1983

The Proterozoic Greyson-Spokane transition sequence: A stratigraphic and gravity study west-central Montana

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THE PROTEROZOIC GREYSON-SPOKANE TRANSITION SEQUENCE: A STRATIGRAPHIC AND GRAVITY STUDY, WEST-CENTRAL MONTANA

by

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B.S., University of Delaware, 1980

Presented in partial fulfillment of the
requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1983

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

3/18/83
Date

ABSTRACT

Bloomfield, Susan L., M.S., Spring, 1983 Geology

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Director: Don Winston

Four stratigraphic sections through the Greyson-Spokane transition sequence were measured at Trout Creek and Beaver Creek, east of the Eldorado thrust and at Wolf Creek and the Spokane Hills, west of the thrust. The transition sequence consists of four sediment types: 1) wavy couplet, 2) fine sand, 3) microlaminated couplet, and 4) coarse sand sediment types.

The four sediment types combine into three lithofacies: A, B, and C. Lithofacies A consists of the microlaminated couplet interbedded with the fine sand sediment type and represents a subtidal environment. Lithofacies B consists of the wavy couplet sediment type interbedded with fine sand beds and planar cross-bedded coarse sand beds. This lithofacies indicates an intertidal environment. Lithofacies C contains upper intertidal deposits represented by the horizontally-laminated coarse sand sediment type.

The repetitive succession of Lithofacies A, B, and C reveals an overall marine regression including four regressive-transgressive cycles. The four cycles define the transition sequence and correlate well across the four measured sections.

While the measure sections straddle the Eldorado thrust, they also straddle a proposed east-west trending Proterozoic fault zone (the Greenhorn line, Winston and others, 1982 ms.). The thickness of the transition sequence increases slightly south of the Greenhorn line possibly reflecting a higher subsidence rate. The data do not strongly suggest a fault zone. However, gravity data support evidence for changes in a tectonic style of thrusting around the Greenhorn line. Uplifted crystalline basement possibly acted as a buttress north of line causing thrusts to ramp steeply. South of the line, where no buttressing existed, the thrusts were able to ride at a low angle possibly into a down-dropped block.

Dedicated to Jan and Bill Bloomfield

for undying support and love.

ACKNOWLEDGEMENTS

I would like to sincerely thank Dr.s Don Winston, Steven Sheriff, and Charles Bryan for their guidance, encouragement, and critical review of my thesis. Funding was provided through a MONTS grant courtesy of Don Winston. Special thanks also go to Dr. David Fountain for providing gravity data and additional funding. My mother and sister, Jennifer, lasted through my entire field season and were outstanding field assistants. Thanks also go to Shirley Pettersen for typing the final draft of this thesis. I would also like to thank Chris McDonald, Jeff Mauk, Paul Kuhn, Bob Burnham, Cindy Livingston, and the Green Death for their support and friendship over the last two years. Finally, special thanks go to Rick Moore for constant support and inspiration.

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CHAPTER I

INTRODUCTION

During Middle Proterozoic time, sediments of the Belt Supergroup were deposited in a basin presently located in parts of Washington, Idaho, Montana, and southern Canada (Fig. 1). Don Winston and others (1982 ms.) proposed that the Belt basin was composed of several fault-bound blocks. The Proterozoic fault-zones between the blocks are referred to as lines (Fig. 2). They base their hypothesis on: 1) stratigraphic thickness changes across the fault zones, 2) response in Cretaceous to Paleocene thrusting, and 3) response in Eocene to Recent extension. This study tests part of Winston's hypothesis by focusing on one critical area: the intersection of the Greenhorn and Townsend lines (Fig. 3). A stratigraphic and sedimentological study of the Proterozoic Greyson-Spokane transition across the Greenhorn and Townsend lines was conducted to see if growth faults were reflected in the stratigraphic sequence or sedimentary environment. In addition, I compiled structural data and available maps and analyzed published gravity data to search for evidence of the proposed Proterozoic growth faults.

Previous Work

Several workers have mapped and described the Greyson and Spokane formations near Helena, Montana (Mertie and others, 1951; Nelson, 1963; Robinson and others, 1969; Weinberg, 1970; Bregman, 1971; Shaffer, 1971;

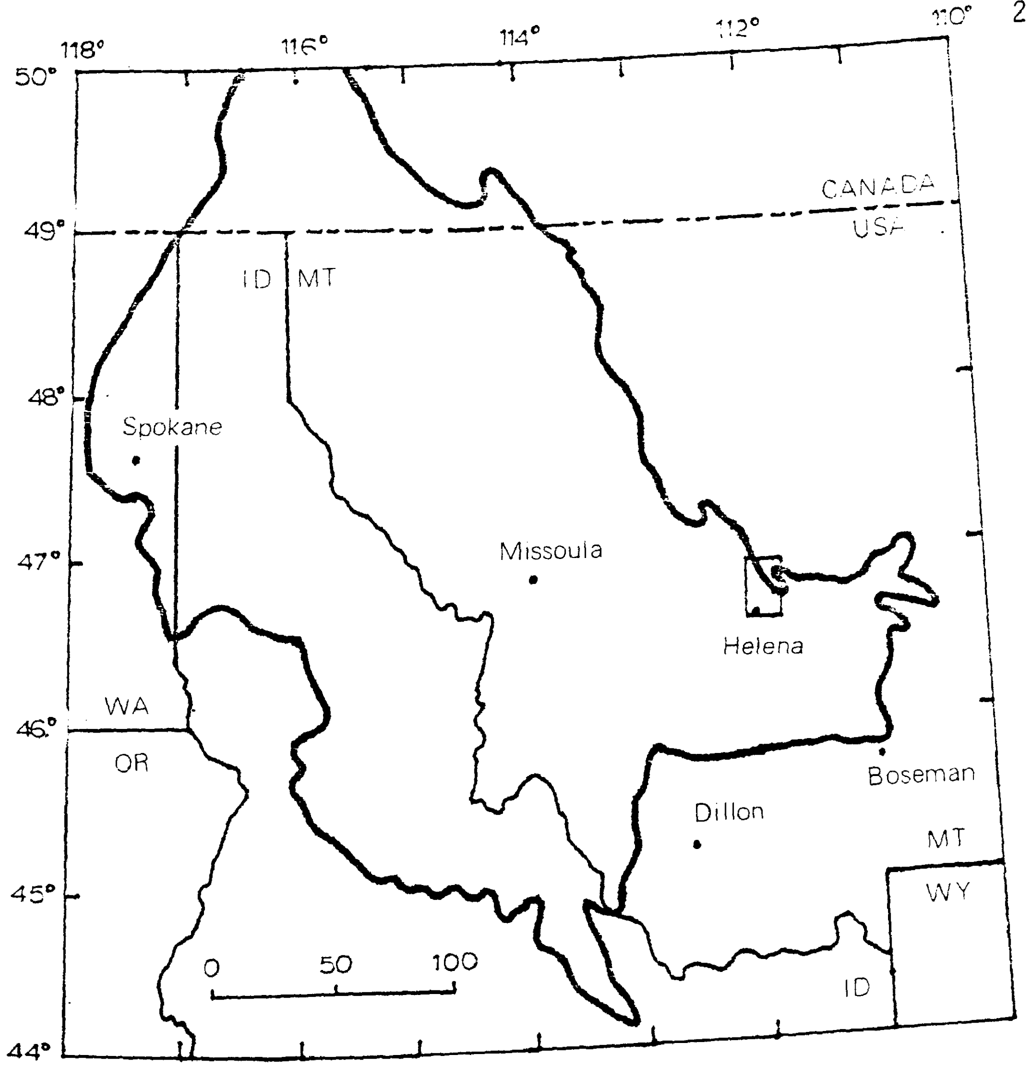


Figure 1. Map of Belt basin (after Harrison and others, 1974).

