat alluvial plain at the distal edge of a coalescing alluvial fan complex.

Absence of scouring and well-defined channel margins plus tabular, laterally-continuous beds indicate that flow was not channelized, but instead sheet floods were the dominant depositional agent. Unimodal cross-strata were formed by migrating sand waves in the lower flow regime and flat-laminated beds of sand were formed by shallower sheet-wash plane beds in the upper flow regime. Alluvial fan skirt deposits extended downslope to distal alluvial plain/sea margin deposits where poorly-consolidated sediment reworked by repeated flood events and wave energy is recorded in the thinly-laminated siltite-argillite rock-type.

A sourceward migration of facies, possibly initiated by back-faulting of the basin margin, brought middle Revett composed of the distal siltier rock-type over more proximal vitreous quartzite of the lower Revett. During upper Revett deposition broad lobes of clean sheetwash sand built out locally over silt and mud near the Belt Sea margin, interbedding vitreous white quartzite and silty argillite rock-types. The St. Regis Formation records a major transgression of sea margin argillite over the fluvial Revett Formation followed in the

Wallace Formation by lacustrine carbonates (Grotzinger, 1981) clearly indicating that either source terranes had subsided significantly, sea level had changed, or a major climatic change had occurred. The well-defined cyclicity of the Wallace Formation (Grotzinger, 1981) and the Mt. Shields quartzite of the Missoula Group (Slover, 1982) and the lack of these cycles during lower Belt deposition may be further evidence supporting a major tectonic or climatic change some time after Revett deposition.

Stratigraphic thickening in the upper Revett Formation southward across the Osburn fault can be most simply explained at this time by a southward-thickening sedimentary prism. Syndepositional growth faulting along the Jocko line or structural juxtaposition of thick next to thin stratigraphic sections are two other possible explanations for the thickening. If growth faulting occurred, the lack of soft-sediment folds and slumps indicates that sediment was draped over the Jocko line which had no topographic expression during Revett deposition.

Informal lower, middle, and upper members of the Revett Formation recognized by White, Winston, and Jacob (1977) and White and Winston (1977, 1982) near Kellogg, Idaho are recognizable at least as far east as St. Regis, Montana and as far north as Thompson Falls, Montana. Further work may demonstrate the usefulness of these informal members through the whole area of Revett outcrop and aid in clarifying many stratigraphic, sedimentologic and structural enigmas, for example:

- How far throughout the basin can upper Revett units be correlated?
- Can the middle Revett be considered a distal facies of the lower Revett? The St. Regis as a distal facies of the Revett?
- How far north does the thick quartzite wedge of the lower Revett extend? Is it equivalent to the thick quartzite in the middle Creston Fm. of the Purcell Supergroup?
- How many major thrust sheets dissect the Belt basin? How much structural offset is there between thrust sheets?
- What characterizes the lateral and distal variation of modern sheet flood deposits?
- Are there recognizable tectonically-generated sedimentary sequences in the Revett? In any other Belt units?
- Are other parts of the Revett better interpreted as sheet braided or braided stream deposits? Could this aid in determining proximity on a large alluvial fan-fan skirt complex?
- How large were the alluvial fan complexes that supplied Revett sediment? Are there identifiable proximal alluvial fan facies preserved?
- What and where was the source terrane of the Revett? Why are there few or no grains larger than medium sand in the lower Belt?

This study contributes a small part of the fundamental knowledge required to build answers to questions of this kind.

REFERENCES

Allen, J.R.L., 1963. Asymmetrical ripple marks and the origin of water cosets of cross strata. Liverpool Manchester Geol., 3: 187-236.

Allen, J.R.L., 1964. Primary current lineation in the lower Old Red Sandstone (Devonian), Anglo-Welsh Basin. Sedimentology, 3: 98-108.

Allen, J.R.L., 1970. Studies in fluviatile sedimentation: A comparison of fining-upwards cyclothems, with special reference to coarse-member composition and interpretation. J. Sed. Pet., 40: 298-323.

Belt, E.S., 1968. Carboniferous continental sedimentation, Atlantic Provinces, Canada in: G. DeV. Klein, ed., Late Paleozoic and Mesozoic continental sedimentation, northeastern North America. G.S.A. Sp. Paper 106: 127-176.

Berry, W.B.N. and Boucot, A.J., 1970. Correlation of the North American Silurian rocks. G.S.A. Sp. Paper 102: 289 p.

Bierwagen, E.E., 1964. Geology of the Black Mountain area, Lewis and Clark and Powell Counties, Montana: unpub. Ph.D. thesis, Princeton Univ., Princeton, N.J., 166 p.

Blatt, H., Middleton, G.V., and Murray, R.C., 1980. Origin of Sedimentary Rocks, 2nd. ed., New Jersey: Prentice-Hall; 782 p.

Blissenbach, Erich, 1964. Geology of alluvial fans in semi-arid regions: G.S.A. Bull., 65: 175-190.

Boothroyd, J.C. and Nummedal, D., 1978. Proglacial braided outwash: a model for humid alluvial fan deposits in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Mem. 5: 641-668.

Bowden, T.D., 1977. Depositional processes and environments within the Revett Formation, Precambrian Belt Supergroup, northwestern Montana and northern Idaho: Master's thesis, Univ. of Calif., Riverside; 161 p.

Bull, W.B., 1963. Alluvial-fan deposits in western Fresno County, California. J. Geol., 71: 243-251.

Bull, W.B., 1964. Alluvial fans and near-surface subsidence in western Fresno County, California. U.S.G.S. Prof. Paper 437-A; 71 p.

Bull, W.B., 1972. Recognition of alluvial-fan deposits in the stratigraphic record in: J. K. Rigby and W.K. Hamblin, eds., Recognition of Ancient Sedimentary Environments. S.E.P.M. Sp. Pub., 16: 63-83.

Burst, J.F., 1965, Subaqueously-formed shrinkage cracks in clay. J. Sed. Pet., 35: 345-353.

Cant, D.J. and Walker, R.G., 1976. Development of a braided-fluvial facies model for the Devonian Battery Point Sandstone, Quebec. Can. J. Ea. Sci., 13: 102-119.

Chevillon, C.V., 1977. Tectonically-induced Proterozoic soft-sediment deformation at the Atlas property, Coeur d'Alene district, Idaho. Abs. Geol. Soc. Am. Reg. Mtg., Missoula, Montana.

Coleman, J.M., 1969. Brahmaputra River: channel processes and sedimentation. Sedimentary Geol., 3: 129-239.

Collinson, J.D., 1978. Vertical sequence and sand body shape in alluvial sequences in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 577-581.

Cotter, Edward, 1978. The evolution of fluvial style, with special reference to the central Appalachian Paleozoic in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 361-383.

Cummins, W.A., 1958. Some sedimentary structures from Lower Keuper sandstones. Geol. Journal, 2: 27-43.

Davis, W.M., 1938. Sheetfloods and streamfloods. G.S.A. Bull., 49: 1337-1416.

Denny, C.S., 1965. Alluvial fans in the Death Valley Region, California and Nevada. U.S.G.S. Prof. Paper 466: 62 p.

Doeglas, D.J., 1962. The structure of sedimentary deposits of braided rivers. Sedimentology, 1: 167-190.

Eriksson, K.A., 1978. Alluvial and destructive beach facies from the Archean Moodies Group, Barberton Mountain Land, South Africa and Swaziland in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 287-311.

Friend, P.F., 1978. Distinctive features of some ancient river systems in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 531-542.

Frostick, L.E. and Reid, I., 1977. The origin of horizontal laminae in ephemeral stream channel fill. Sedimentology, 24: 1-10.

Grotzinger, John P., 1981. The stratigraphy and sedimentation of the Wallace Formation, northwest Montana and northern Idaho. Master's thesis, Univ. of Montana: 153 p.

Harms, J.C., Southard, J.B., Spearing, D.R., and Walker, R.G., 1975. "Depositional Environments as Interpreted from Primary Sedimentary Structures and Stratification Sequences." Soc. Econ. Paleont. Mineral. Short Course Lecture Notes 2.

Harrison, J.E., 1972. Precambrian Belt basin of northwestern United States: its geometry, sedimentation, and copper occurrences. U.S.G.S. Bull., 83: 1215-1240.

Harrison, J.E. and Campbell, A.B., 1963. Correlations and problems in Belt series stratigraphy, northern Idaho and western Montana. G.S.A. Bull., 74: 1413-1428.

Harrison, J.E. and Jobin, D.A., 1963. Geology of the Clark Fork quadrangle, Idaho-Montana. U.S.G.S. Bull., 1141-K: 38 p.

Harrison, J.E. and Grimes, D.J., 1970. Mineralogy and geochemistry of some Belt rocks, Montana and Idaho. U.S.G.S. Bull. 1312-O; 49 p.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1974a. Preliminary geologic map of part of the Wallace 1:250,000 sheet, Idaho-Montana. U.S.G.S. Open file report OF-74-37.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1974b. Tectonic features of the Precambrian Belt basin and their influence on post-Belt structures. U.S.G.S. Prof. Paper 866; 15 p.

Harrison, J.E., Kleinkopf, M.D., Wells, J., 1980. Phanerozoic thrusting in Proterozoic Belt rocks, northwestern United States. Geology, 8: 407-411.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1981. Generalized Geologic Map of the Wallace 1°x 2° Quadrangle, Montana and Idaho. U.S.G.S. Map MF-1354-A.

Heward, Alan P., 1978. Alluvial fan sequence and megasequence models: with examples from Westphalian D-Stephanian coalfields, northern Spain in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 669-702.

Hobbs, S.W., Griggs, A.B., Wallace, R.E., and Campbell, A.B., 1965. Geology of the Coeur d'Alene district, Shoshone County, Idaho. U.S.G.S. Prof. Paper 478; 139 p.

Hobday, D.K., 1978. Fluvial deposits of the Ecca and Beaufort Groups in the Eastern Karoo Basin, Southern Africa in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 413-429.

Hoffman, J. and Hower, J., 1979. Clay mineral assemblages as low grade metamorphic geothermometers: Application to the thrust faulted disturbed belt of Montana, U.S.A. in: Aspects of Diagenesis. S.E.P.M. Sp. Pub. 26: 55-79.

Hooke, Roger LeB., 1967. Processes on arid-region alluvial fans. J. Geol., 75: 438-460.

Hrabar, S.V., 1971. Stratigraphy and depositional environment of the St. Regis Formation of the Ravalli Group (Precambrian Belt Megagroup), northwestern Montana and Idaho. Ph.D. dissertation, Univ. of Cincinnati, University Microfilms 72-1438.

Jopling, A.V., 1965. Hydraulic factors and the shape of laminae. J. Sed. Pet., 35: 777-791.

Jopling, A.V., 1966. Some principles and techniques used in reconstructing the hydraulic parameters of a paleo-flow regime. J. Sed. Pet., 36: 5-49.

Jopling, A.V. and Walker, R.G., 1968. Morphology and origin of ripple-drift cross lamination, with examples from the Pleistocene of Massachusetts. J. Sed. Pet., 38: 971-984.

Kessler, L.G., 1971. Characteristics of a braided stream depositional environment with examples from the South Canadian River, Texas. West. Geol. Assoc. Earth Sci. Bull., 4: 25-35.

Laming, D.J.C., 1966. Imbrication, paleocurrents, and other sedimentary features in the lower New Red Sandstone, Devonshire, England. J. Sed. Pet., 36: 940-959.

Laursen, E.M., 1953. "Observations on the Nature of Scour," State Univ. Iowa Hydraulics Conf. Proc. Studies in Eng., Bull. 34: 179-198.

Long, Darrel G.F., 1978a. Depositional environments of a thick Proterozoic sandstone: the (Huronian) Mississagi Fm. of Ontario, Canada. C.J. Ea. Sci., 15: 190-206.

Long, Darrel G.F., 1978b. Proterozoic stream deposits: some problems of recognition and interpretation of ancient sandy fluvial systems in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 313-341.

McGee, W.J., 1897. Sheetflood erosion. G.S.A. Bull., 8: 87-112.

McKee, E.D., Crosby, E.J. and Berryhill, H.L. Jr., 1967. Flood deposits, Bijou Creek, Colorado, June, 1965. J. Sed. Pet., 37: 829-851.

McLean, J.R. and Jerzykiewicz, Tomasz, 1978. Cyclicity, tectonics, and coal: some aspects of fluvial sedimentology in the Brazeau-Paskapoo Formations, Coal Valley Area, Alberta, Canada in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 441-468.

McMannis, W.J., 1963. LaHood Formation - a coarse facies of the Belt Series in southwestern Montana. G.S.A. Bull., 74: 407-436.

Miall, A.D., 1970. Continental-marine transition in the Devonian of Prince of Wales Island, N.W. Terr. Can. Jour. Ea. Sci., 7: 125-144.

Miall, Andrew D., 1977. A review of the braided river depositional environment. Ea. Sci. Reviews, 13: 1-62.

Miall, A.D., ed., 1978. Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5; 859 p.

Moody-Stuart, M., 1966. High- and low-sinuosity stream deposits, with examples from the Devonian of Spitzbergen. J. Sed. Pet., 36: 1102-1117.

Nami, M. and Leeder, M.R., 1978. Changing channel morphology and magnitude in the Scalby Fm. (M. Jurassic) of Yorkshire, England in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 431-440.

Norwick, Stephen A., 1972. The regional Precambrian metamorphic facies of the Prichard Fm. of western Montana and northern Idaho. Ph.D. dissertation, Univ. of Montana; 129 p.

Pearce, Andrew J., 1976. Geomorphic and hydrologic consequences of vegetation destruction, Sudbury, Ontario. Can. Jour. Ea. Sci., 13: 1358-1373.

Peterson, F.F., 1981. Landforms of the Basin and Range Province defined for soil survey. Desert Research Institute, Technical Bulletin 28; 52 p.

Picard, M.D. and High, L.R., 1972. Sedimentary Structures of Ephemeral Streams. Developments in Sedimentology 17. Elsevier, Amsterdam; 223 p.

Rahn, P.H., 1967. Sheetfloods, streamfloods, and the formation of sediments. Ann. Am. Assoc. Geogr., 57: 593-604.

Ransome, F.L., 1905. Ore deposits of the Coeur d'Alene district, Idaho. U.S.G.S. Bull., 260: 274-303.

Reineck, H.E. and Singh, I.B., 1980. Depositional Sedimentary Environments with Reference to Terrigenous Clastics, 2nd ed. New York, Springer-Verlag; 549 p.

Rich, J.L., 1935. Origin and evolution of rock fans and pediments. G.S.A. Bull., 46: 999-1024.

Rust, Brian R., 1978. A classification of alluvial channel systems in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 187-198.

Schumm, S.A., 1961. Effect of sediment characteristics on erosion and deposition in ephemeral stream channels. U.S.G.S. Prof. Paper 352-C: 31-70.

Schumm, S.A., 1968. Speculations concerning paleohydraulic controls of terrestrial sedimentation. G.S.A. Bull., 79: 1573-1588.

Scott, A.J., Hoover, R.A., and McGowan, J.H., 1969. Effects of Hurricane 'Beulah', 1967, on Texas coastal lagoons and barriers. UNESCO, Simposia Internacional Sobre Lagunas Costeras: 221-236.

Slover, Susan M., 1982. Fining upward sequences in the lower Mount Shields Formation, middle Proterozoic Belt Supergroup, west-central Montana. Master's thesis, Univ. of Montana; 55 p.

Smith, N.D., 1970. The braided stream depositional environment: Comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians: G.S.A. Bull., 81: 2993-3014.

Smith, N.D., 1972. Some sedimentologic aspects of planar cross-stratification in a sandy braided river. J. Sed. Pet., 42: 624-634.

Steel, R.J., Maehle, S., Nilsen, H., Roe, S.L., and Spinnager, A., 1977. Coarsening-upward cycles in the alluvium of Hornelen Basin (Devonian), Norway: Sedimentary response to tectonic events. G.S.A. Bull., 88: 1124-1134.

Steel, Ron and Aasheim, Sjur M., 1978. Alluvial sand deposition in a rapidly subsiding basin (Devonian, Norway) in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 385-412.

Tolman, C.F., 1909. Erosion and deposition in the southern Arizona bolson region. J. Geol., 17: 136-163.

Tunbridge, I.P., 1981. Sandy high-energy flood sedimentation - Some criteria for recognition, with an example from the Devonian of S.W. England. Sedimentary Geology, 28: 79-95.

Turner, P., 1974. Lithostratigraphy and facies analysis of the Ringerike Group of the Oslo Region. Nor. Geol. Unders., 314: 101-132.

Walker, R.G., ed., 1980. Facies Models. Geoscience Canada, reprint series 1, 211 p.

Wallace, C.A., Harrison, J.E., Llepper, M.R., and Wells, J.E., 1976. Carbonate sedimentary breccias in the Wallace Formation (Belt Supergroup), Idaho and Montana, and their paleogeographic significance. G.S.A. Abs. with programs, 8: 1159.