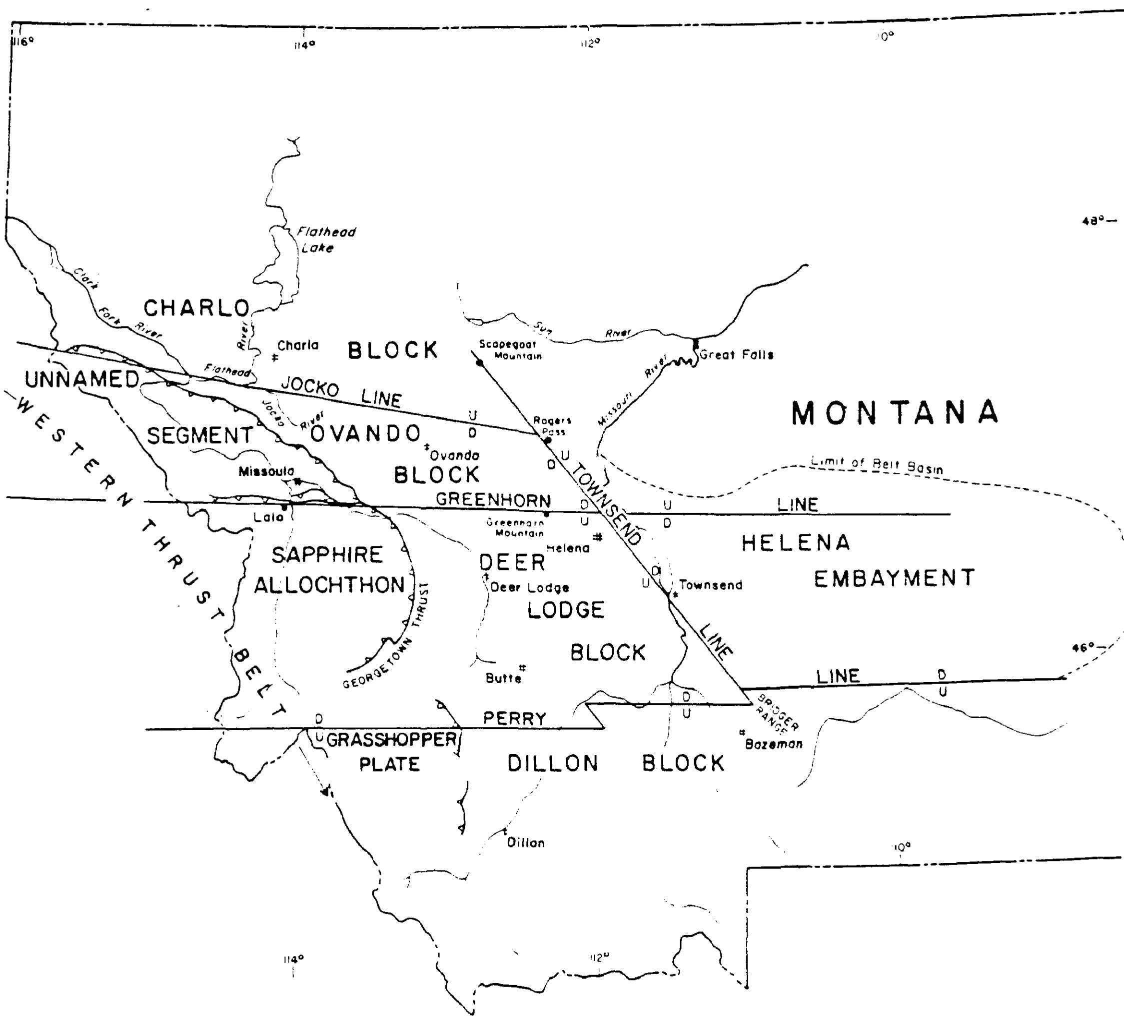


Figure 2. Map of proposed Proterozoic fault zones and crustal blocks in Montana (after Winston and others, 1982 MS).

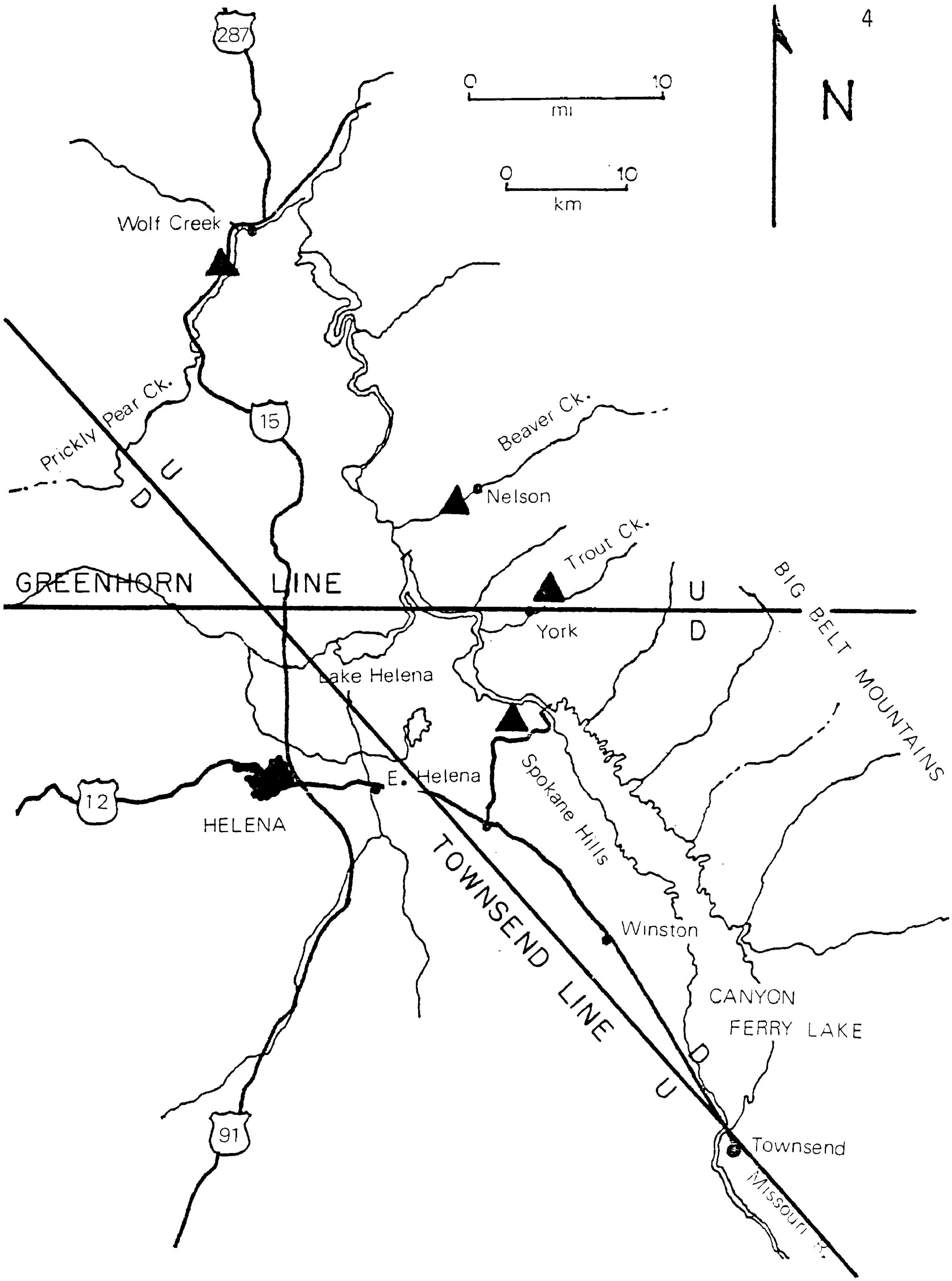


Figure 3. Map showing location of measured sections (black triangles) and orientation of Greenhorn and Townsend lines.

Durham, 1972; Schmidt, 1972; Whipple, 1980; see Fig. 4). Davis and others (1963) also conducted a gravity and aeromagnetic study of the East Helena and Canyon Ferry quadrangles. Structural studies concerned with Mesozoic and Cenozoic tectonics and their effect on the Belt terrane have also been conducted in this area (Bregman, 1976; Reynolds, 1978; Woodward, 1981).

Present Study

I measured stratigraphic sections through the Greyson-Spokane transition sequence at Trout Creek, Beaver Creek, Wolf Creek, and the Spokane Hills (Fig. 5). Exact locations are given in Appendix A. All sections were measured by Brunton compass and Jacob's staff from the brown and grey, sandy shale of the upper Greyson into red sandy silt and argillite of the lower Spokane. Data from a total of 595 meters of measured section include a graphic and written log of each section compiled at a scale of 1 inch to 5 feet (Appendix B).

The gravity data used in this study came from United States Department of Defense files and United States Geological Survey Open-file reports (Appendix C). A two dimensional modelling program provided a basis for interpreting the data (Appendix D).

Structural Setting

The locations of the four measured sections spatially bracket the Eldorado thrust, the easternmost major north-northwestern-trending thrust of the overthrust belt (Mudge, 1970). The Wolf Creek and Spokane Hills sections lie to the east of the Eldorado thrust, and the Trout

Figure 4. Index to geologic maps used in compilation of geologic map of study area. Numbers are keyed to references as follows: 1, Bregman (1971); 2, Durham (1972); 3, Davis and others (1963); 4, Knopf (1963); 5, Lyons (1944); 6, Mertie and others (1951); 7, Robinson and others (1969); 8, Shaffer (1971); 9, Weinberg (1970).