Wallace, Robert E. and Hosterman, John W., 1956. Reconnaissance Geology of western Mineral County, Montana. U.S.G.S. Bull. 1027-M: 575-612.

Wasson, R.J., 1977. Last-glacial alluvial fan sedimentation in the Lower Derwent Valley, Tasmania. Sedimentology, 24: 781-799.

Webster, Terence A., 1981. Faulting and slumping during deposition of the Precambrian Prichard Formation, near Quinns, Montana: A model for sulfide deposition. Master's thesis, Univ. of Montana; 71 p.

White, B.G. and Winston, Don, 1977. The Revett/St. Regis "transition zone" near the Bunker Hill Mine, Coeur d'Alene mining district, Idaho. Abs. Coeur d'Alene Field Converence, Wallace, Idaho, Nov. 3-5, 1977. Soc. Econ. Geol. and College of Mines, Univ. of Idaho, Moscow, Idaho.

White, Brian G. and Winston, Don, 1982. The Revett-St. Regis "Transition Zone" near the Bunker Hill Mine, Coeur d'Alene District, Idaho. In: R.R. Reid and G.A. Williams, eds., Soc. Econ. Geol. Coeur d'Alene Field Conf. Idaho - 1977, Bull. 24: 25-30.

White, B.G., Winston, Don, and Jacob, P.J., 1977. The Revett Formation near Kellogg, Idaho. Abs. G.S.A. Regional Meeting, Missoula, Montana.

Williams, G.E., 1970. The central Australian stream floods of February-March 1967. J. Hydrol., 11: 185-200.

Williams, G.E., 1971. Flood deposits of the sand-bed ephemeral streams of central Australia. Sedimentology, 17: 1-40.

Wilson, Michael D. and Pitman, Edward D., 1977. Authigenic clay in sandstone: Recognition and influence on reservoir properties and paleoenvironmental analysis. J. Sed. Pet., 47: 3-31.

Winston, Don, 1978. Fluvial systems of the Precambrian Belt Supergroup, Montana and Idaho, U.S.A. in: A.D. Miall, ed., Fluvial Sedimentology. Can. Soc. Petrol. Geol. Memoir 5: 343-359.

Winston, Don, 1982. Late Precambrian faulting in the Belt basin, Montana and Idaho, and its effect on Cretaceous and Tertiary thrusting. Manuscript; 83 p.

Wolman, M. Gordon and Leopold, Luna B., 1957. River flood plains: some observations on their formation. U.S.G.S. Prof. Paper 282-C: 87-107.

Yeakel, Lloyd S., Jr., 1962. Tuscarora, Juniata, and Bald Eagle paleocurrents and paleogeography in the central Appalachians. G.S.A. Bull., 73: 1515-1540.

APPENDIX A

MEASURED SECTION LOCATIONS

Location of measured sections (Figure 4 in text):

Placer Creek section --- in the Wallace, Idaho 15' quadrangle south of Wallace along the West Fork of Placer Creek in the north-central part of section 4, T. 47 N., R. 4 E. and in the southwest 1/4 of section 33, T. 48 N., R. 4 E. This area has been mapped by S.W. Hobbs and others (1965) and by J.E. Harrison and others (1974a, 1981).

Glidden Lakes section --- in the Cooper Gulch, Montana 15' quadrangle about 1/2 mile southwest of lower Glidden Lake in the central part of section 19, T. 48 N., R. 6 E. This area has been mapped by J.E. Harrison and others (1974a, 1981).

Lookout Pass section --- in the Saltese, Montana 15' quadrangle along the northeast side of Interstate Highway 90 in the central and northwest 1/4 of section 4, T. 19 N., R. 32 W. This area has been mapped by Wallace and Hosterman (1956) and by J.E. Harrison and others (1974a, 1981).

Silver Cable section --- in the Saltese, Montana 15' quadrangle in the south-central part of section 13 and the north-central part of section 24, T. 20 N., R. 32 W., about 1/2 mile north of the Silver Cable Mine. This area has been mapped by Wallace and Hosterman (1956) and by J.E. Harrison and others (1974a, 1981).

West Twin Creek section --- in the Haugan, Montana 15' quadrangle along the west side of West Twin Creek in sections 12 and 1, T. 19 N., R. 30 W. This area has been mapped by Wallace and Hosterman (1956) and by J.E. Harrison and others (1974a, 1981).

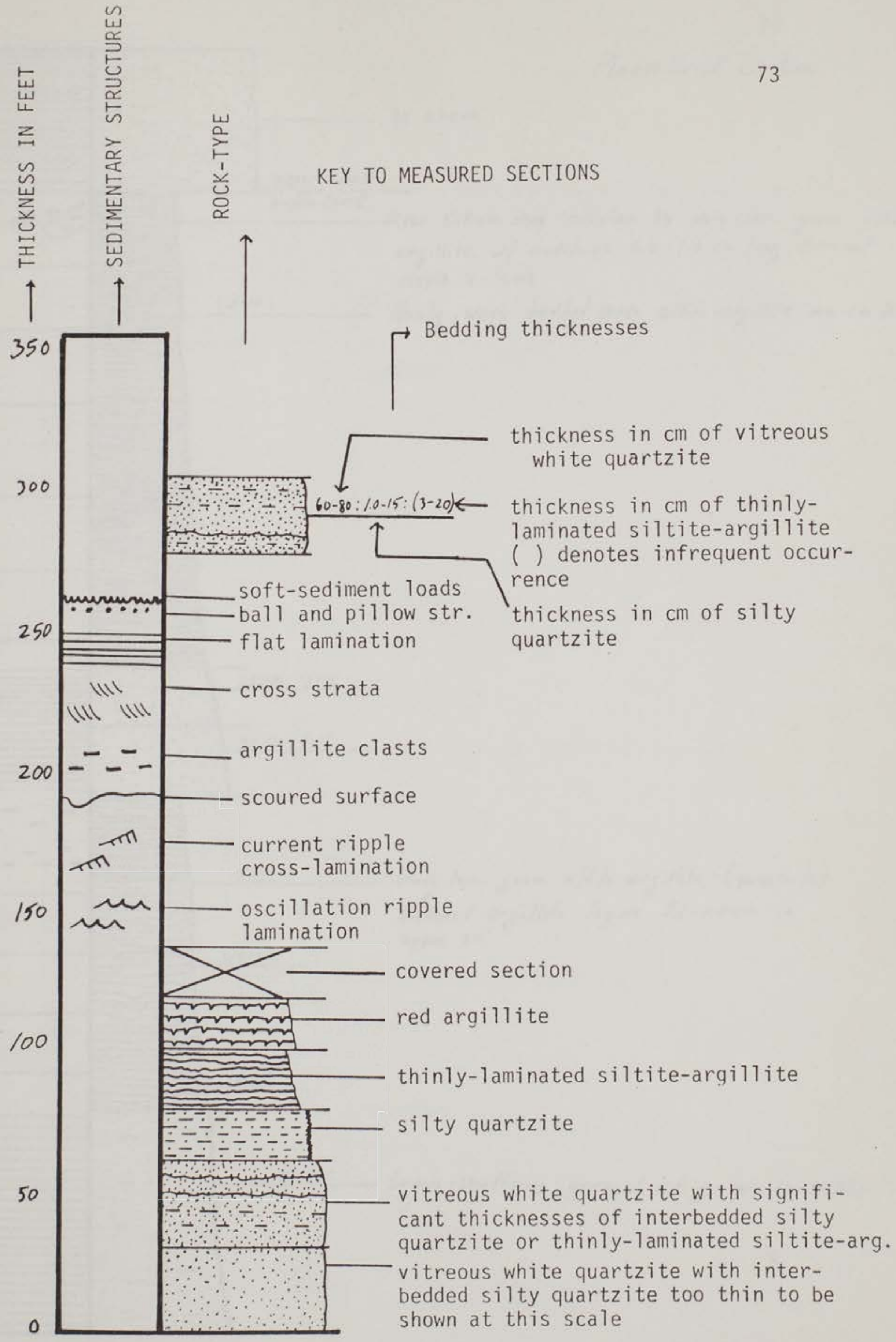
Flat Rock Creek section --- in the St. Regis, Montana 15' quadrangle along the northwest side of Flat Rock Creek in the southeast 1/4 of section 23 and the northwest 1/2 of section 24, T. 19 N., R. 29 W. This area has been mapped by Wallace and Hosterman (1956) and by J.E. Harrison and others (1974a, 1981).

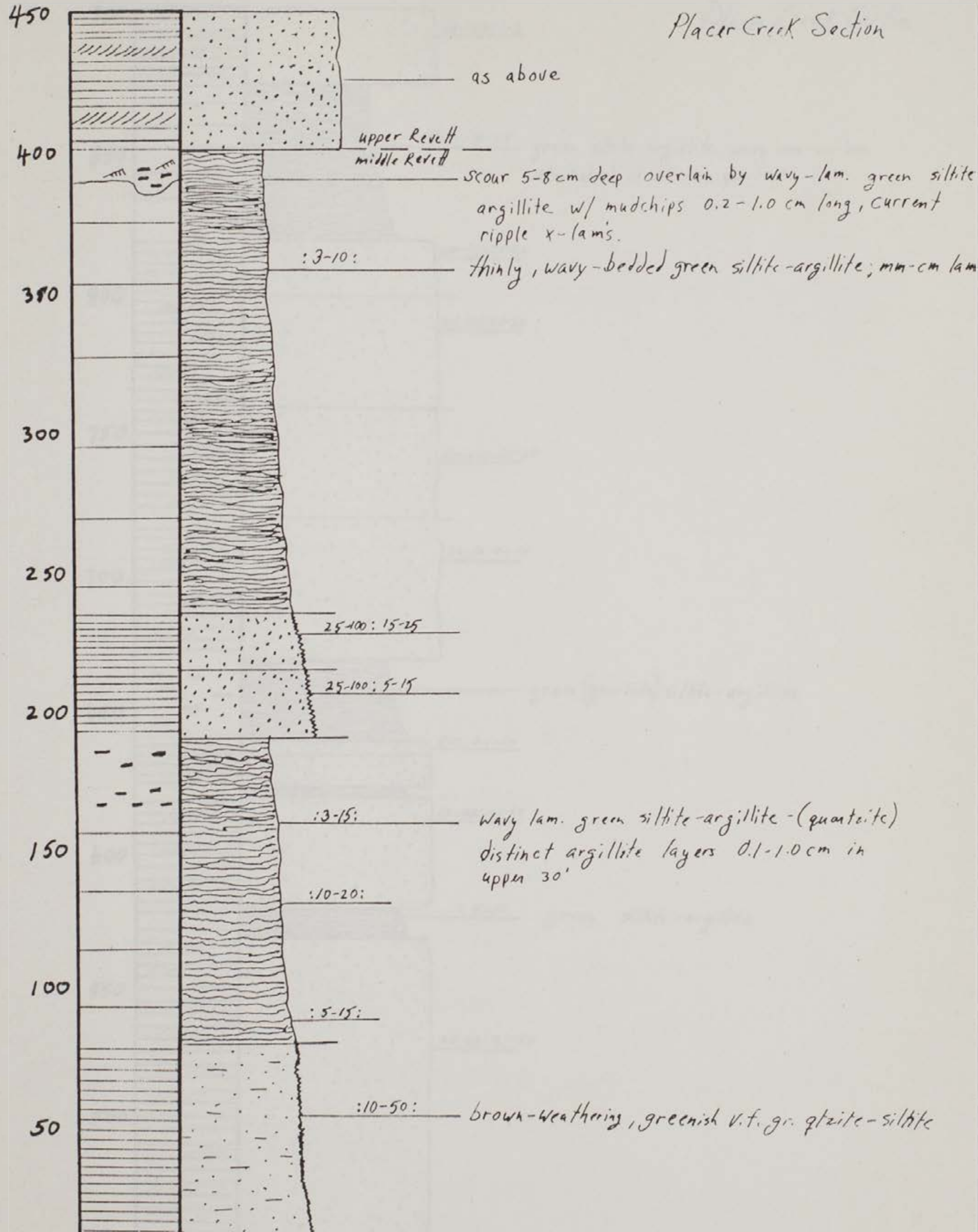
Eddy Mountain section --- in Eddy Mountain, Montana 7 1/2' quadrangle, in the cirque wall below Eddy Mountain Lookout in the northeast 1/4 of section 33, T. 21 N., R. 28 W. This area has been mapped by J.E. Harrison and others (1974a, 1981).