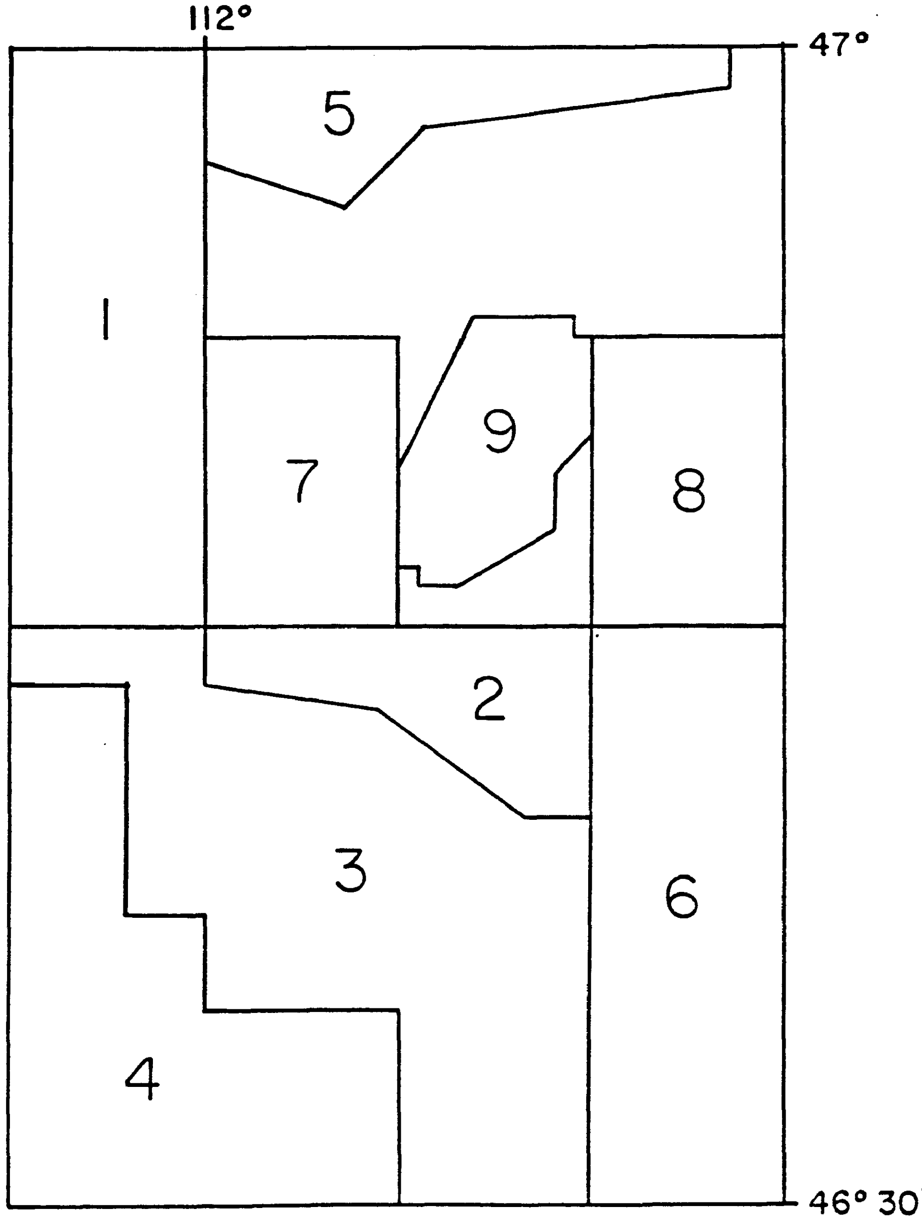


Figure 4

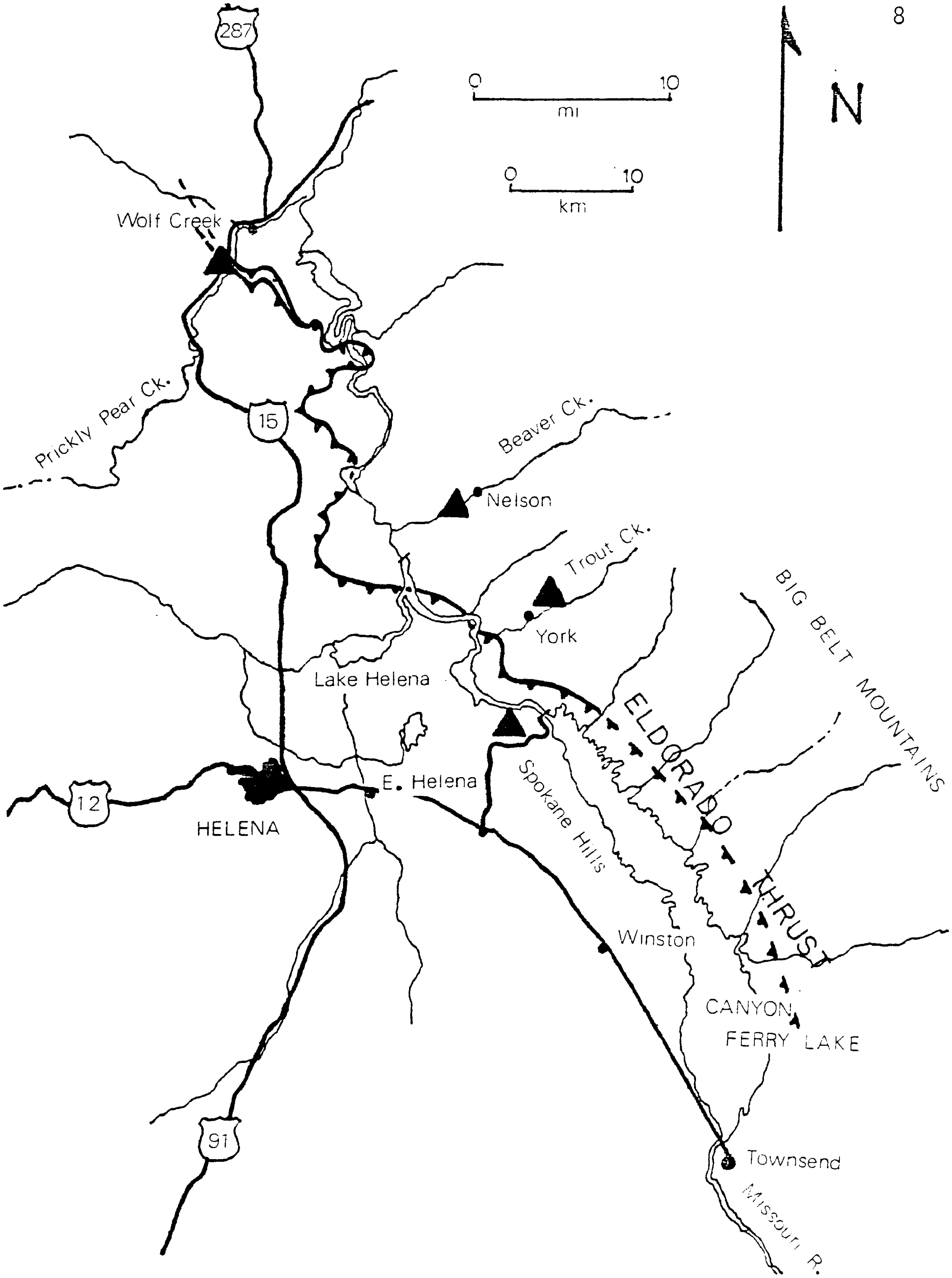


Figure 5. Map showing locations of measured sections (black triangles) in relation to Eldorado thrust fault.

Creek and Beaver Creek sections lie to the west of the thrust (Fig. 5). Bregman (1971) calculated a minimum displacement of 16.9 kilometers for the Eldorado thrust based on stratigraphic thicknesses and the geometry of the thrust. Bregman (1976) also noted a change in the configuration of the thrust along the north edge of the Helena embayment. South of the Greenhorn line the Eldorado is a low-angle thrust, whereas north of the Greenhorn line the Eldorado has ramped steeply, possibly onto a Precambrian cyrstalline buttress (Bregman, 1976; Woodward, 1981; Winston, 1982 ms.). Reynolds (1978) recognized extensional strike slip faults and listric normal which curve westward as they approach the Greenhorn line from the south.

CHAPTER II

SEDIMENT TYPES: DESCRIPTION AND INTERPRETATION

Several lithologies occur in the Greyson-Spokane transition sequence. Although these lithologies reflect original sedimentation, diagenesis and metamorphic history, they are classified chiefly on the basis of original sedimentary characteristics because diagenesis and metamorphism are of secondary importance in constructing a paleon-environmental model. Criteria such as composition, grain size, sorting, and primary sedimentary structures define the sediment types.

The Greyson-Spokane transition consists of four major sediment types. They are in order of decreasing abundance: 1) wavy couplets; 2) fine sand; 3) microlaminated couplets; and 4) coarse sand. Each sediment type is described individually and interpreted in terms of sedimentary processes and paleoenvironment.

Wavy Couplet Sediment Type

The wavy couplet sediment type consists of silty, very fine sand layers sharply overlain by mud layers (Fig. 6). Both sand and mud layers are continuous, forming wavy bedding as described by Reineck and Singh (1975). Sand layers 0.5 to 2.5 cm. thick show current and wave ripple cross-laminations. These layers thicken and thin with average wavelengths of 8 cm. and amplitudes of 2 cm.. Most ripples are symmetrical and sharp-crested but some are flat-topped or reworked into

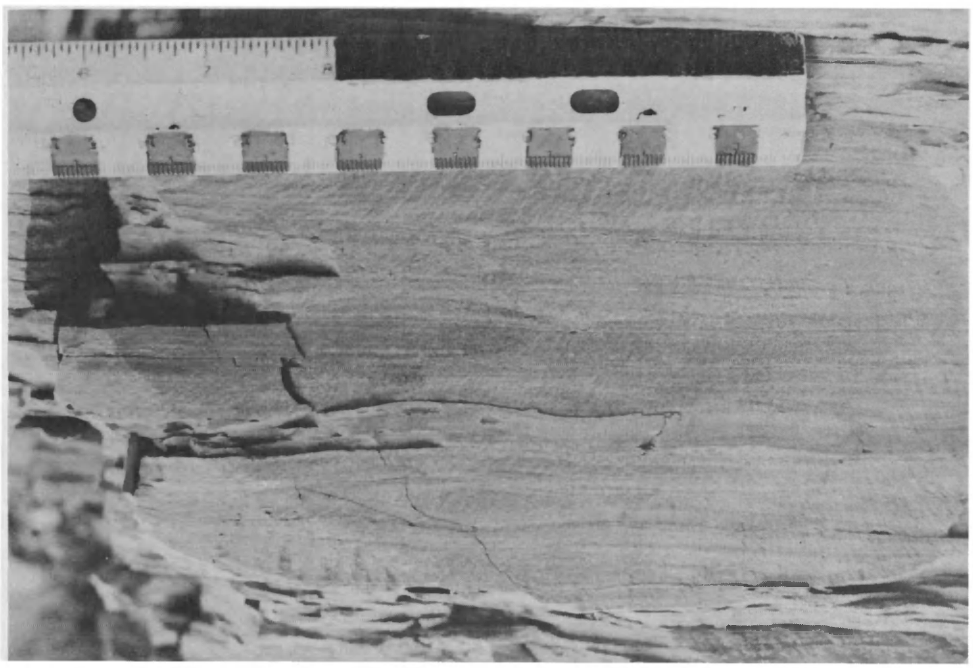


Figure 6. Wavy couplet sediment type.

interference patterns. Thin mud layers form drapes less than 1 cm. thick over the rippled sand layer beds. Together, a sand layer overlain by a mud layer constitutes a couplet which ranges from 0.5 to 3 cm. thick. Couplets cut by mudcracks commonly occur in this sediment type but in many parts of the section they are absent.