APPENDIX B

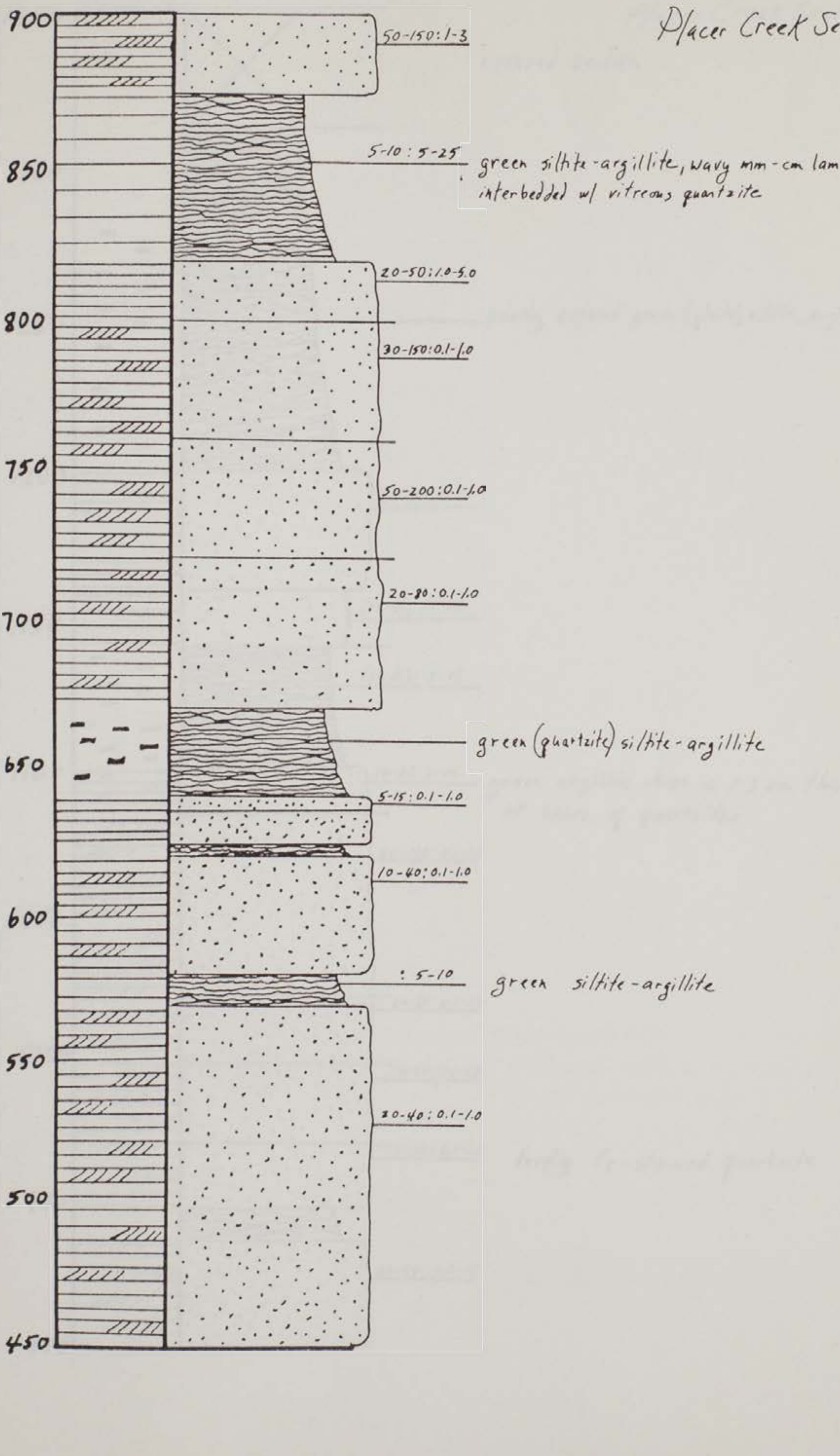
MEASURED SECTION PROFILES

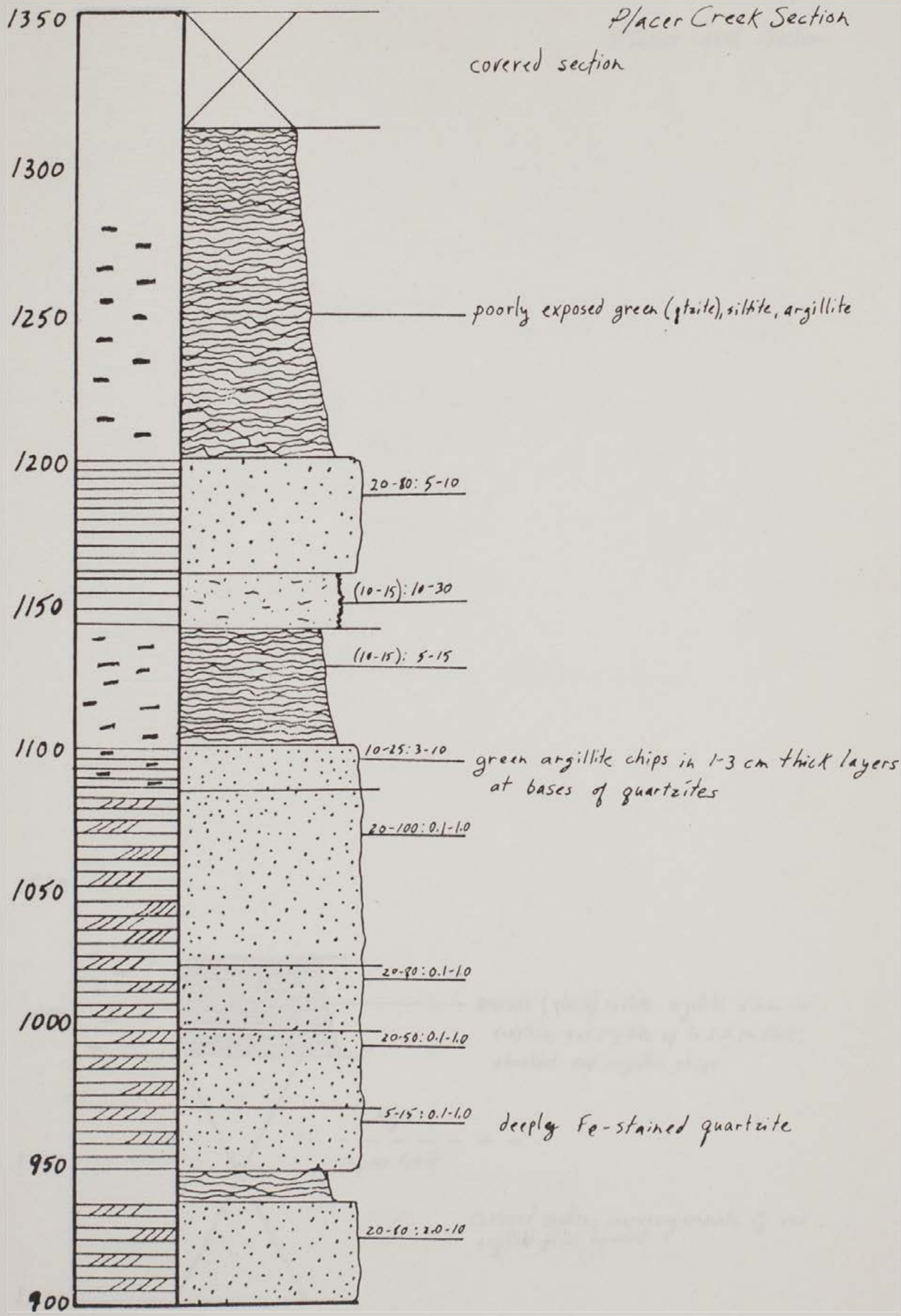
KEY TO MEASURED SECTIONS



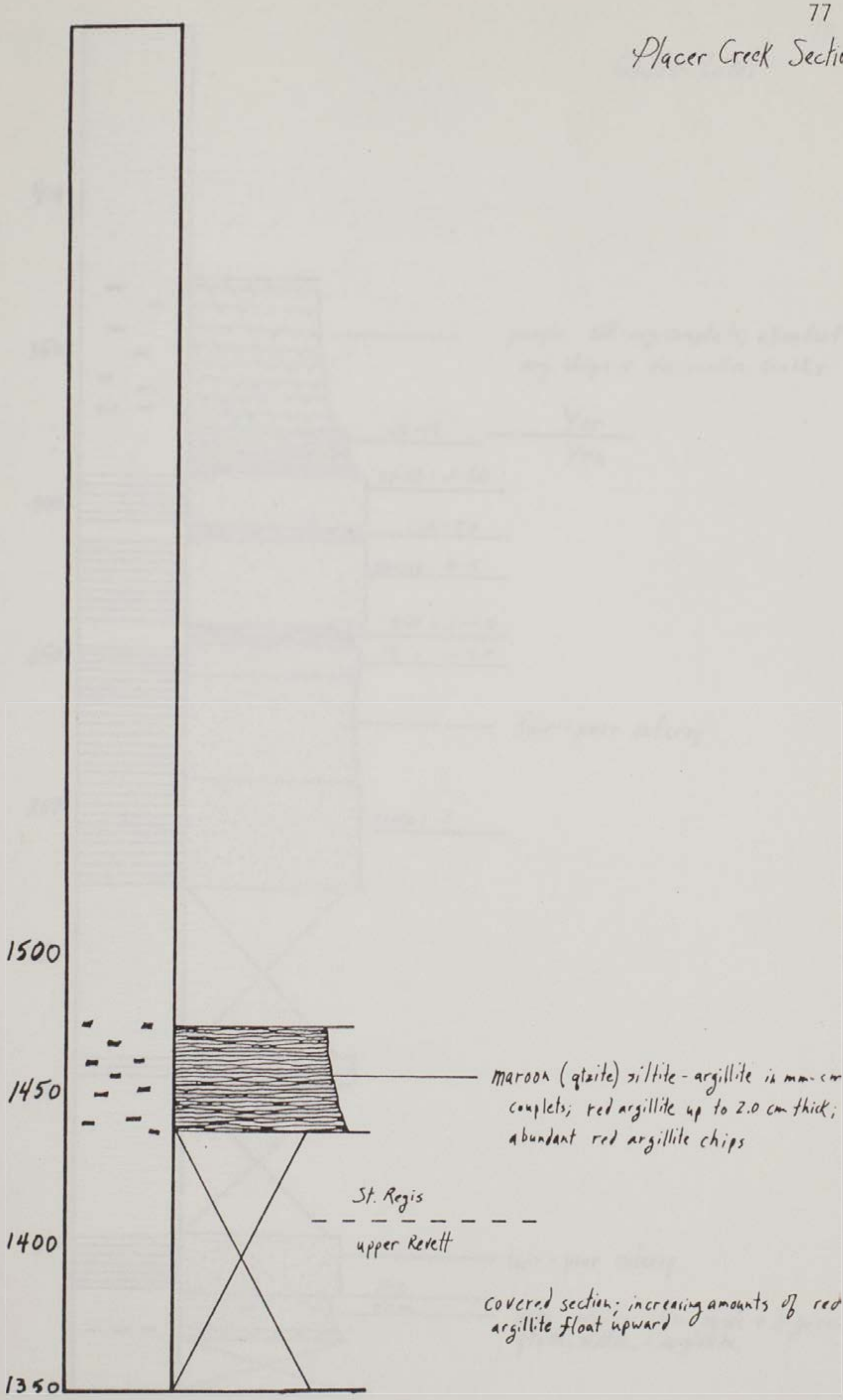

Placer Creek Section
450
400
350
300
250
200
150
100
50
0
as above
upper Revett
middle Revett
scour 5-8 cm deep overlain by wavy-lam. green siltite-argillite w/ mudchips 0.2-1.0 cm long, current ripple x-lam's.
:3-10:
thinly, wavy-bedded green siltite-argillite; mm-cm lam.
25-100: 15-25
25-100: 5-15
:3-15:
wavy lam. green siltite-argillite-(quartzite) distinct argillite layers 0.1-1.0 cm in upper 30'
:10-20:
:5-15:
:10-50:
brown-weathering, greenish v.f. gr. qtzite-siltite

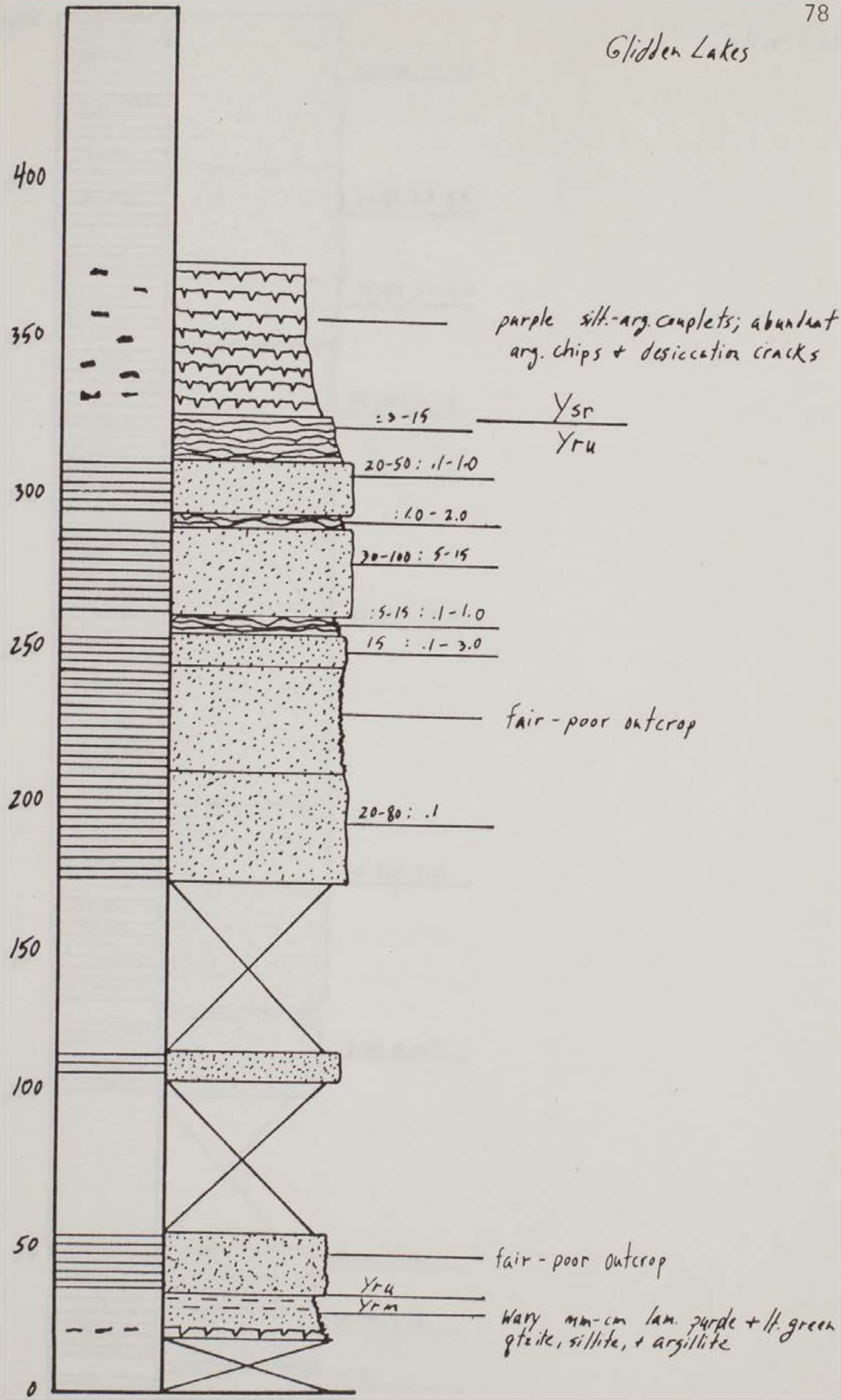
Placer Creek Section



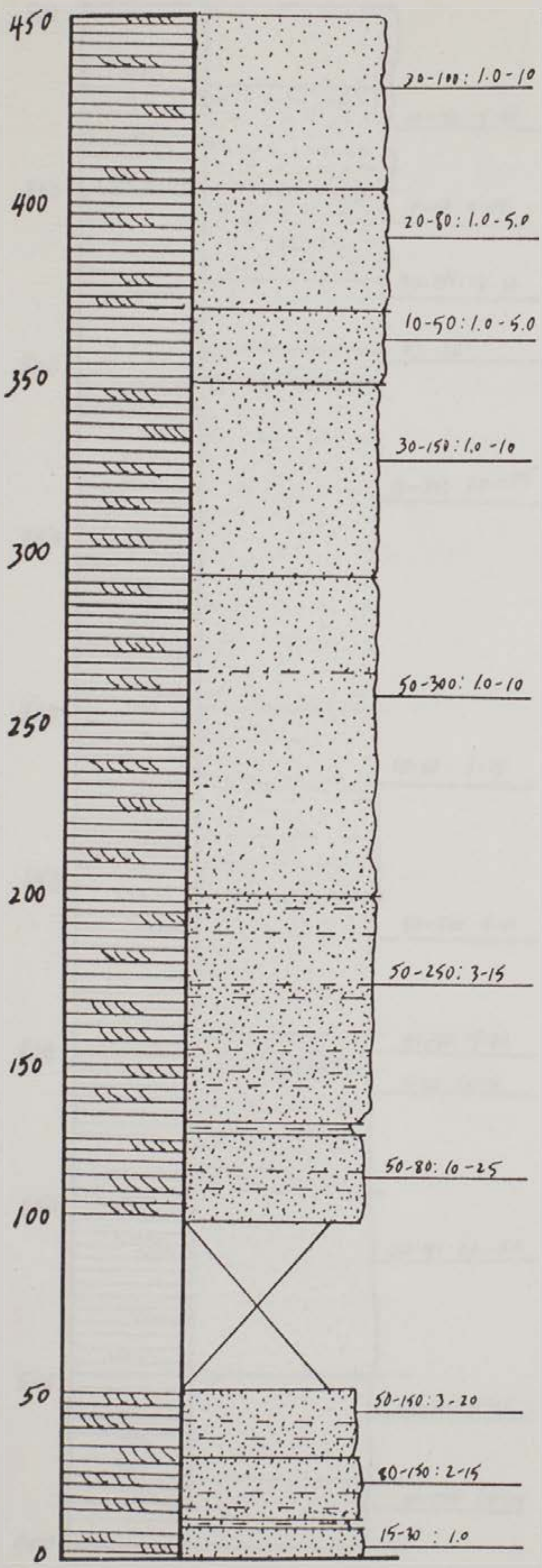

Placer Creek Section
1350
covered section
1300
1250
poorly exposed green (qtzite), siltite, argillite
1200
20-80: 5-10
(10-15): 10-30
1150
(10-15): 5-15
1100
10-25: 3-10
green argillite chips in 1-3 cm thick layers at bases of quartzites
20-100: 0.1-1.0
1050
20-80: 0.1-1.0
1000
20-50: 0.1-1.0
5-15: 0.1-1.0
deeply Fe-stained quartzite
950
20-60: 2.0-10
900

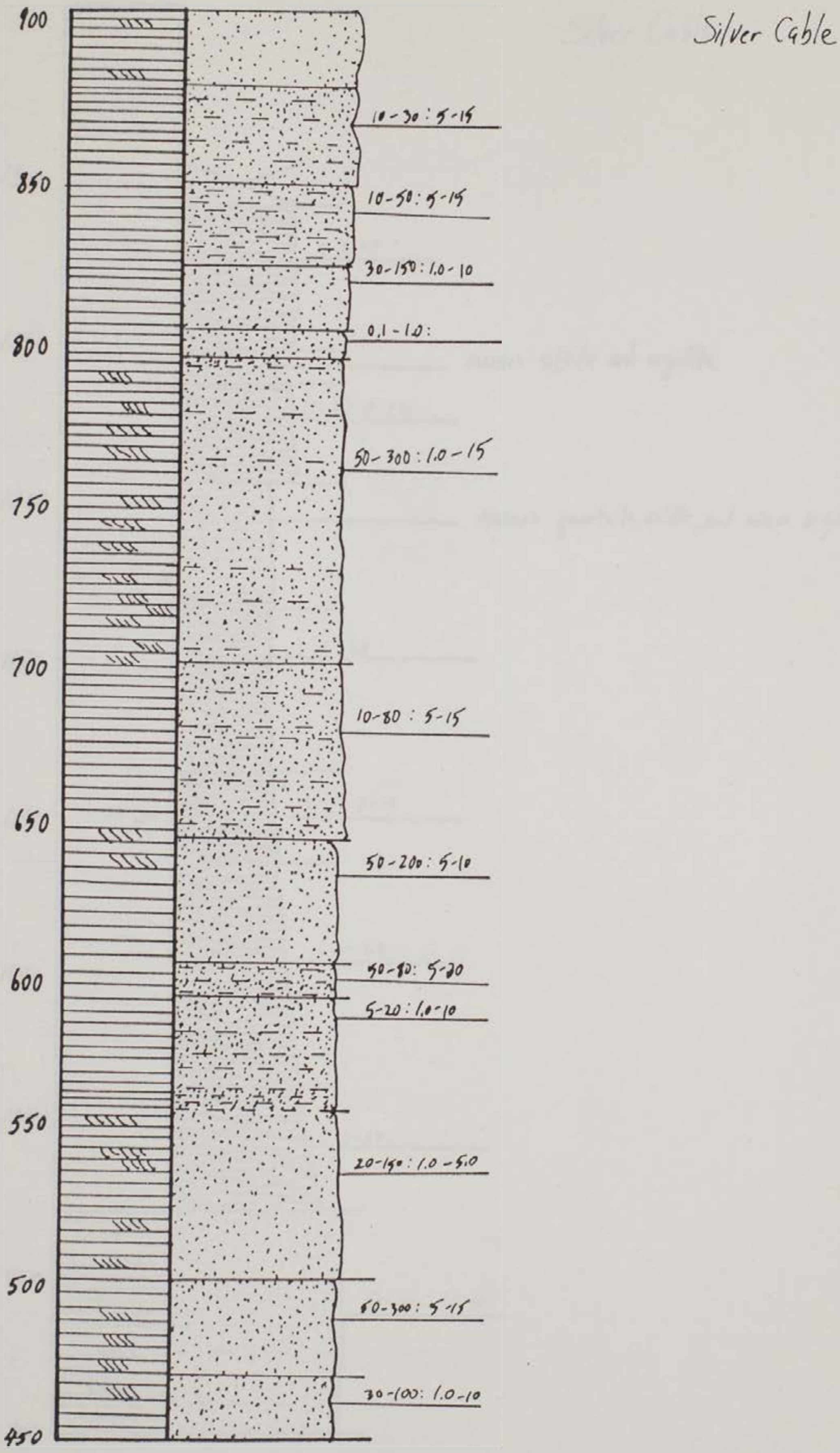
Placer Creek Section

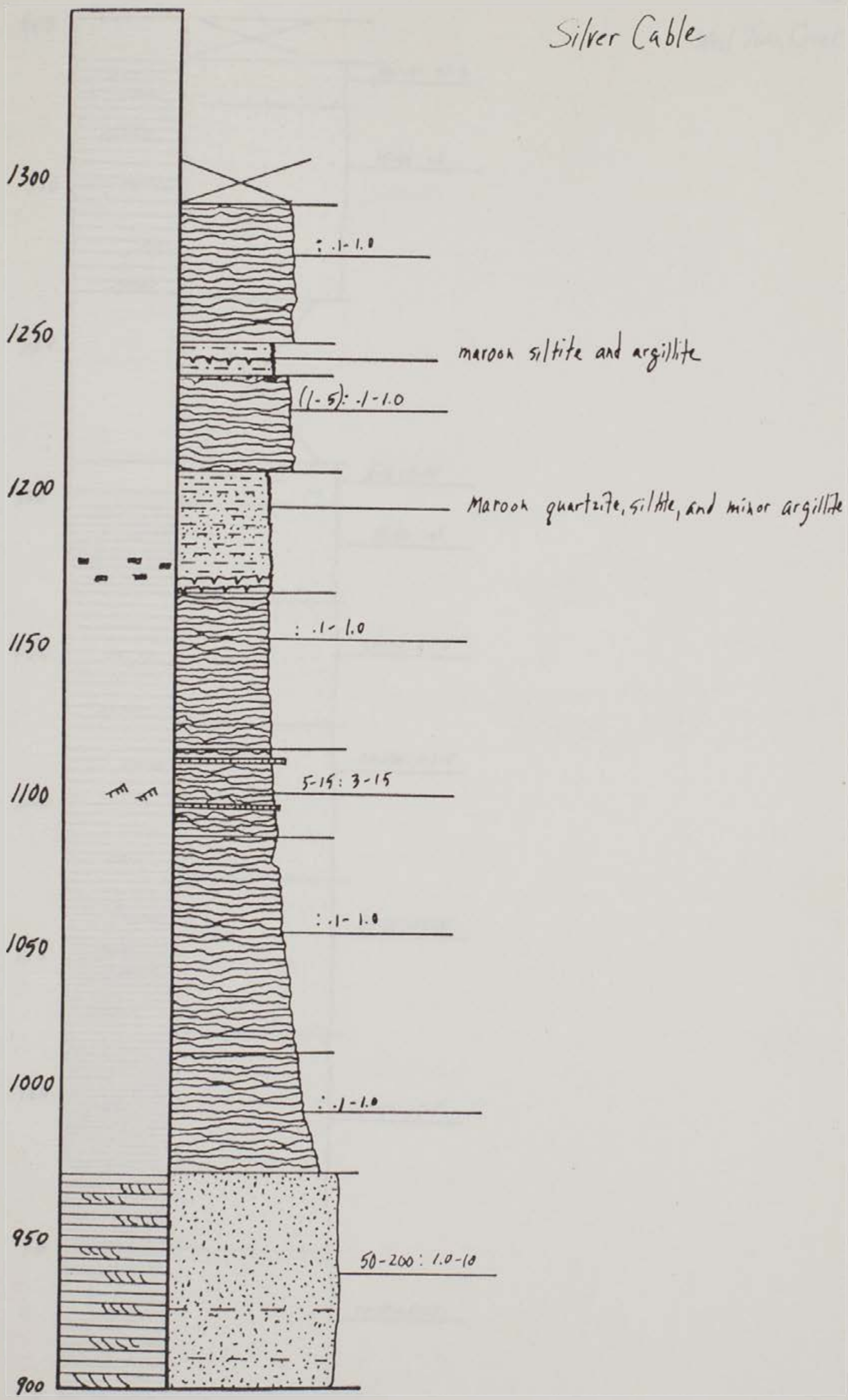



Glidden Lakes
400
350
300
250
200
150
100
50
0
purple silt.-arg. couplets; abundant arg. chips + desiccation cracks
: 3-15
Ysr
Yru
20-50 : .1-1.0
: 1.0 - 2.0
30-100 : 5-15
: 5-15 : .1-1.0
15 : .1 - 3.0
fair - poor outcrop
20-80 : .1
fair - poor outcrop
Yru
Yrm
wavy mm-cm lam. purple + lt. green qtzite, siltite, + argillite

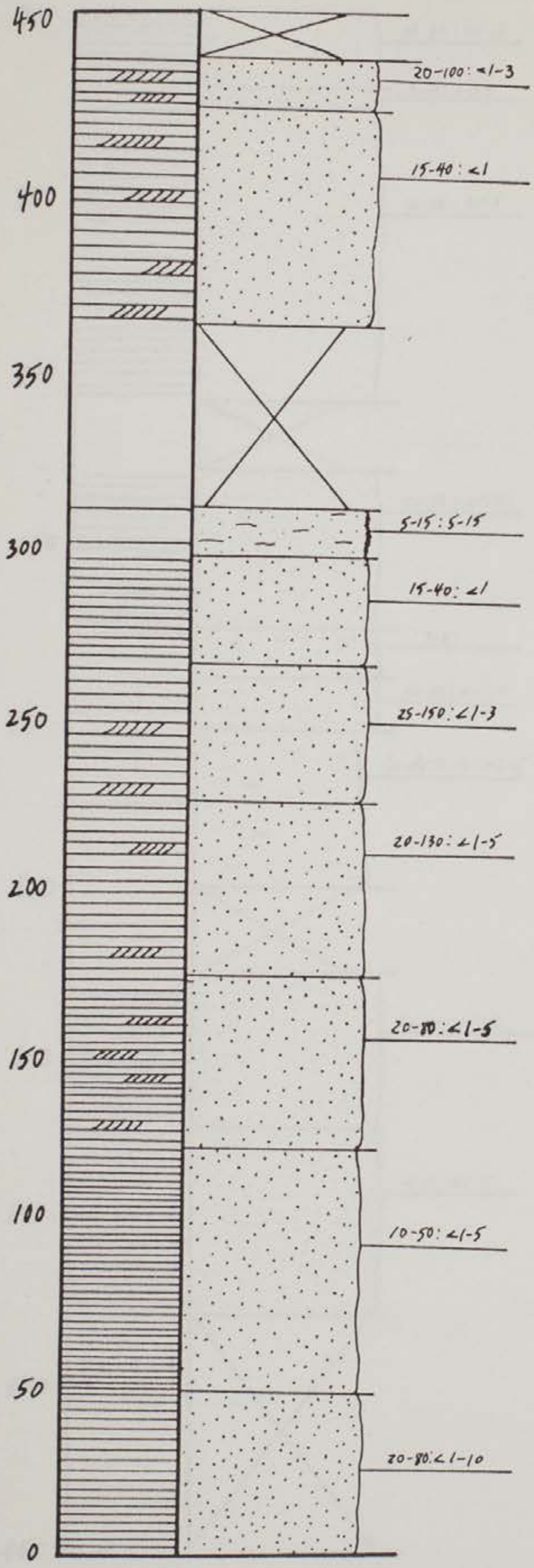
Silver Cable



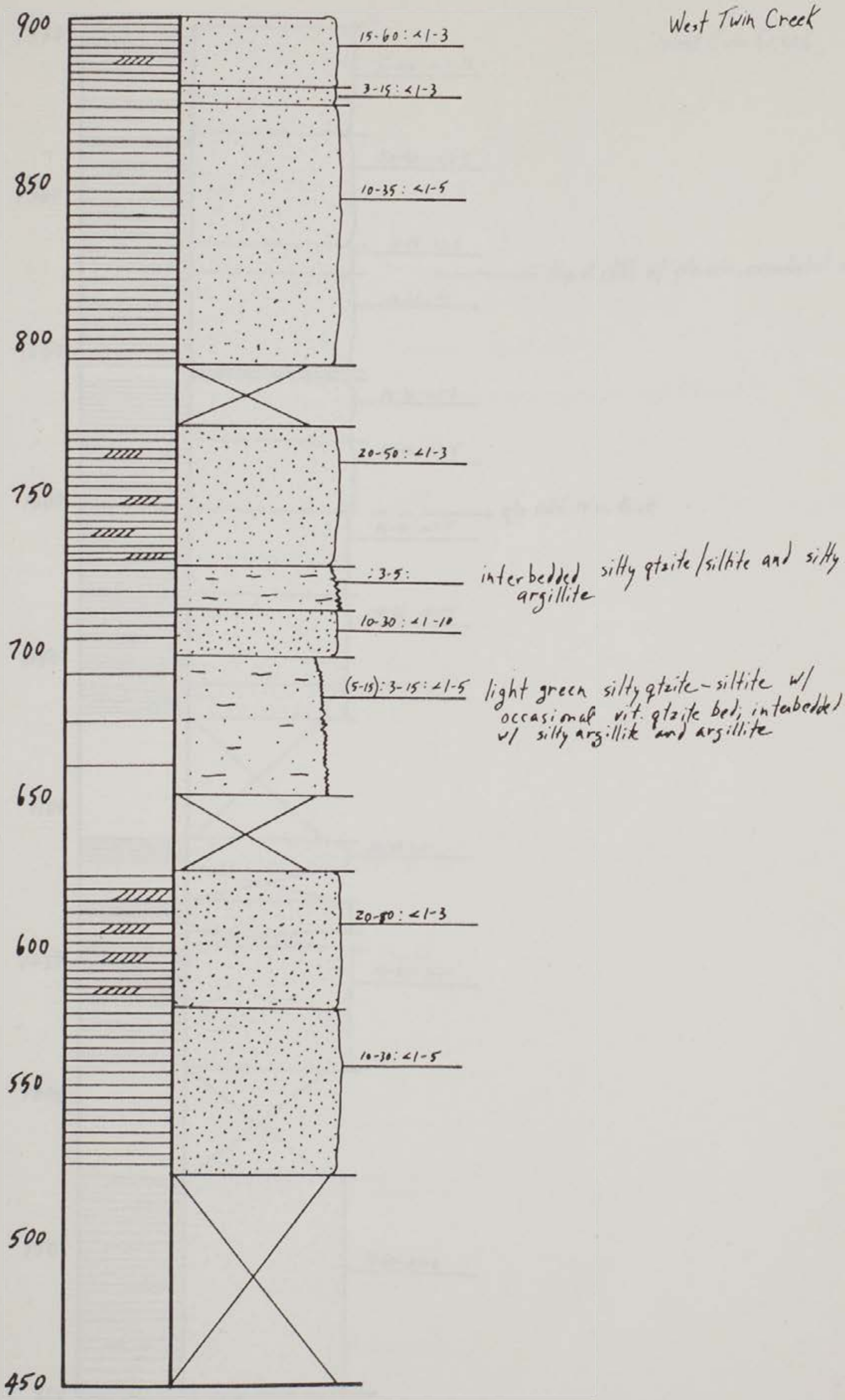

Silver Cable
900
850
800
750
700
650
600
550
500
450
10-30 : 5-15
10-50 : 5-15
30-150 : 1.0-10
0.1-1.0 :
50-300 : 1.0-15
10-80 : 5-15
50-200 : 5-10
50-80 : 5-20
5-20 : 1.0-10
20-150 : 1.0-5.0
50-300 : 5-15
30-100 : 1.0-10

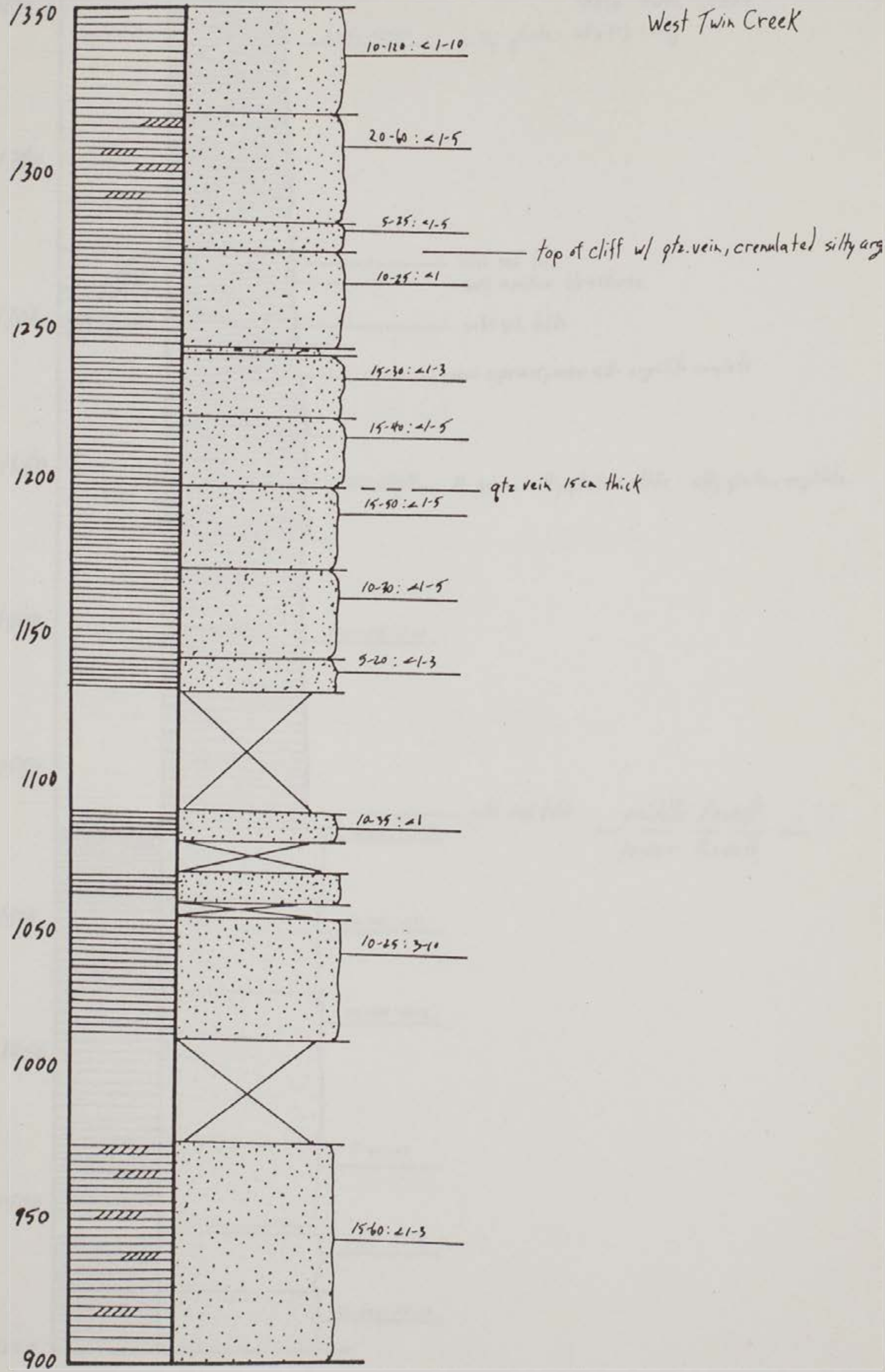

Silver Cable
1300
1250
1200
1150
1100
1050
1000
950
900
: .1-1.0
maroon siltite and argillite
(1-5): .1-1.0
Maroon quartzite, siltite, and minor argillite
: .1-1.0
5-15: 3-15
: .1-1.0
: .1-1.0
50-200: 1.0-10