Interlamination of sand and clay forming wavy beds result from periods of traction-load transport and deposition from diurnal tidal currents alternating with periods of suspended-load deposition from standing water (Reineck and Singh, 1975). Because mud layers are preserved in wavy bedding, current velocities were probably low. Asymmetrical ripples in the sand layers result from tidal currents. During high water, symmetrical ripples formed by wave oscillation in shallow water and flat-topped ripples formed by receeding water and subsequent exposure. Finally, clay settled from suspension in standing water onto these rippled beds. Shallow mudcracks indicate brief subaerial exposure. Mudchips were probably deposited by tidal currents in the sand layers (Fig. 7).

Many workers describe similar sedimentary packages from modern tidal environments (Reineck and Singh, 1975; Reineck, 1975; Sellwood, 1975) and others have interpreted similar Proterozoic sequences as intertidal deposits (Button and Vos, 1977; Bhattacharyya and others, 1980; Watchorn, 1980; Whipple, 1980).

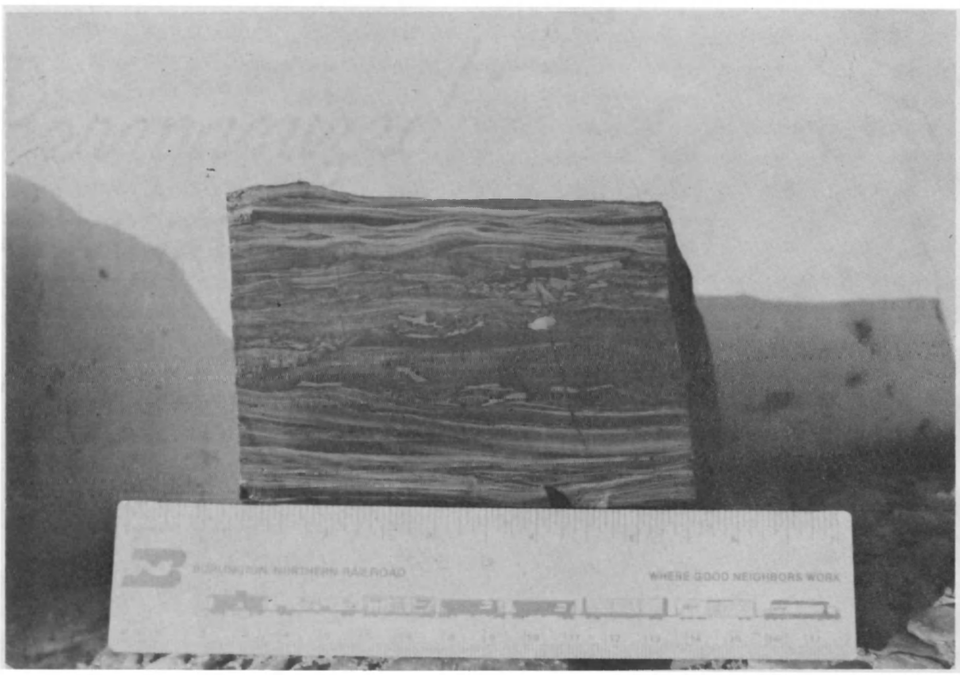


Figure 7. Mudchips in the wavy couplet sediment type.

Fine Sand Sediment Type

The fine sand sediment type consists of very fine-grained, well-sorted, quartzose sand beds which average 3 to 8 cm. in thickness. Locally they range up to 40 cm. thick. Where fine sand beds are less than 5 cm. thick, internal stratification is dominated by asymmetrical ripple cross-laminations. As in the wavy couplete sediment type, they mostly appear sharp-crested, but are locally flat-topped and reworked. Beds thicker than 5 cm. are horizontally-laminated at the base, changing to ripple cross-laminated near the top (Fig. 8). Fine sand beds capped by mud drapes are interstratified with the wavy couplet sediment type.

Horizontally-laminated sand beds form in the plane-bed phase of the upper flow regime by traction-load current sedimentation (Simons and others, 1965). Flat laminations have also been produced in a flume by migrating oscillation ripples (McBride and others, 1975). Several workers have interpreted horizontally-laminated and ripple-topped sand layers as subtidal to intertidal deposits. Button and Vos (1977) and Klein (1970) proposed shallow subtidal sand bodies or bars as a possible explanation for these types of sand beds. Some authors postulate a more landward environment, such as shoreface deposits or reworked tidal sand shoals (Bhattacharyya and others, 1980; Watchorn, 1980). Ripple-topped sand beds may also be evidence for late-stage emergence run-off in an intertidal flat (Watchorn, 1980). Fine sand beds probably formed in environments that ranged from subtidal to high intertidal. They are common throughout the section regardless of evidence for subaerial exposure in the surrounding wavy couplete sediment type.

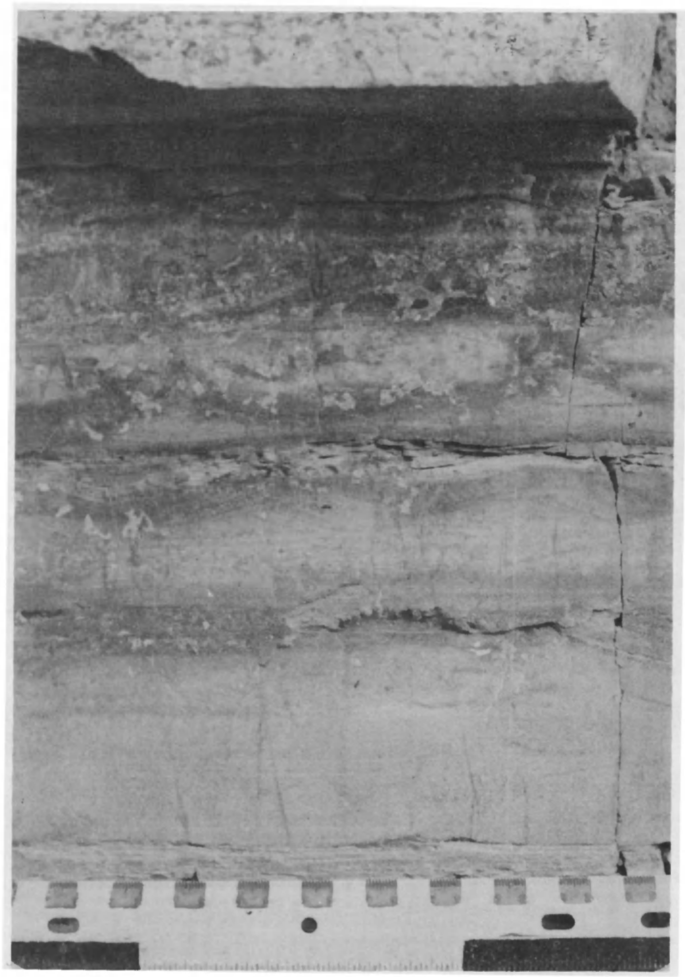


Figure 8. Fine sand bed horizontally-laminated at base, changing to current ripple cross-laminated near top.

The frequency and regularity of fine sand beds suggest that they represent fair weather processes. Whipple (1980) interprets fining-upward sequences that begin with similar fine sand beds as fluvial or sheetwash deposits in the Upper Middle Spokane. The fine sand beds of the Greyson-Spokane transition sequence probably represent fluvial or sheetwash deposits reworked by tides.

Microlaminated Couplet Sediment Type

The microlaminated couplet sediment type consists of millimeter-scale silt layers sharply overlain by mud layers of the same scale. Individual couplets are less than 5 mm. thick and are laterally continuous for several meters. Locally, silt layers pinch out or pass laterally into millimeter-scale foreset cross-laminations. Couplet thickness ranges from less than 1 to 5 mm. and composition ranges from terrigenous through carbonaceous or calcareous. Thinner, carbonaceous couplets are commonly dislocated as tabular sheets and form centimeter-scale soft sediment folds. Locally, sets of couplets are truncated by scour and fill structures (Fig. 9). These carbonaceous couplets commonly occur interstratified with dolomitic couplets, which are normally thicker and contain "molar-tooth" (Fig. 10; see O'Connor, 1972, for description of molar-tooth). Stromatolites and stromatoforms are interstratified with molar-tooth structures.

Silt layers overlain by clay layers reflect alternating current velocities, possibly from tidal currents. Variations in currents and subsequent reworking caused the laminations (Thompson, 1975). The

Figure 9. Soft-sediment deformation in carbonaceous microlaminated couplets.

Figure 10. Molar-tooth structures in calcareous microlaminated couplets.

carbon-rich couplets incorporate organic material which may represent very thin cohesive mats that required slightly higher current velocities to remove (Grotzinger, 1981). Stronger, possibly storm currents induced the soft-sediment folds and scour and fill structures in the carbonaceous couplets. Stromatolites have been recognized as both intertidal and supratidal indicators (Reineck and Singh, 1975; Button and Vos, 1977) and as subtidal indicators as well (Gebelein, 1969; Bhattacharyya and others, 1980). Stromatolites within the microlaminated couplet sediment type are probably a good indicator for the subtidal environment because they lack any evidence for subaerial exposure.

Coarse Sand Sediment Type

A. Horizontally-laminated Coarse Sand Subtype

The horizontally-laminated coarse sand subtype consists of individual, horizontally-laminated sand beds up to 80 cm. thick (Fig. 11). Grain size varies from less than 1.0Ø to 2.5Ø, with poor to good sorting. Grains probably from the coarse sand environment are scattered in the fine sand sediment type and in the sand layers of the wavy couplet sediment type. These beds are interstratified with the wavy couplet sediment type.

Horizontally-laminated beds of the coarse sand sediment type record deposition from the upper flow regime like those of the fine sand sediment type. However, this sediment subtype is less abundant and includes a wider range of grain size and sorting than the fine sand sediment type. Larger grain size and individual bed size indicate

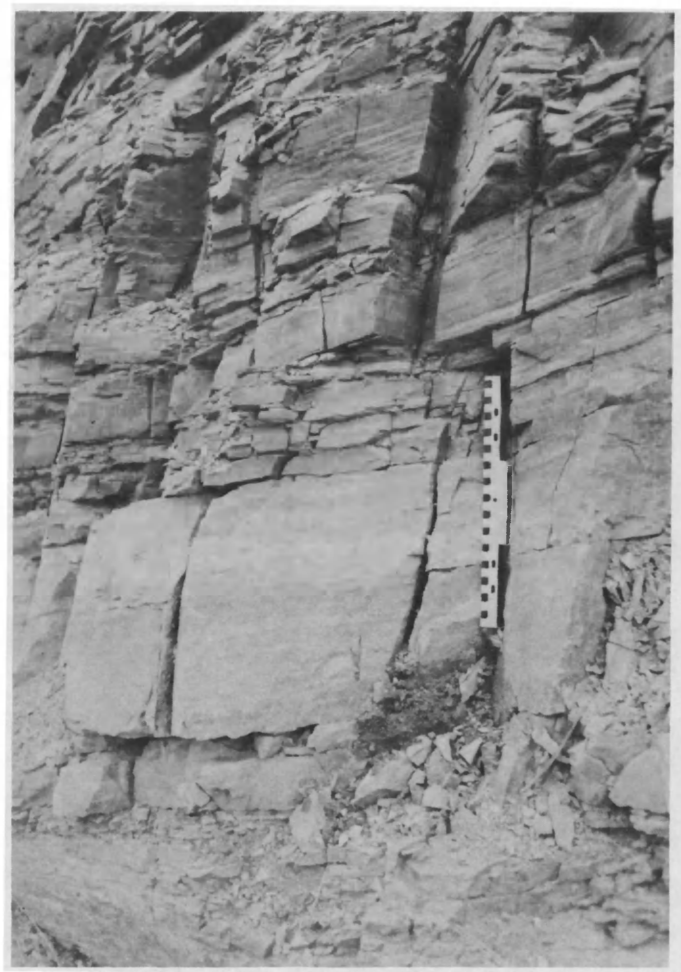


Figure 11. Horizontally-laminated coarse sand bed interbedded with the wavy couplet sediment type.

greater and more variable current velocities and perhaps a different source area, possibly reflecting transport by longshore currents (Winston, pers. comm.). Bhattacharyya and others (1980) interpreted poorly-sorted, horizontally-laminated sand beds as high intertidal storm deposits. Variations in bed size, grain size, and sorting plus association with subaerial sedimentary structures also support this hypothesis.

B. Planar Cross-bedded Coarse Sand Subtype

Planar cross-bedded sand beds form low angle tabular sets which range from 10 to 50 cm. thick (Fig. 12). Individual sets are continuous across several meters of outcrop but locally contain foreset laminations or are truncated by other low-angle cross-beds. This subtype is interbedded with the wavy couplet sediment type.

Low-angle planar cross-beds may represent upper flow regime processes in the marine foreshore. Slight deviations in beach slope between tidal cycles causes truncation of previously deposited layers and therefore produces low-angle cross-bedding that is typical of foreshore deposits (Clifton, 1969). Foresets within this subtype may represent microdelta bar deposits formed by washover fans (Schwartz, 1982).

Figure 12. Low-angle planar cross-bedded coarse sand bed interbedded with the wavy couplet sediment type.

CHAPTER III

CORRELATION AND STRATIGRAPHIC SYNTHESIS

The last chapter discussed individual sediment types and proposed some depositional environments. The vertical succession of these sediment types in the Greyson-Spokane transition sequence defines three lithofacies labelled A, B, and C. This section 1) describes specific depositional environments for each of the lithofacies based on sediment type and stratigraphic juxtaposition, 2) correlates the measured sections, and 3) discusses conclusions based on the stratigraphy and sedimentation of the Greyson-Spokane transition sequence.

Lithofacies A

Lithofacies A consists primarily of the microlaminated couplet sediment type with occasional interstratified beds of the fine sand sediment type. Parallel lamination, absence of subaerial sedimentary structures, common dolomite, and stromatolites typify this lithofacies.

The structures within this lithofacies are characteristic of subtidal deposits. Carbonaceous microlaminated couplets probably formed by algal mats and stromatolites indicate deposition in the photic zone. Therefore, the subtidal environment of this part of the Helena embayment was probably shallow. The fine sand beds within this subfacies are generally thicker and less common than those interbedded with the wavy couplet sediment type. Subtidal fine sand beds were probably deposited and reworked by longshore currents (Whipple, 1980).

Lithofacies B

Lithofacies B consists primarily of interbedded wavy couplet and fine sand sediment types. The planar cross-bedded coarse sand subtype also occurs in this lithofacies. Mudcracks and mudchips commonly occur within the wavy couplets sediment type. Wavy bedding along with desiccation structures generally indicates an intertidal flat environment. Horizontally-laminated fine sand beds represent reworked, lower intertidal sand shoals. Planar cross-bedded coarse sand beds represent beach deposits also in a lower intertidal environment.

Lithofacies C

Lithofacies C consists of the horizontally-laminated coarse sand sediment subtype. This lithofacies occurs interstratified with the wavy couplet sediment type and is interpreted as an upper intertidal deposit. Whipple (1980) interpreted similar deposits in the Upper Spokane formation as beach berm deposits. Bhattacharyya and others (1980) interpreted horizontally-laminated coarse sand beds to be storm deposits which resulted from more intense wave action and turbulence.

Correlation

Each measured section has been subdivided into sequences of Lithofacies A, B and C. Correlation based on the succession of lithofacies reveals four marine regressive-transgressive cycles. Each cycle comprises an upward succession of Lithofacies ABCB (Fig. 13).

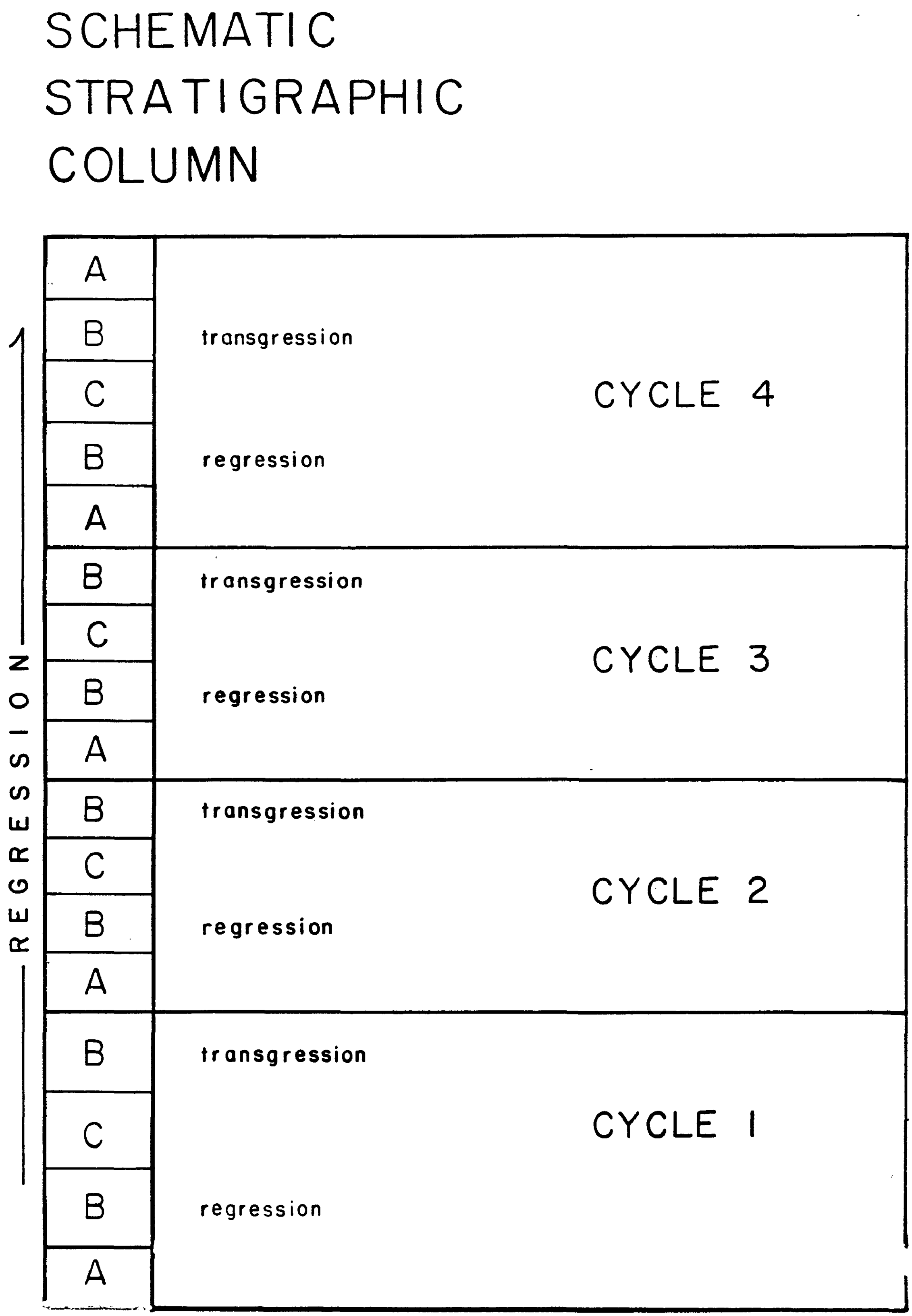


Figure 13. Schematic stratigraphic column showing four regressive-transgressive cycles.