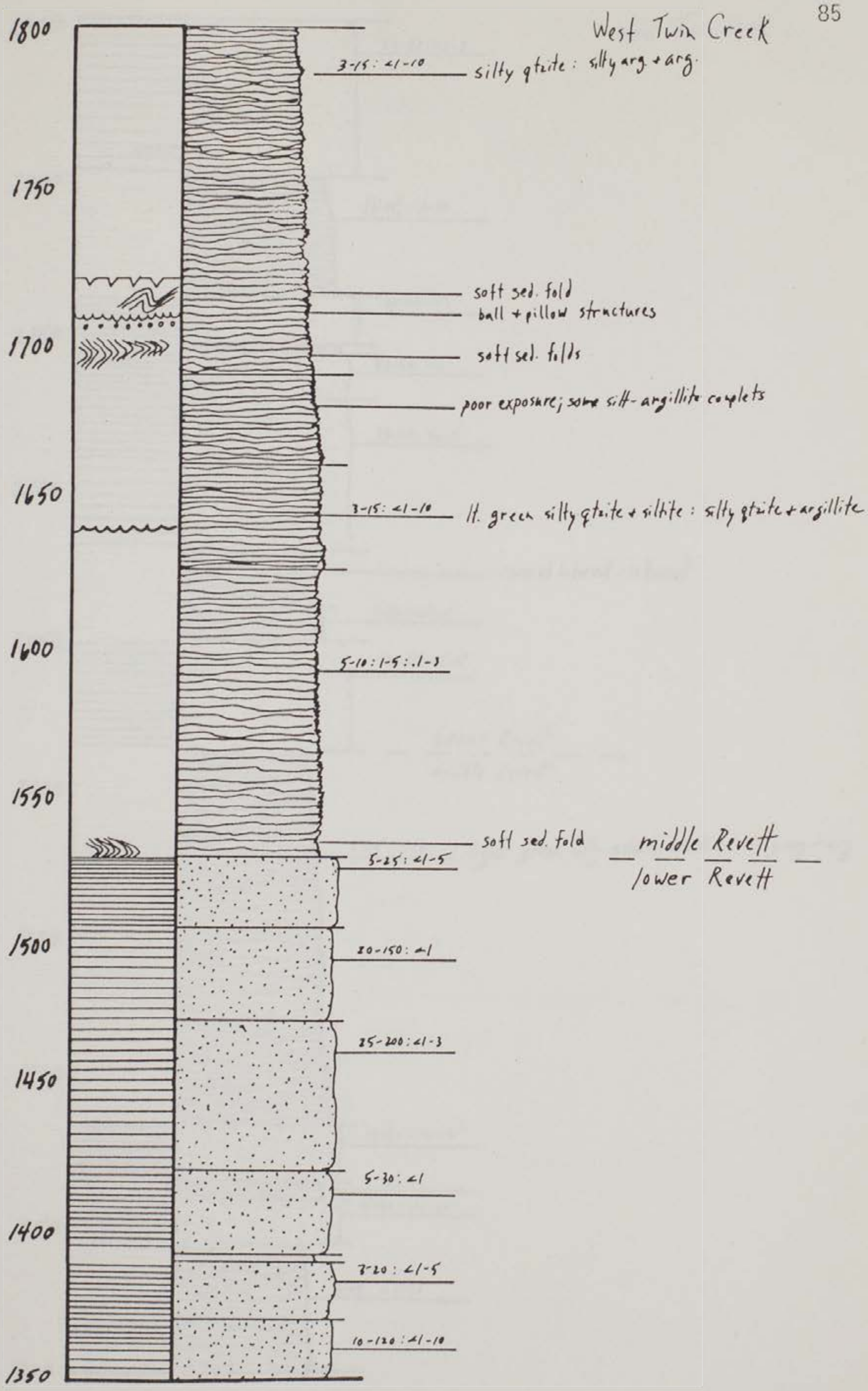
West Twin Creek



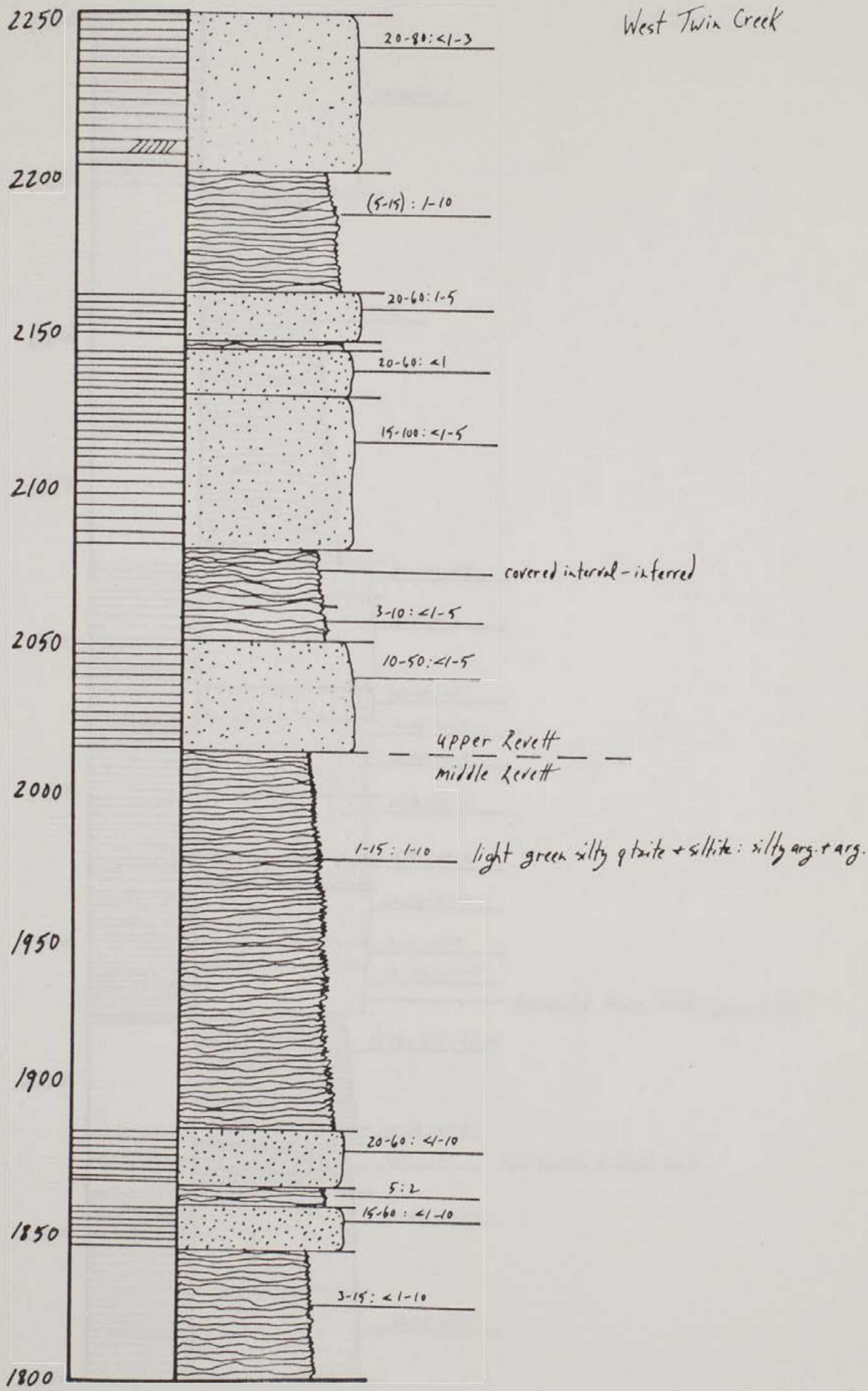
West Twin Creek

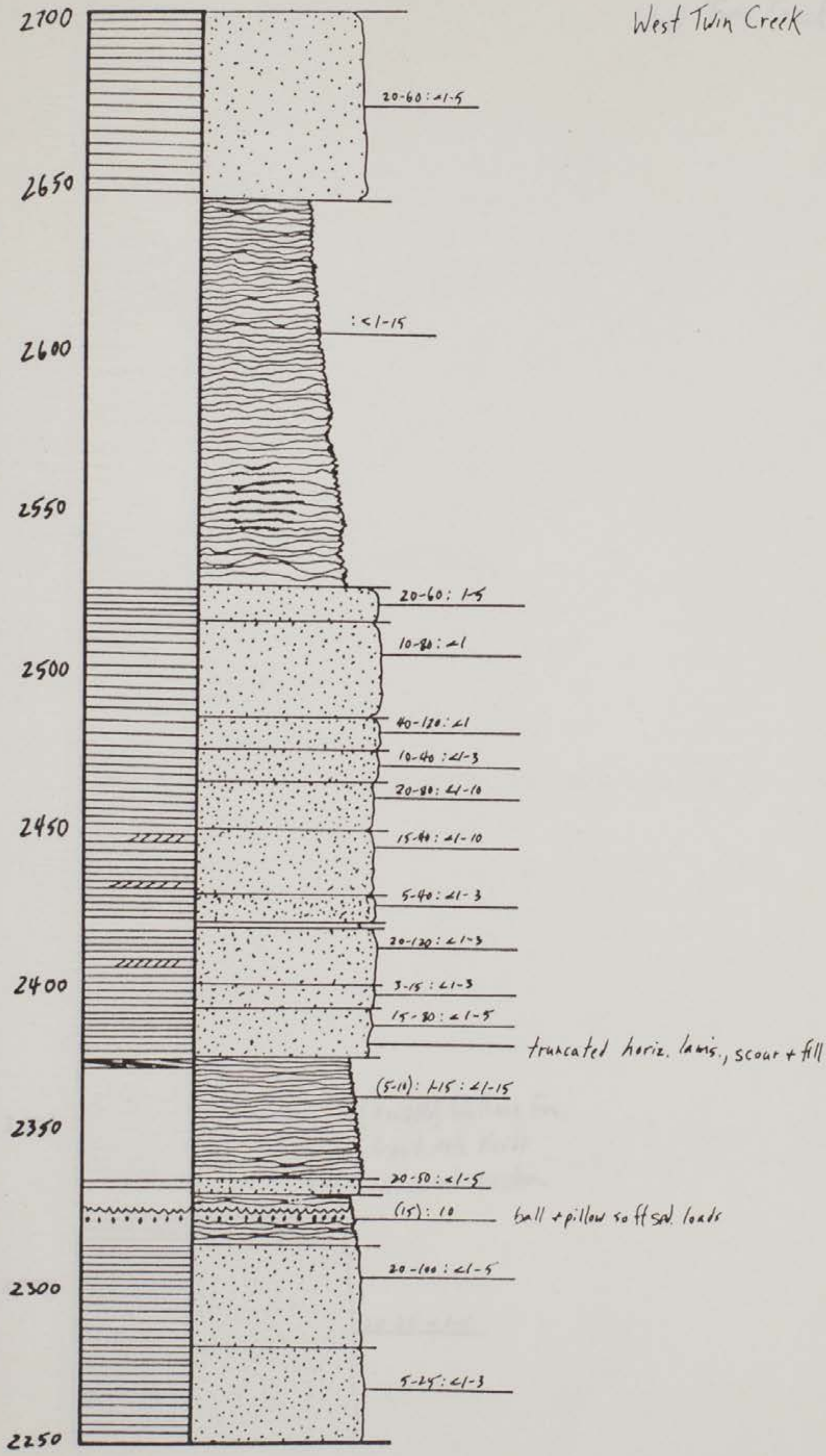



West Twin Creek
1350
10-120 : <1-10
20-60 : <1-5
1300
5-35 : <1-5
top of cliff w/ qtz. vein, crenulated silty arg.
10-25 : <1
1250
15-30 : <1-3
15-40 : <1-5
1200
qtz vein 15cm thick
15-50 : <1-5
10-30 : <1-5
1150
5-20 : <1-3
1100
10-35 : <1
1050
10-25 : 3-10
1000
950
15-60 : <1-3
900

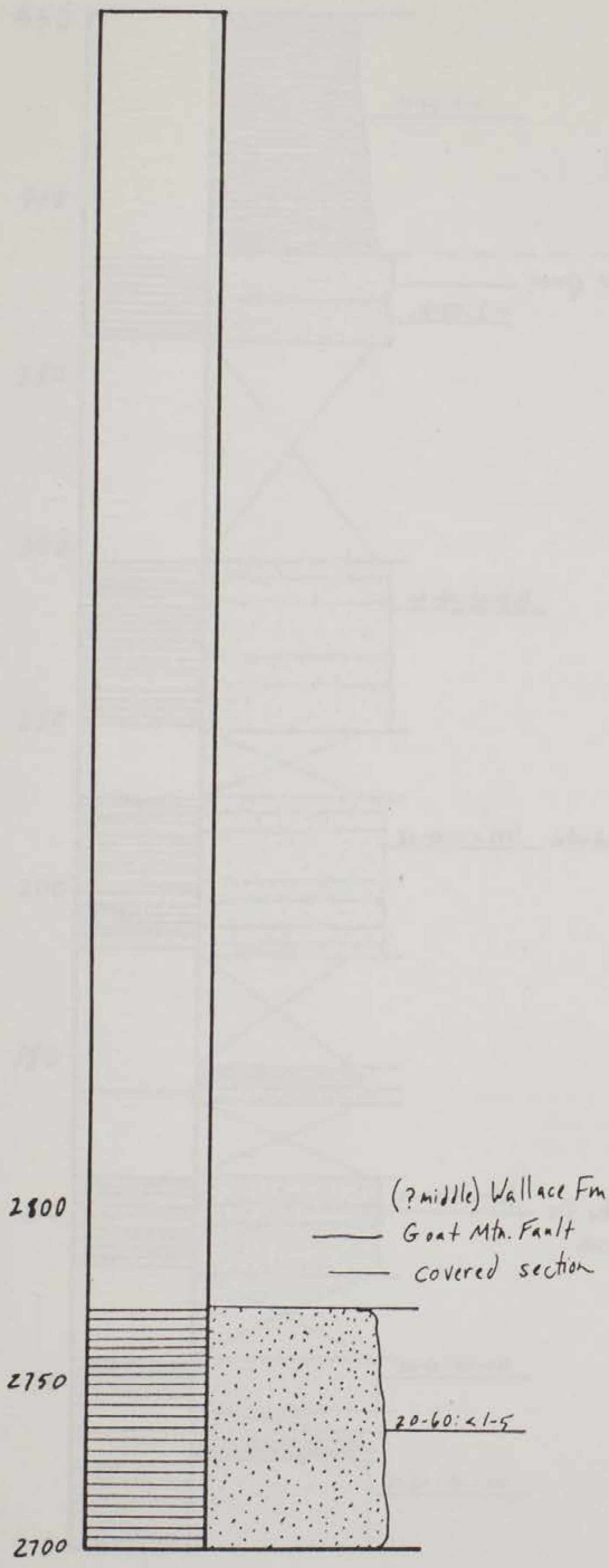

West Twin Creek
1800
1750
1700
1650
1600
1550
1500
1450
1400
1350
3-15 : <1-10
silty qtzite : silty arg. + arg.
soft sed. fold
ball + pillow structures
soft sed. folds
poor exposure; some silt-argillite couplets
3-15 : <1-10
lt. green silty qtzite + siltite : silty qtzite + argillite
5-10 : 1-5 : .1-3
soft sed. fold
middle Revett
lower Revett
5-25 : <1-5
30-150 : <1
25-200 : <1-3
5-30 : <1
3-20 : <1-5
10-120 : <1-10