The four cycles form the transition sequence and each cycle correlates well throughout all four measured sections (Fig. 14). Sections at Wolf Creek, Trout Creek, and Beaver Creek are approximately 100 meters thick while the Spokane Hills section is 220 meters thick.

Stratigraphic Synthesis

The Greyson-Spokane transition sequence represents a regressive sequence in a tide-dominated environment. However, it does not fit the "classic" tidal sequence because: 1) it lacks tidal channel deposits, and 2) lack of documented bimodal-bipolar current directions.

Several workers have interpreted Precambrian sequences (Klein, 1970a; Siedlecka, 1978) and Paleozoic sequences (Barnes and Klein, 1975; Walker and Harms, 1975) which lack evidence for tidal channels as tidal deposits. Several conditions might explain the absence of tidal channels. In a predominantly fine-grained system, a large volume of silt and clay that overwhelms sand may diminish development of beaches and shoals. Therefore, unrestricted tidal currents move over the flats in broad, uniform flow with little tendency to form channels. Lack of vegetation in the Proterozoic and the subsequent lack of a cohesive framework binding the surface of the tidal flat also enabled tidal currents to flow uniformly over the flat.

Sedimentary structures and bed configuration in the Greyson-Spokane transition sequence suggest an environment with low hydraulic energy. Extensive lateral continuity of individual beds suggest a broad, flat, featureless tidal flat and shelf. Nearshore wave intensity

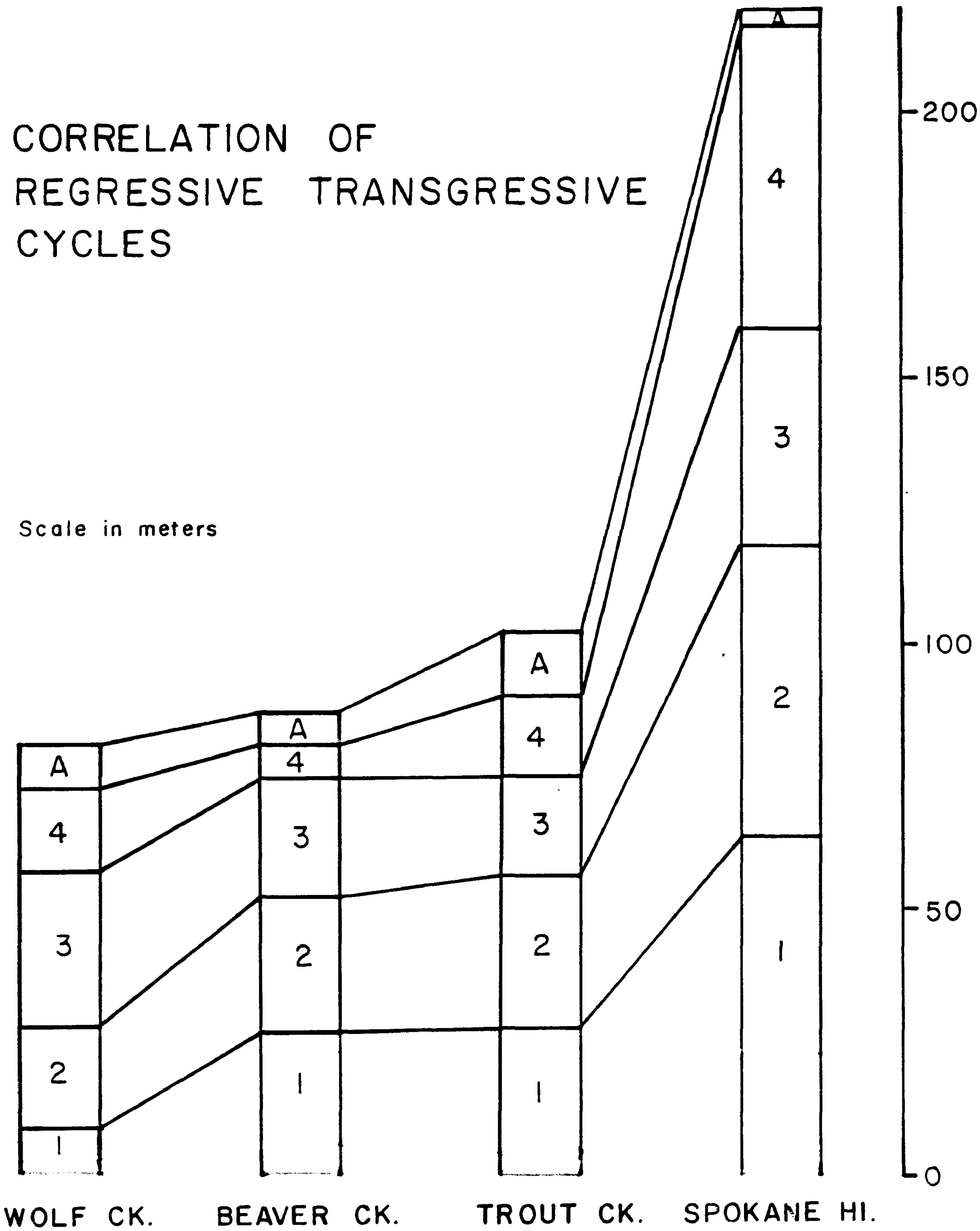


Figure 14. Correlation across four measured sections based on succession of lithofacies A, B, C, and D.

was probably generated by local winds rather than the wind fetch across the entire Belt sea. Because of the very large, shallow shelf, waves generated further out in deeper water "felt bottom" and lost energy as they travelled to shore. Additional evidence for low energy includes: 1) suspension-deposited silt and clay in the subtidal and intertidal zones rather than cross-bedded sands of more turbulent systems, and 2) preserved clay in wavy bedding rather than flaser bedding in the current-formed deposits.

Only apparent current directions were observed at the measured sections, therefore bimodal-bipolar current directions could not be documented. Although bimodal-bipolar current directions provide strong evidence for tidal currents, not all tidal deposits are bipolar. Time-velocity asymmetry produces unimodal crossbed directions in some tidal regimes (Klein, 1971; Watchorn, 1980). Therefore, even though tidal channels and bimodal-bipolar current directions are not documented in the Greyson-Spokane transition zone, a tidal flat interpretation is still possible.

Very fine sand, silt, and clay dominate the Greyson-Spokane transition zone. In the upper middle Spokane Formation, Whipple (1980) interprets horizontally-laminated subfeldspathic arenites as delta sheetwash and braided alluvial deposits surrounded by tidal flat deposits. The fluvial sediment input certainly affected sedimentation in the Spokane Formation. However, fine sand beds in the Greyson-Spokane transition sequence never occur in sets and never appear to be channel deposits. They probably represent totally reworked sediments of a tidal environment whereas higher in the Spokane, they may represent primary fluvial deposits. The coarse sand size in the beach and storm deposits may indicate a different source with transport by longshore currents.

CHAPTER IV

GRAVITY ANALYSIS

The purpose of a gravity analysis of the study area was to look for more evidence for the proposed Proterozoic fault zones. Ideally, blocks of crystalline basement vertically offset near the fault zones would cause lateral changes in density and produce gentle, low frequency gravity trends. High frequency anomalies result from shallower sources. This study examines regional trends, anomalous residual features, and discusses interpretation of these features with respect to the proposed fault zones.

Gravity data were obtained from the U.S. Department of Defense. I hand-contoured Bouguer anomaly values at 5 milligal intervals over the study area and used a computer program to model a gravity profile over the area. Density contrasts are based on values published by Davis and others (1963) and Harrison and others (1980).

A generalized geologic map and Bouguer gravity map are shown in Figures 15 and 16. Major structural features include: 1) the Eldorado and related thrusts (York, Trout Creek, and Wolf Creek thrusts), 2) the exposed Paleozoic rocks north and east of the Scout Camp thrust, 3) the Helena and Townsend Valleys, and 4) the Boulder batholith and other Cretaceous intrusives.