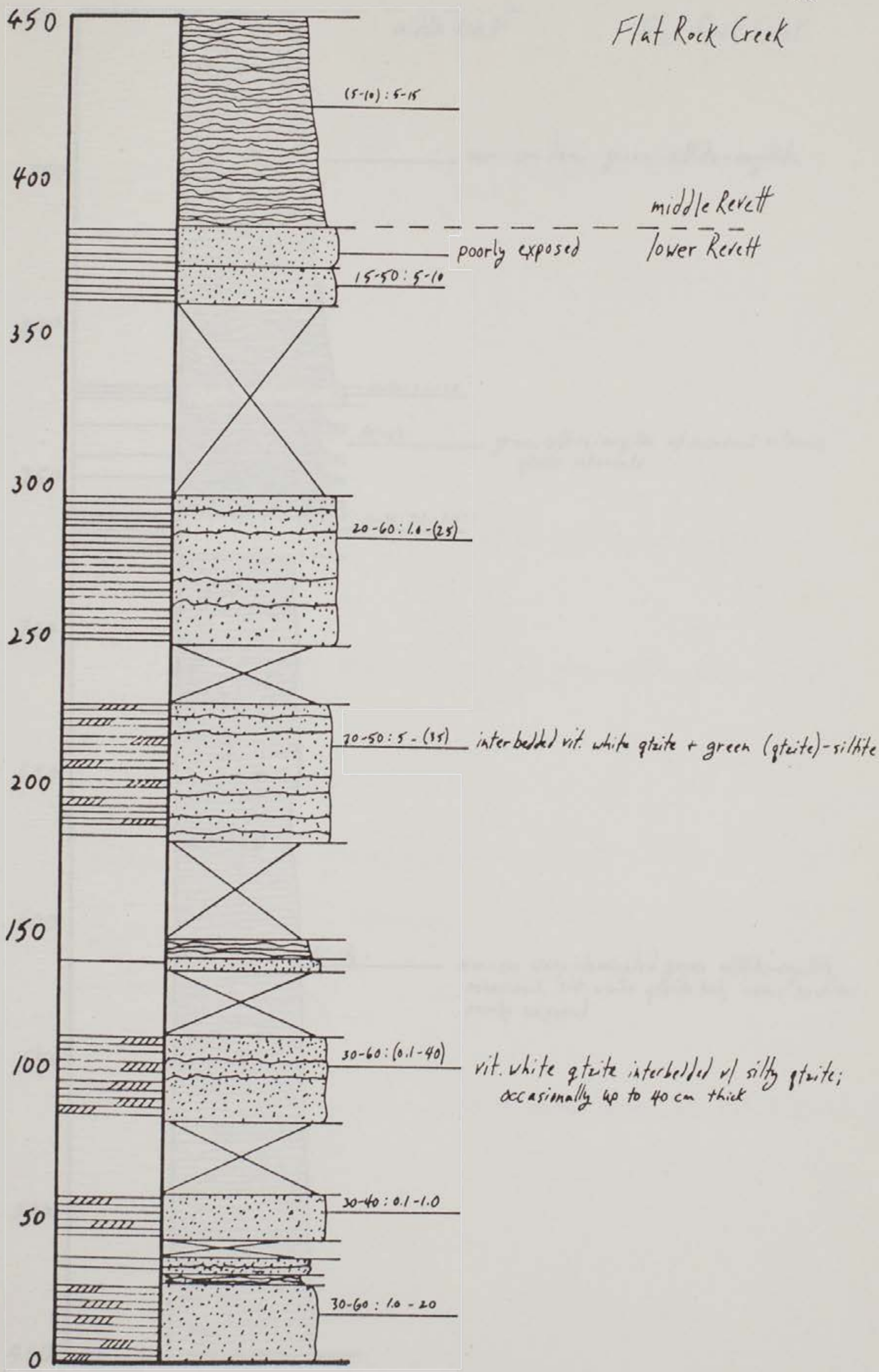
West Twin Creek



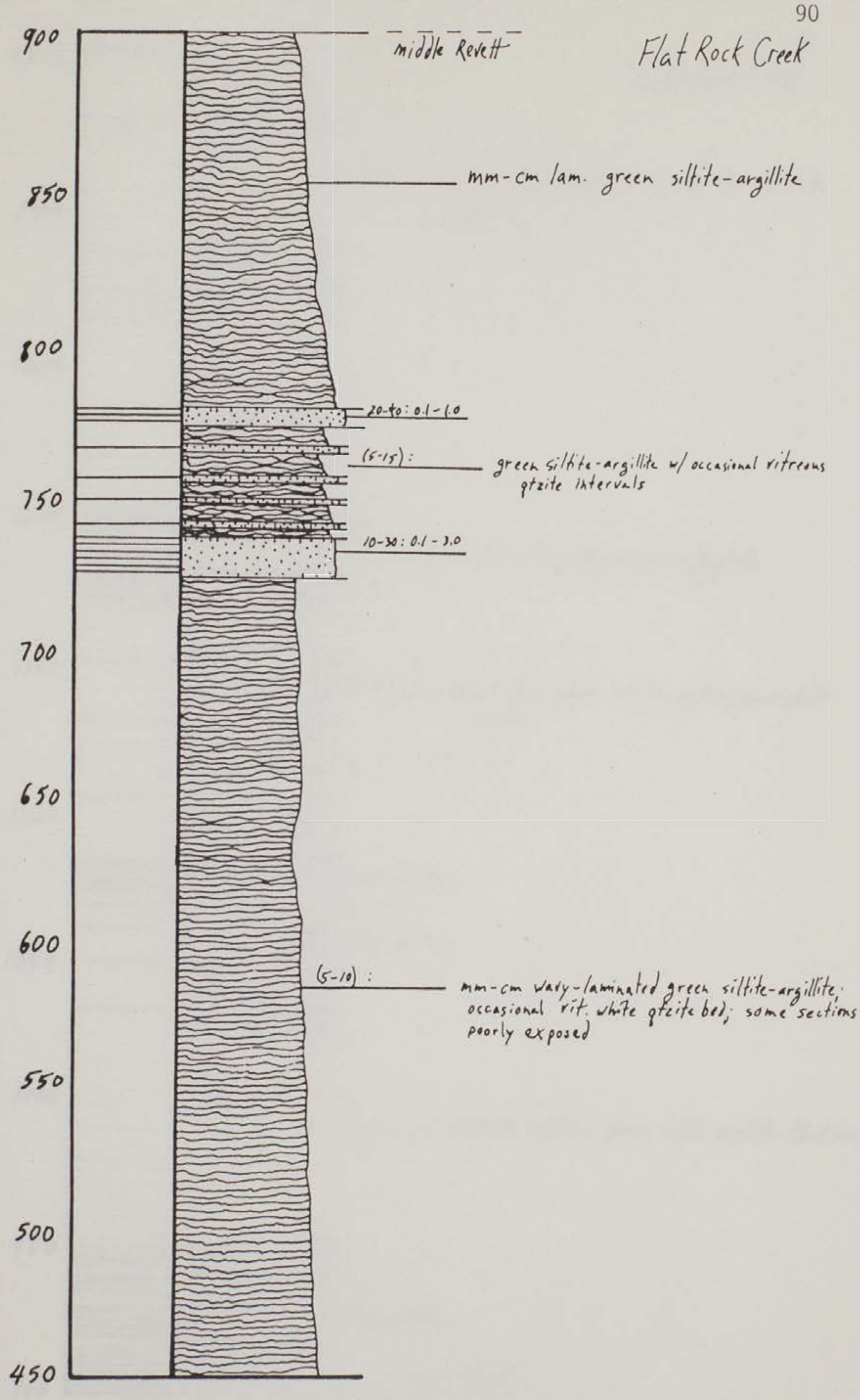

West Twin Creek
2700
20-60 : <1-5
2650
: <1-15
2600
2550
20-60 : 1-5
10-80 : <1
2500
40-120 : <1
10-40 : <1-3
20-80 : <1-10
2450
15-40 : <1-10
5-40 : <1-3
20-120 : <1-3
2400
3-15 : <1-3
15-30 : <1-5
truncated horiz. lams., scour + fill
(5-10) : 1-15 : <1-15
2350
20-50 : <1-5
(15) : 10
ball + pillow soft sed. loads
20-100 : <1-5
2300
5-25 : <1-3
2250

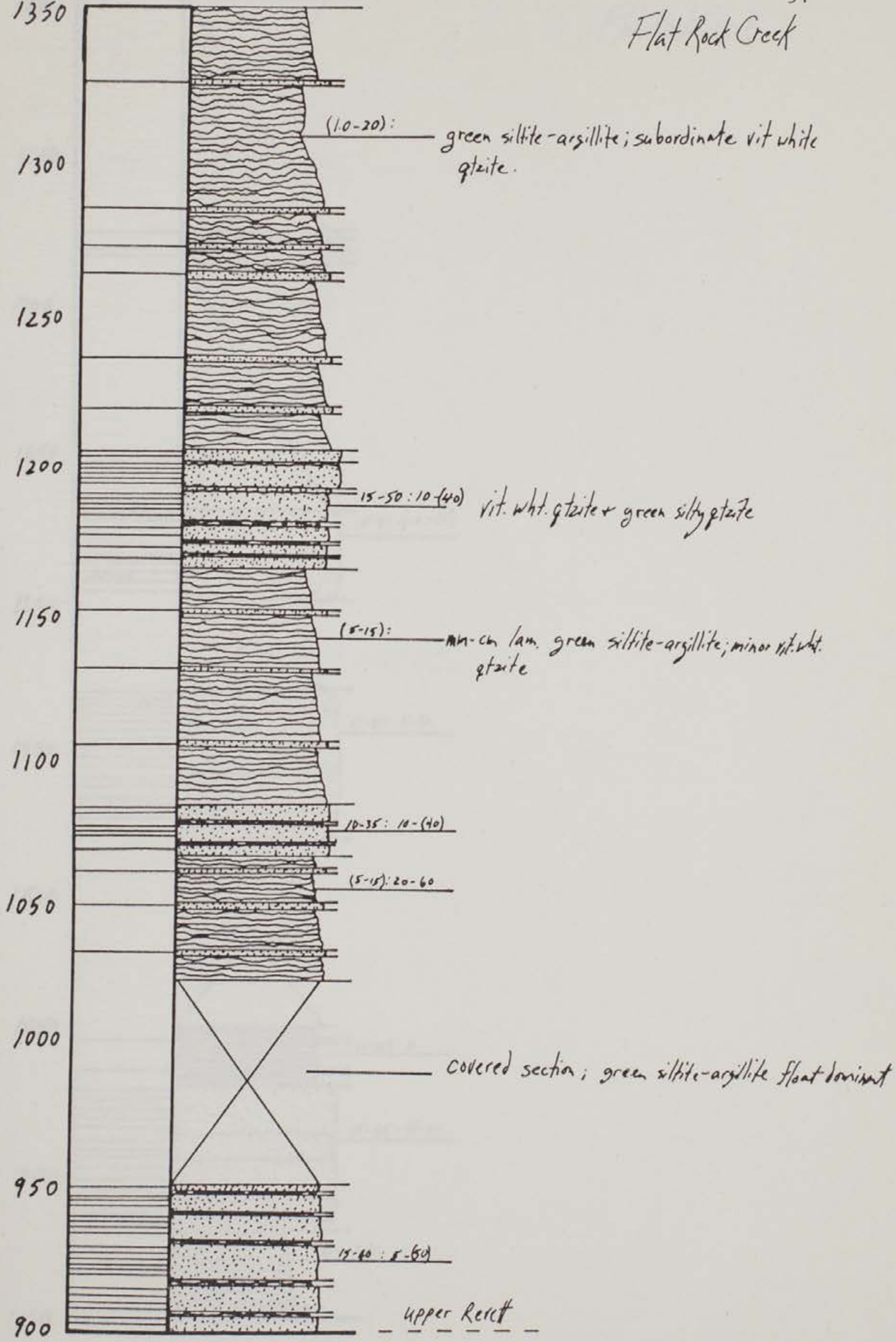
West Twin Creek





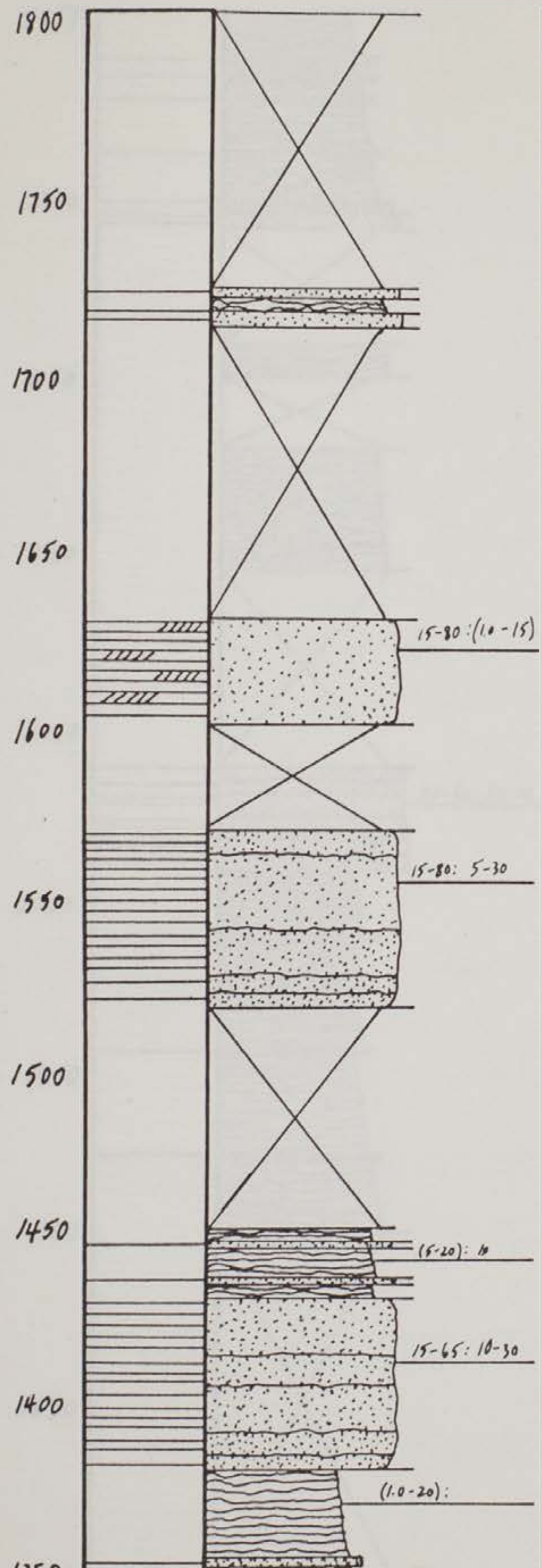
Flat Rock Creek
450
400
350
300
250
200
150
100
50
0
(5-10) : 5-15
middle Revett
lower Revett
poorly exposed
15-50 : 5-10
20-60 : 1.0 - (25)
70-50 : 5 - (35)
interbedded vit. white qtzite + green (qtzite)-siltite
30-60 : (0.1 - 40)
vit. white qtzite interbedded w/ silty qtzite;
occasionally up to 40 cm thick
30-40 : 0.1 - 1.0
30-60 : 1.0 - 20


middle Revett
Flat Rock Creek
900
850
mm-cm lam. green siltite-argillite
800
20-40: 0.1-1.0
(5-15):
green siltite-argillite w/ occasional vitreous qtzite intervals
750
10-30: 0.1-3.0
700
650
600
(5-10):
mm-cm wavy-laminated green siltite-argillite; occasional vit. white qtzite bed; some sections poorly exposed
550
500
450

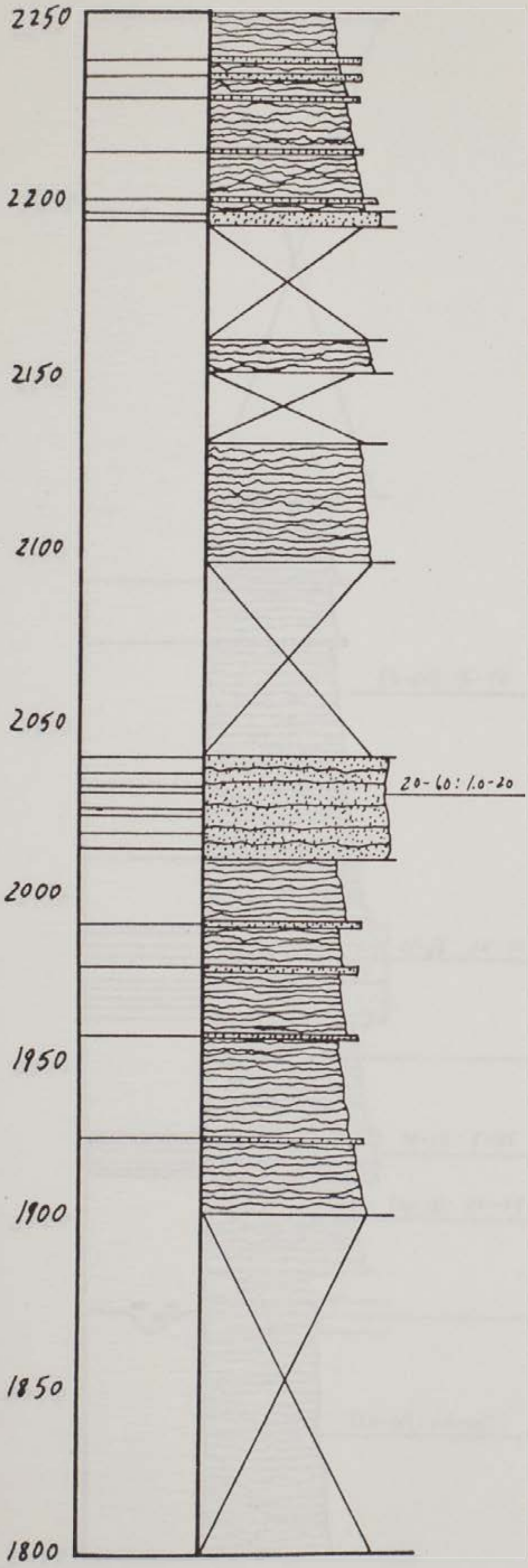


Flat Rock Creek
1350
1300
1250
1200
1150
1100
1050
1000
950
900
(1.0-20): green siltite-argillite; subordinate vit white qtzite.
15-50 : 10-(40) vit. wht. qtzite + green silty qtzite
(5-15): mm-cm lam. green siltite-argillite; minor vit. wht. qtzite
10-35 : 10-(40)
(5-15): 20-60
covered section; green siltite-argillite float dominant
15-60 : 5-(50)
upper Revett