The limited availability of gravity data beyond the study area made it difficult to discern a regional trend. Ballard (1980)

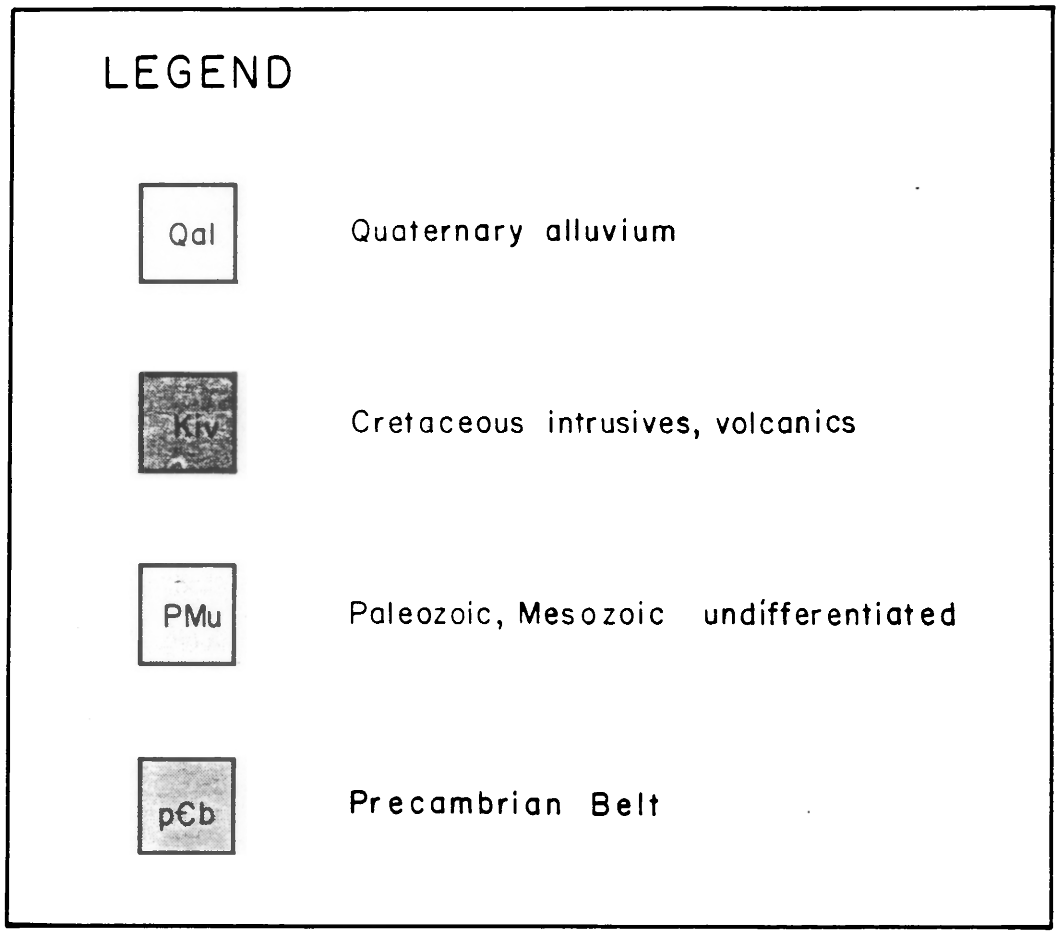
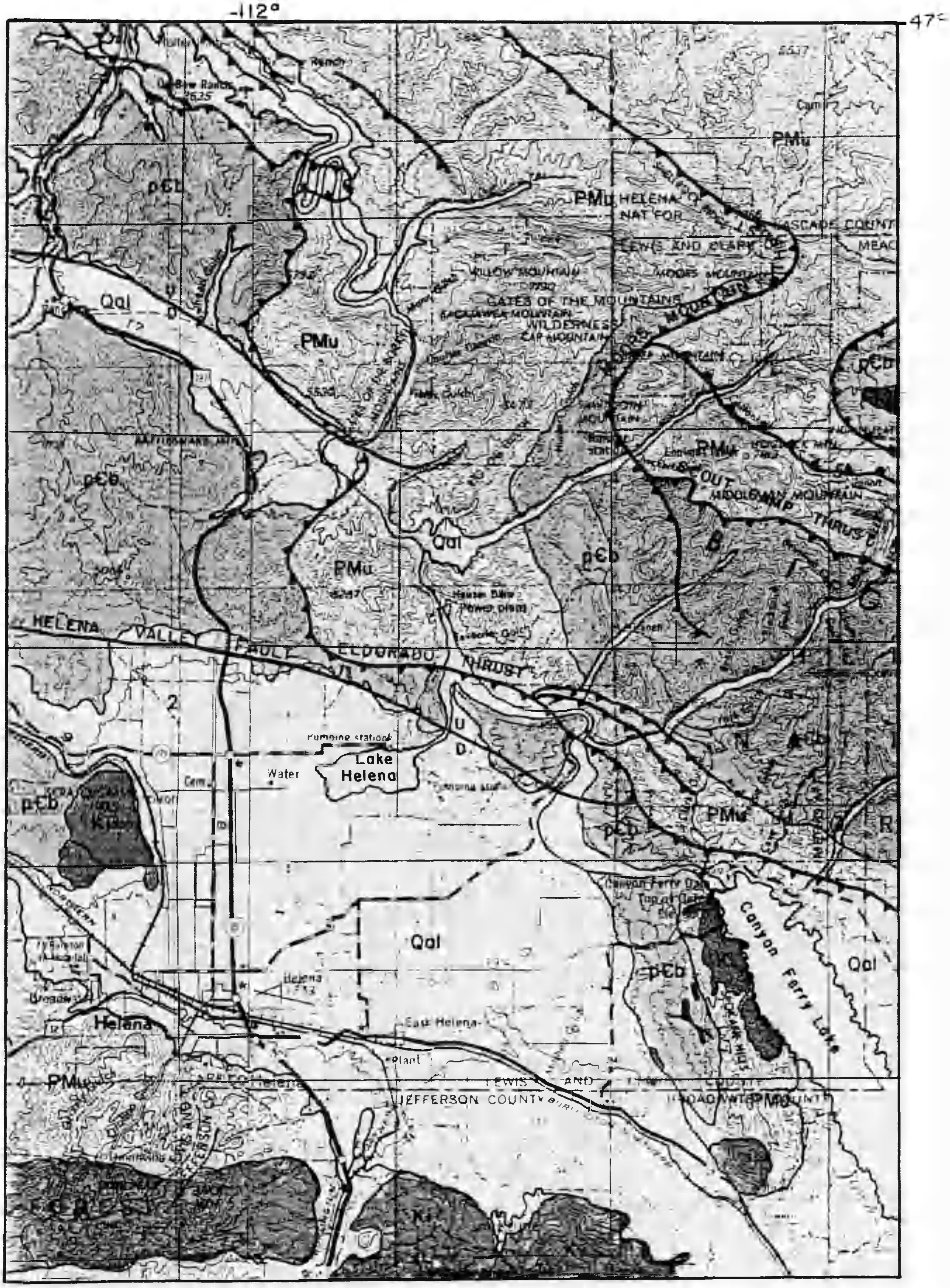


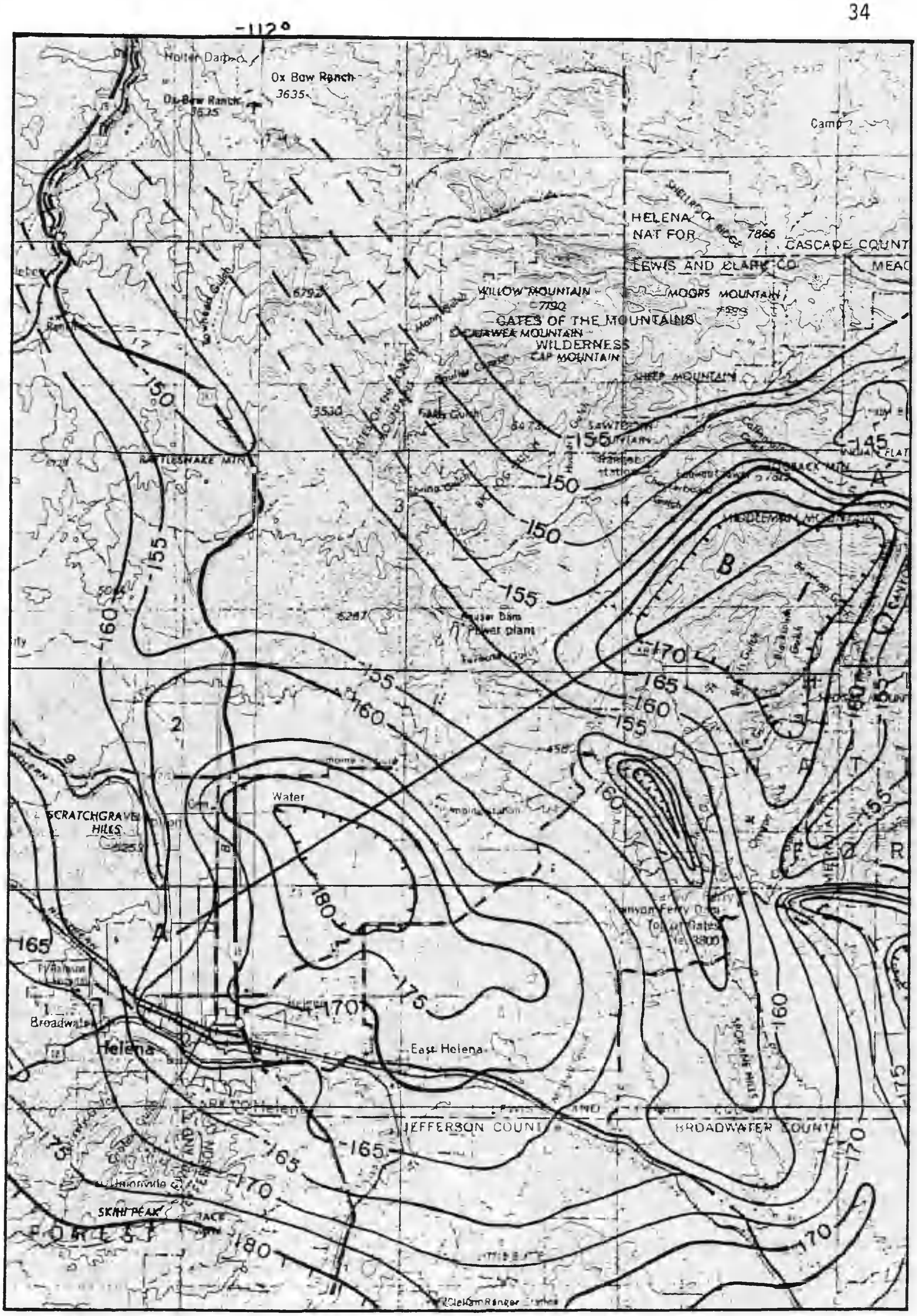
Figure 15. Generalized geologic map of the study area. See figure 4 for compilation index.