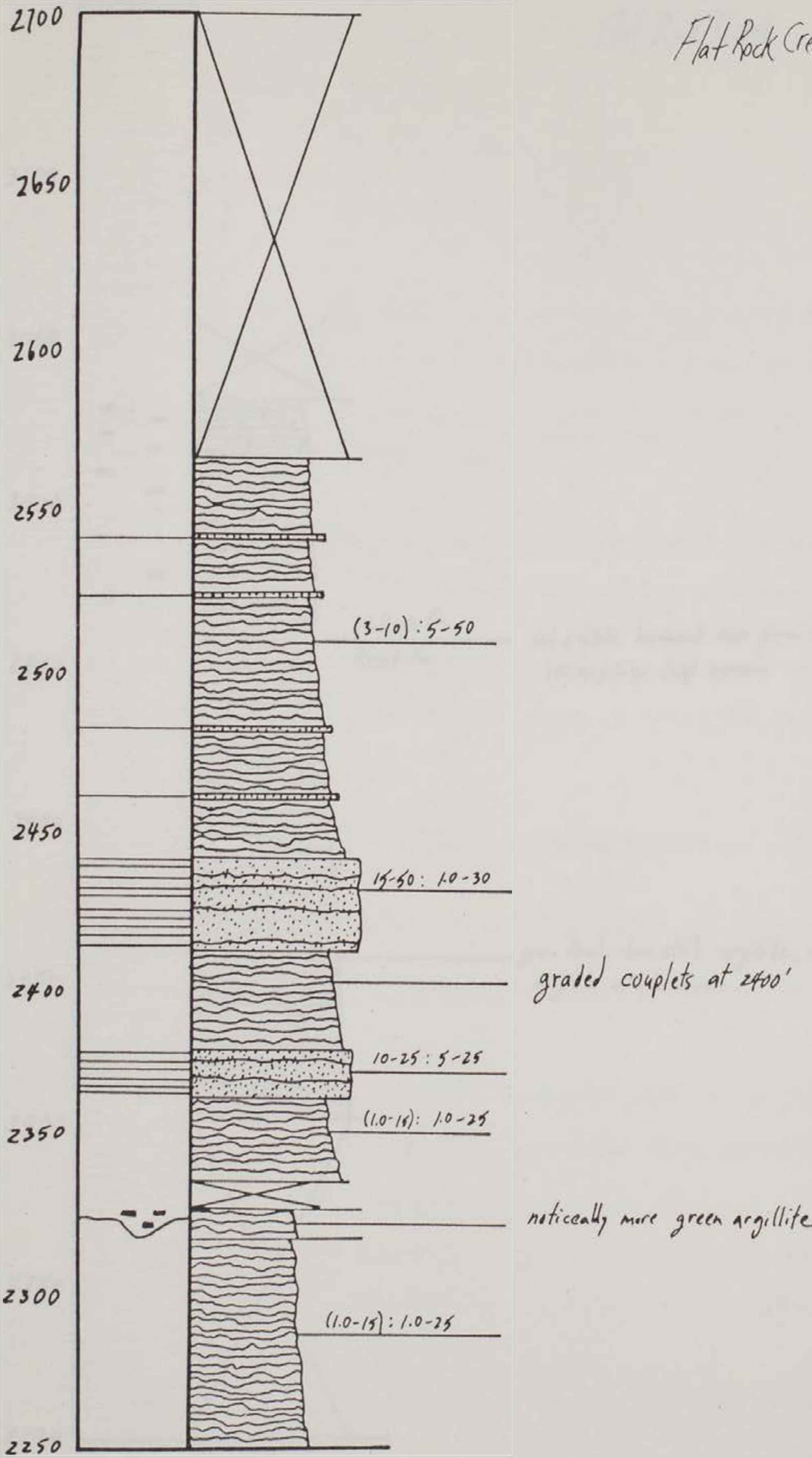
Flat Rock Creek



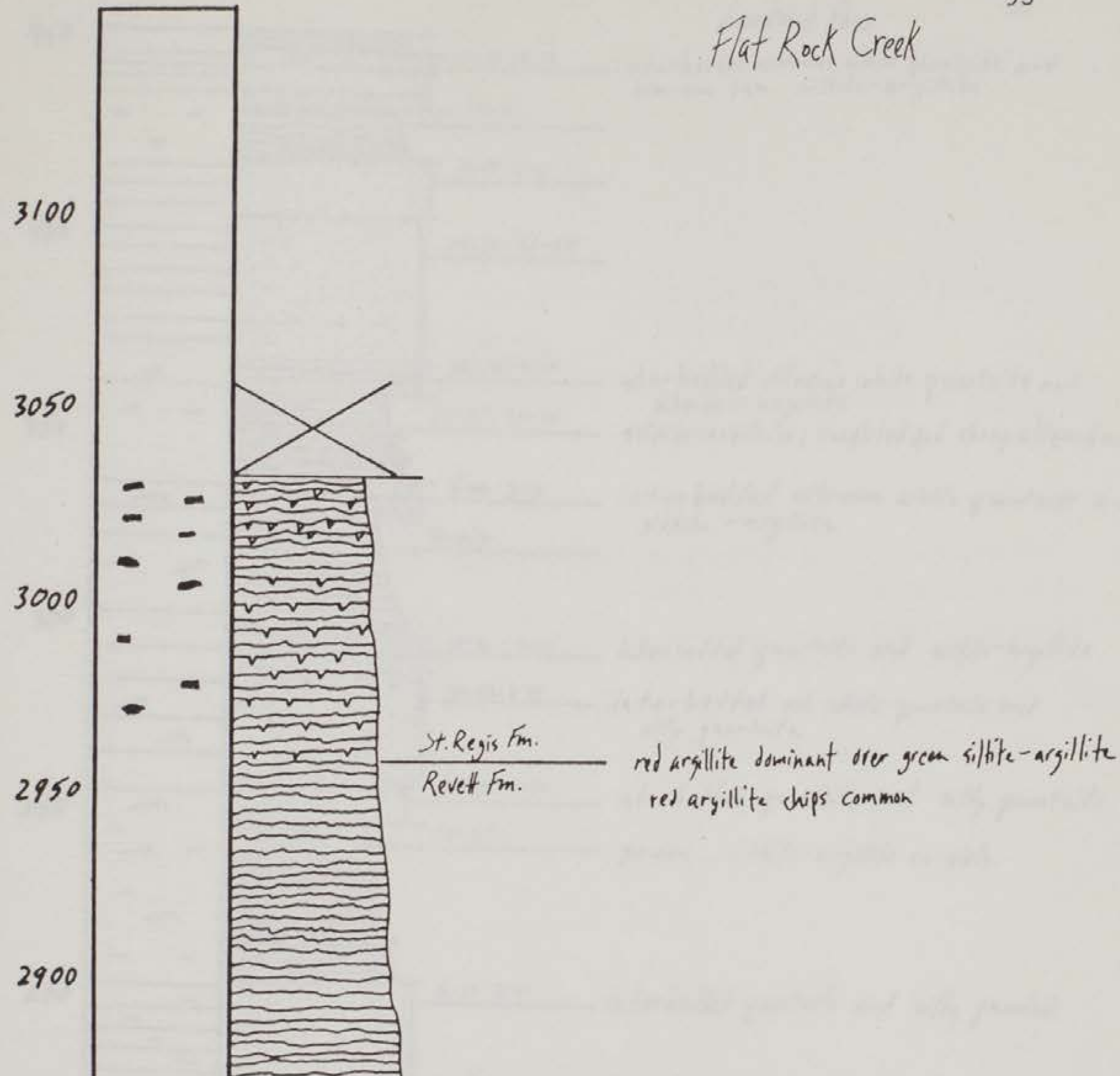
Flat Rock Creek

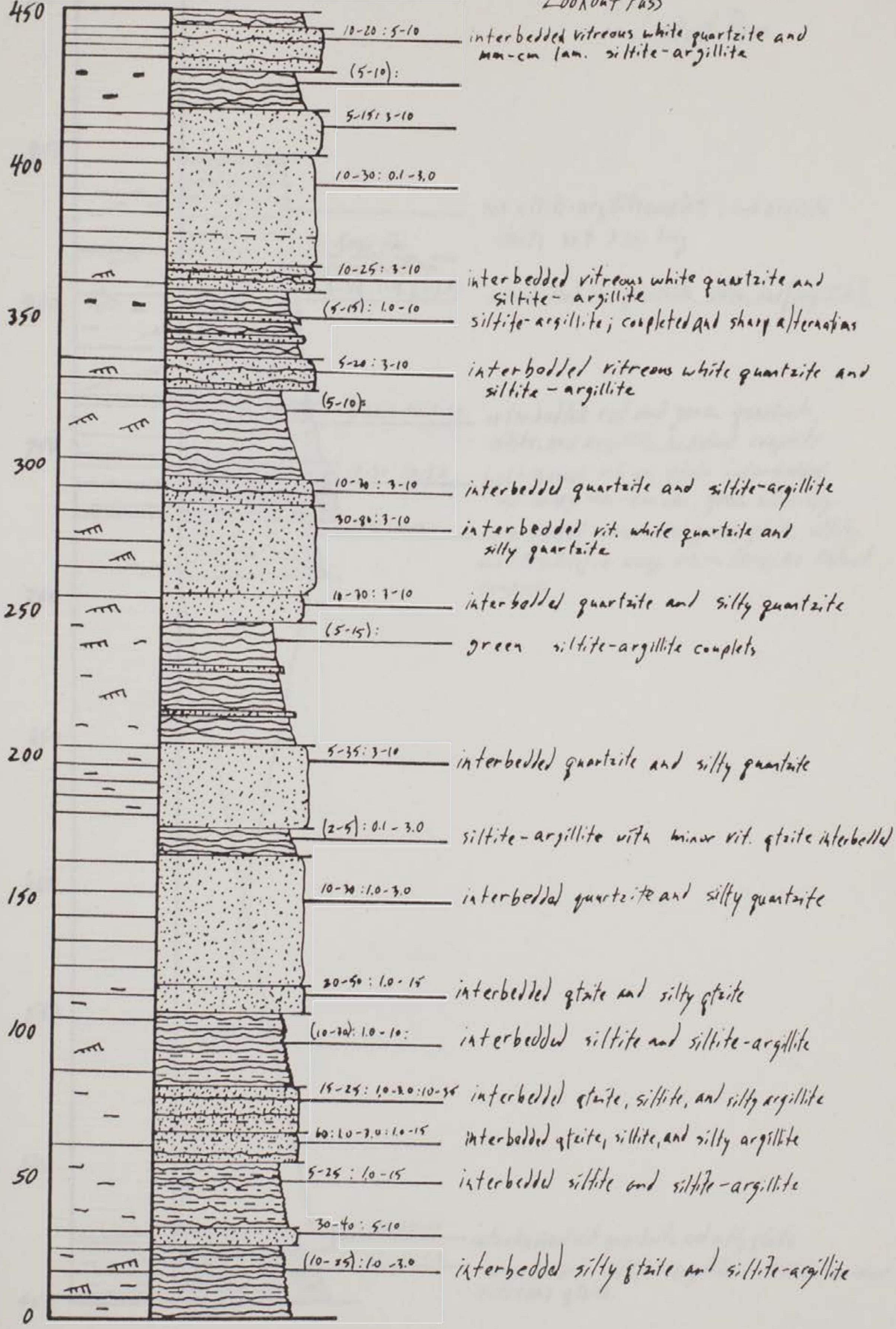


Flat Rock Creek

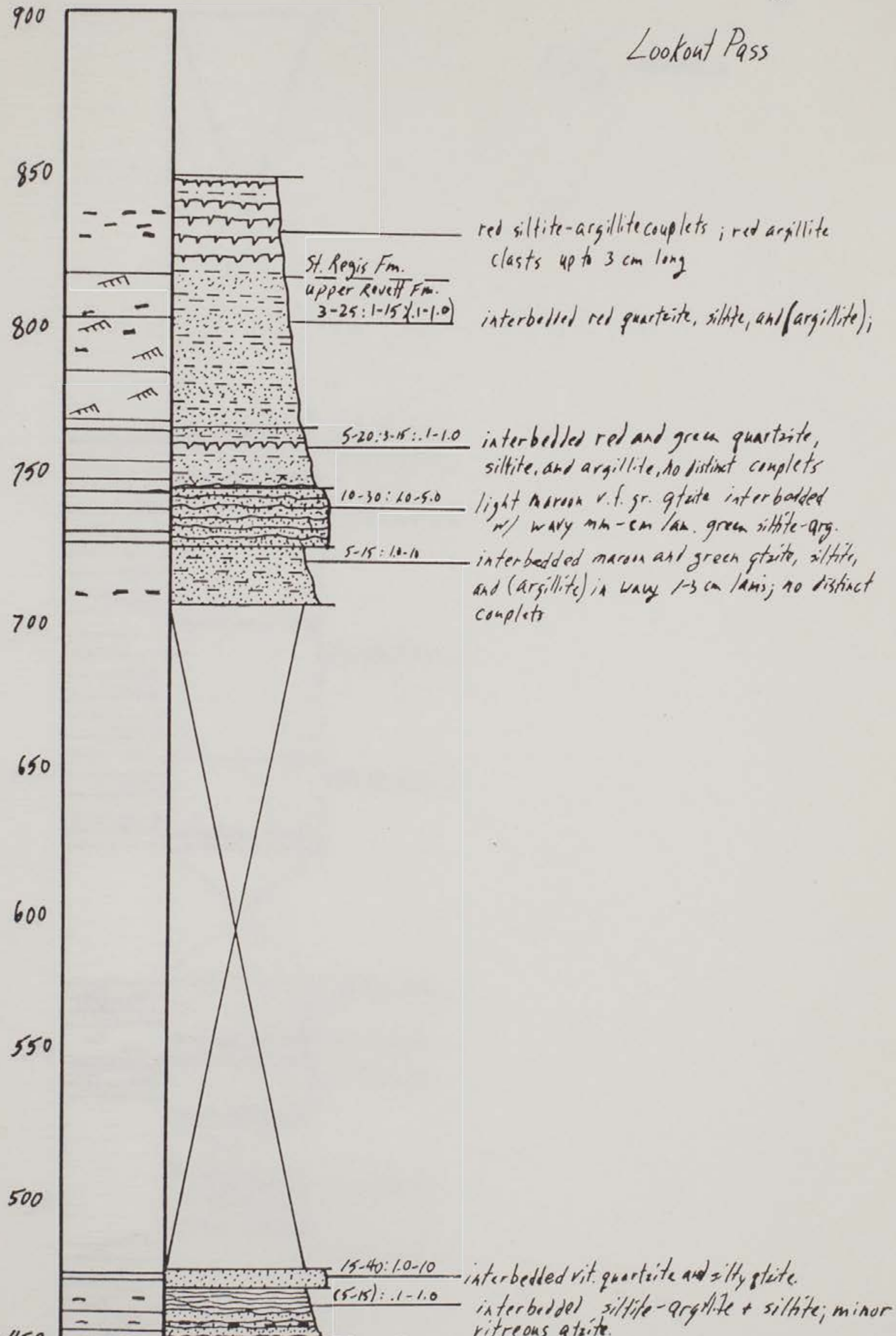


Flat Rock Creek

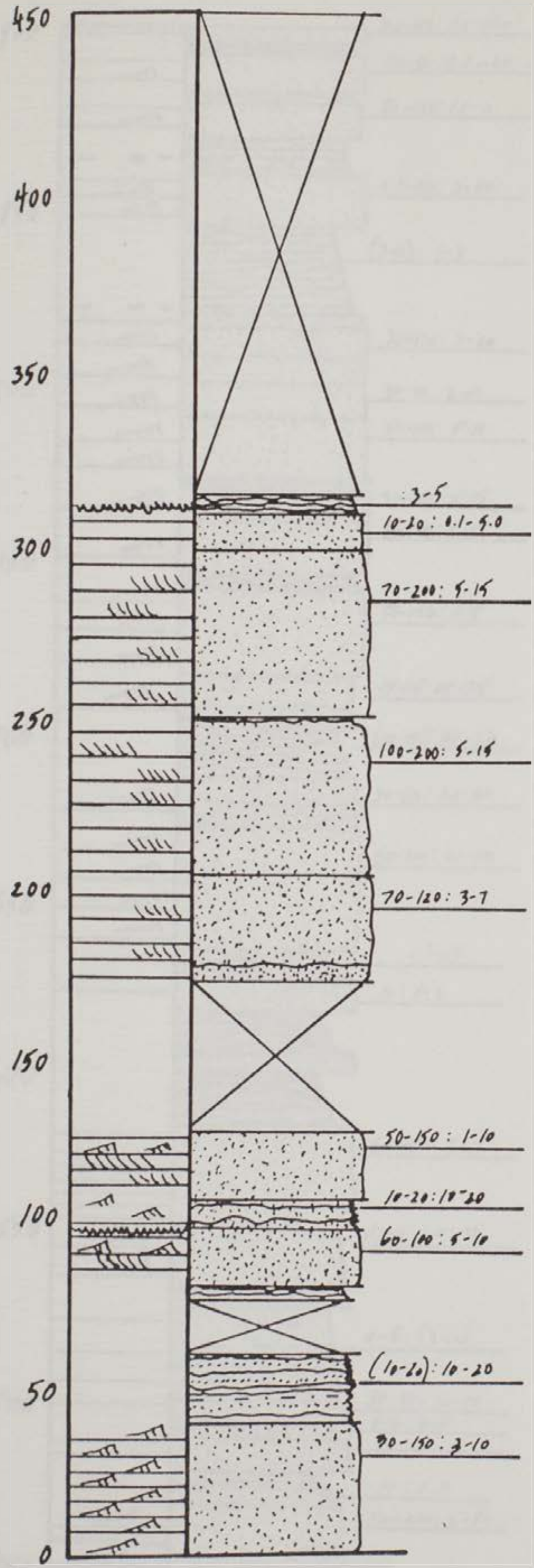



450
400
350
300
250
200
150
100
50
0
10-20 : 5-10
interbedded vitreous white quartzite and mm-cm lam. siltite-argillite
(5-10):
5-15 : 3-10
10-30: 0.1-3.0
10-25: 3-10
interbedded vitreous white quartzite and siltite-argillite
(5-15): 1.0-10
siltite-argillite; couplets and sharp alternations
5-20 : 3-10
interbedded vitreous white quartzite and siltite-argillite
(5-10):
10-30 : 3-10
interbedded quartzite and siltite-argillite
30-80: 3-10
interbedded vit. white quartzite and silty quartzite
10-30: 3-10
interbedded quartzite and silty quartzite
(5-15):
green siltite-argillite couplets
5-35: 3-10
interbedded quartzite and silty quartzite
(2-5): 0.1-3.0
siltite-argillite with minor vit. qtzite interbeds
10-30 :1.0-3.0
interbedded quartzite and silty quartzite
30-50 : 1.0-15
interbedded qtzite and silty qtzite
(10-30): 1.0-10:
interbedded siltite and siltite-argillite
15-25: 1.0-3.0:10-35
interbedded qtzite, siltite, and silty argillite
60: 1.0-3.0 : 1.0-15
interbedded qtzite, siltite, and silty argillite
5-25 : 1.0-15
interbedded siltite and siltite-argillite
30-40 : 5-10
(10-35): 1.0-3.0
interbedded silty qtzite and siltite-argillite

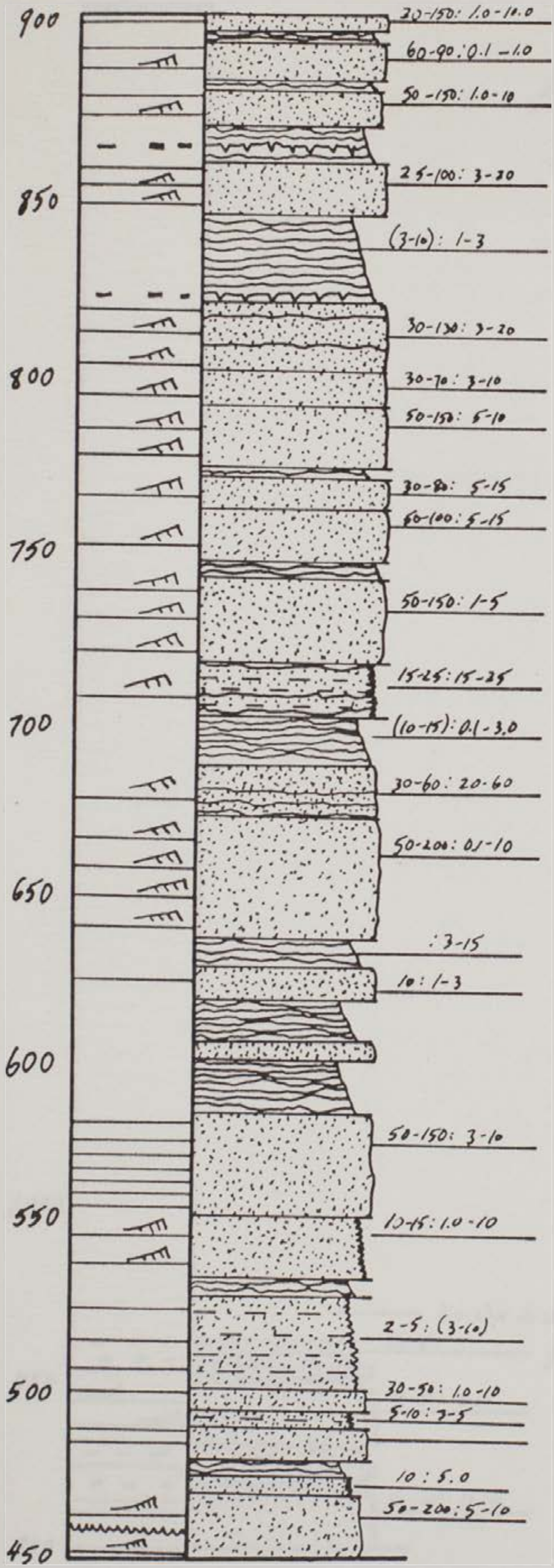
Lookout Pass



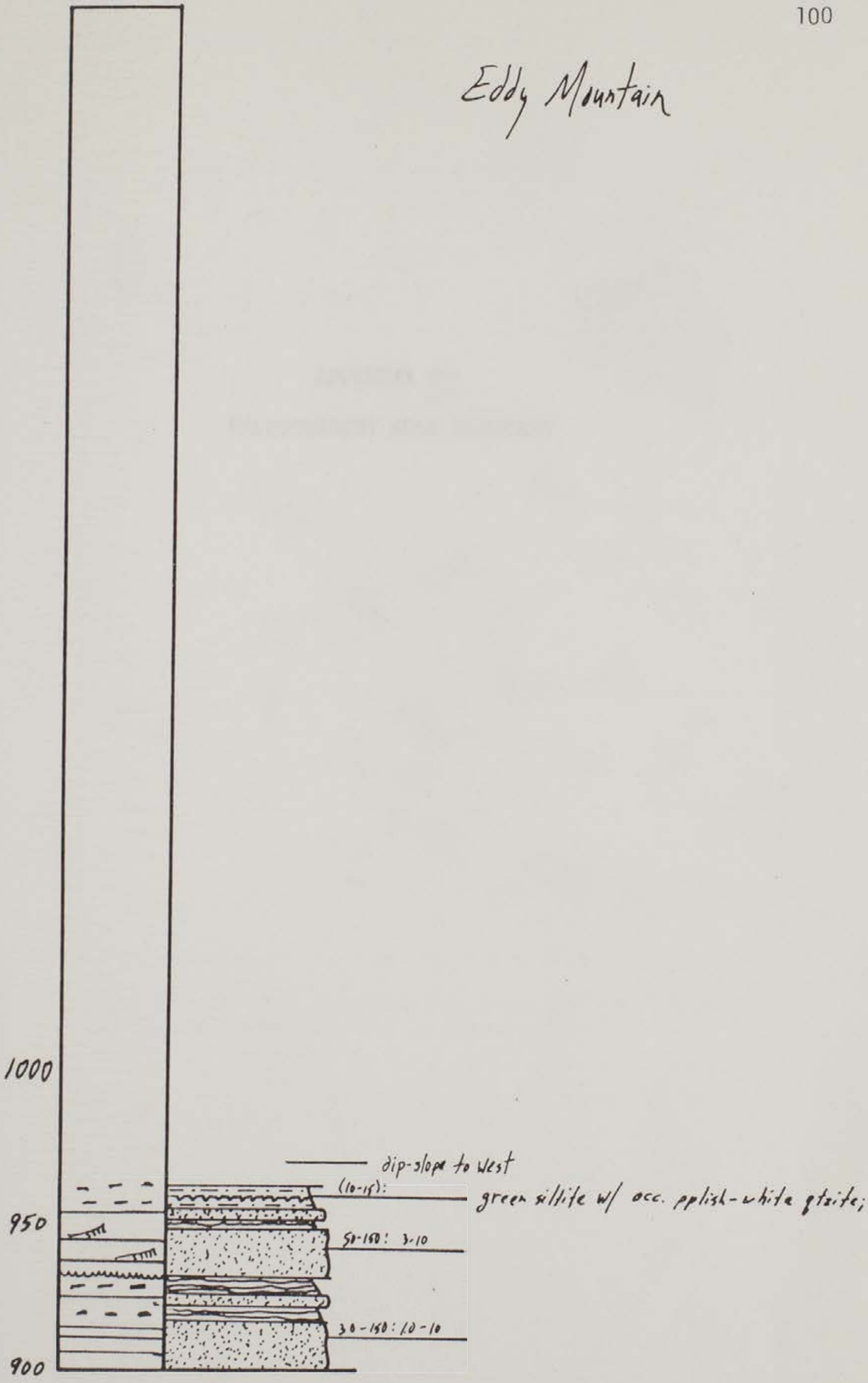
Eddy Mountain



Eddy Mountain

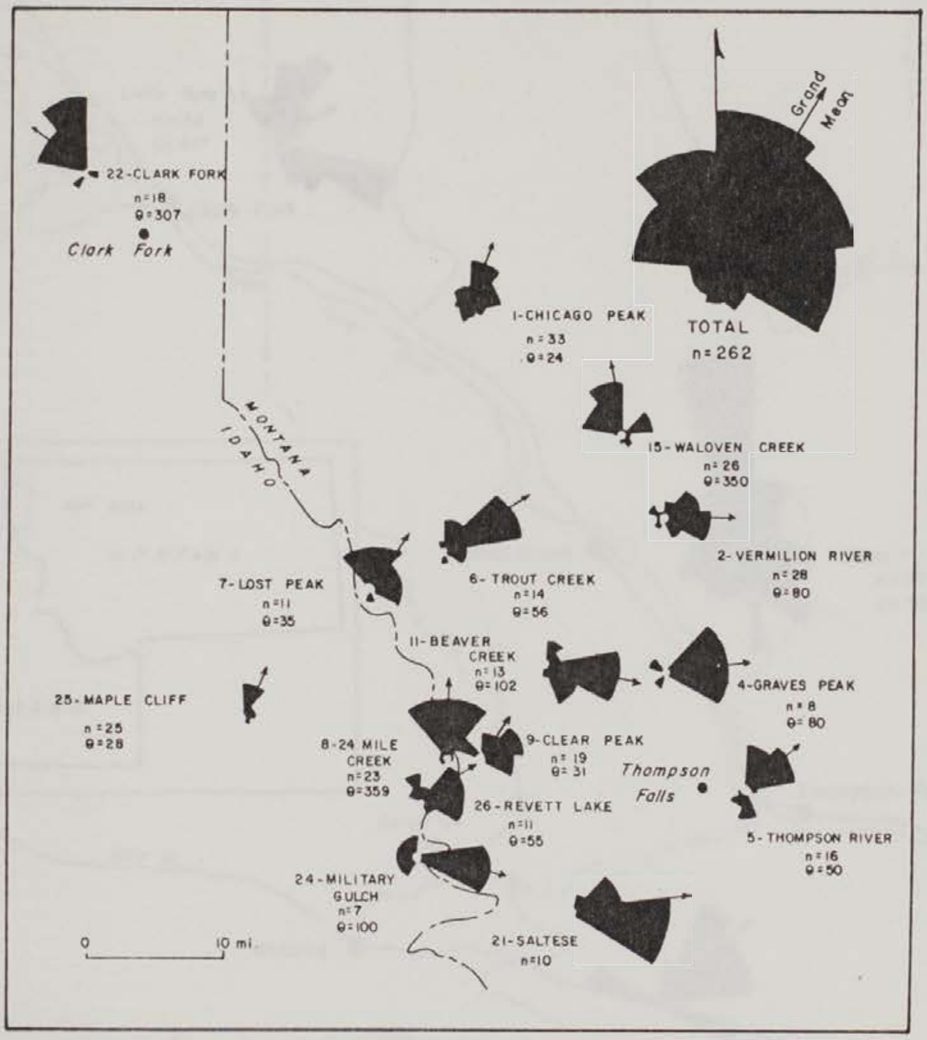


Eddy Mountain

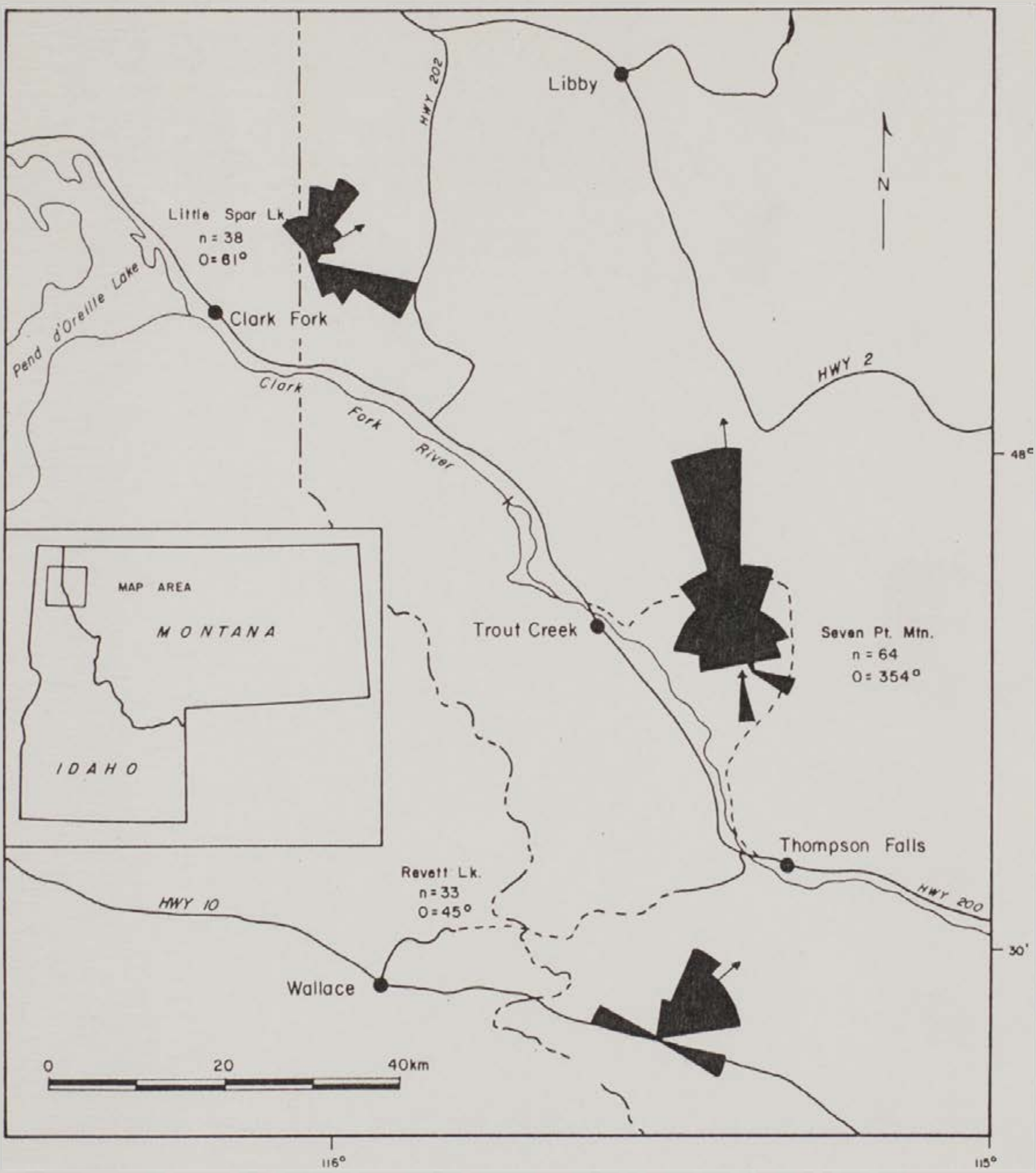


APPENDIX C

PALEOCURRENT ROSE DIAGRAMS



Paleocurrent rose diagrams for cross stratification in the Revett Formation. After Hrabar (1971).



Paleocurrent rose diagrams for cross stratification in the Revett Formation. After Bowden (1977). Revett Lakes' rose translated 30 km eastward to eliminate the effect of right-lateral movement along Osburn fault.