-112°
47°
PMu
pCb
Qal
HELENA VALLEY FAULT
ELDORADO THRUST
Lake Helena
Helena
East Helena
Canyon Ferry Lake
JEFFERSON COUNTY
GATES OF THE MOUNTAINS
WILDERNESS
Ki

Figure 15.

Figure 16. Bouguer gravity map of the study area. Contours at 5 mgal. Cross-section in figure 17 from A to A'.



-112°
47°
Holter Dam
Ox Bow Ranch
3635
HELENA
NAT FOR
7866
CASCADE COUNT
LEWIS AND CLARK CO
WILLOW MOUNTAIN
7190
MOORS MOUNTAIN
GATES OF THE MOUNTAINS
WILDERNESS
CAP MOUNTAIN
SHEEP MOUNTAIN
RATTLESNAKE MTN
Hauser Dam
Power plant
SCRATCHGRAVEL
HILLS
Water
East Helena
Helena
Broadwater
JEFFERSON COUNTY
BROADWATER COUNTY
SKIHI PEAK
A
B
145
150
155
160
165
170
175
180

Figure 16

determined the regional trend near Helena to be a southwest-dipping plane which varies no more than 5 milligals through the study area. Therefore, regional gravity was ignored because of its negligible effect over the study area.

The higher frequency anomalies are well correlated with local geology. The Eldorado and related thrusts are reflected by a relatively high ridge which follows the thrust's north-northwesterly trend. Gravity lows with amplitudes of 20 to 25 milligals coincide with the Helena and Townsend Valleys and their low density fill (about 2.4 g/cm3). The Boulder batholith and satellite quartz monzonite intrusives also show up as gravity lows because of their negative density contrast with Belt rocks. Belt rocks generally coincide with higher gravity readings than the Paleozoic rocks so that the gravity low situated just south and west of the Scout Camp thrust and east of the Eldorado thrust requires further explanation.

Figure 17 shows the observed gravity and calculated anomalies from A to A' on Figure 16, a subsurface structure map and assumed density contrasts. In the cross-section, the gravity low over the Helena Valley is best modelled using a -0.4 g/cm3 density contrast with surrounding Belt rocks. Using this model, basin fill approximates 2000 meters thick, in good agreement with values of 1800 meters obtained by Davis and others (1963). The gravity high to the east of Helena Valley may be explained by Belt rocks ramped over Belt rocks. Belt rocks also crop out immediately east of the York and associated thrusts, although the gravity is anomalously low. Further to the

GRAVITY PROFILE ACROSS A – A′

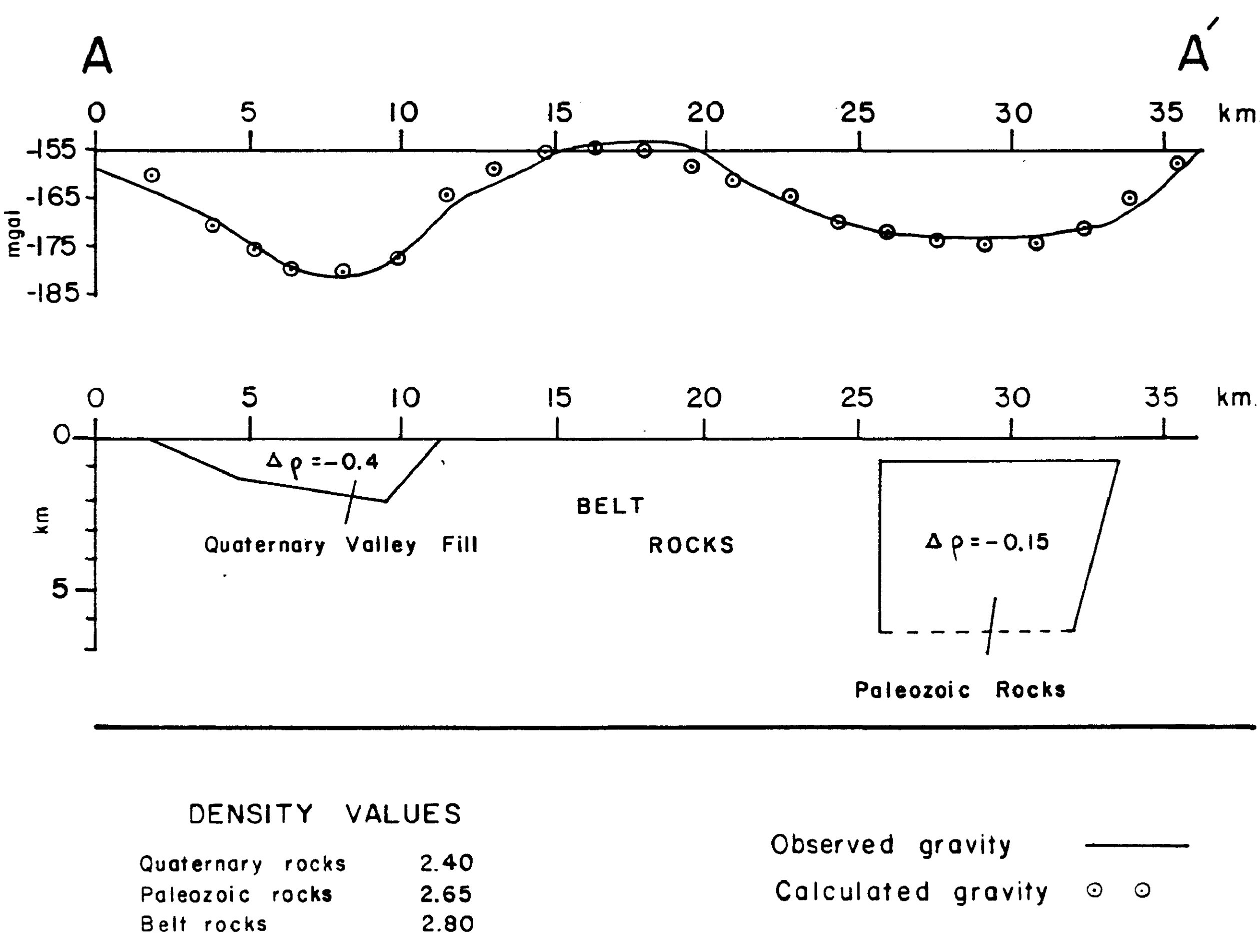


Figure 17. Observed and calculated gravity anomalies from A to A' with model and densities used given below.

east, Paleozoic rocks are exposed along the Scout Camp thrust, and generally cover the northeastern corner of the study area. The anomalous gravity low over the Belt rocks south of the Scout Camp thrust may best be explained by Belt rocks thrust over Paleozoic rocks. A gravity model which places a lower density slab beneath Belt rocks in between the Eldorado and Scout Camp thrusts adequately accounts for the observed gravity low. As shown in Figure 17, the low density slab is flat-lying and near the surface.

The high frequency gravity data of this study are well explained by near surface geology, such as basin fill, intrusive stocks, and major thrust faults. Crystalline basement can not be delineated because the maximum anomaly expected over the uplifted basement block would be 10 to 12 milligals (using +0.1 g/cm3 density contrast at 2400 meters depth). Near surface structures produce anomalies with amplitudes of 20 to 25 milligals which might mask lower amplitude anomalies. However, it is reasonable to discuss the possible control of near surface structures by deeper structures. Several workers note changes in tectonic style around the area marked by the intersection of Winston's (1982 ms.) Greenhorn and Townsend lines.

Major thrusts within the Helena embayment steepen and curve westward as they approach the Greenhorn line (Reynolds, 1978) and pass into left-lateral strike slip faults north of the line (Birkholtz, 1967; Bregman, 1976; Woodward, 1981; Fig. 18). The Eldorado thrust also shifts westward north of the Greenhorn line. Bregman (1971, 1976) noticed that the thrust changed from high-angle imbricate slices north of the Helena embayment to a single, low-angle slab near the Greenhorn line. He concluded that the imbricate thrusts north of the line resulted from buttressing by the crystalline basement. South of the line, where no similar buttressing exists, the thrust was able to ride at a low angle into the Helena embayment (Fig. 18). The most significant finding of this gravity study supports the hypothesis of low-angle, single sheet thrusting in the Helena embayment. Presumably, Belt rocks moved over nearly flat-lying Paleozoic rocks as a single sheet without the buttressing effect from a crystalline basement block.

The gravity part of this study did not prompt any new conclusions about crustal or near surface structure. Also in part, because of limited data outside the study area, there are no indications of "deep" basement offsets in the data. However, they do suggest a change in the tectonic style of the eastern thrust belt near Helena, which might represent a change in deeper crustal configuration.

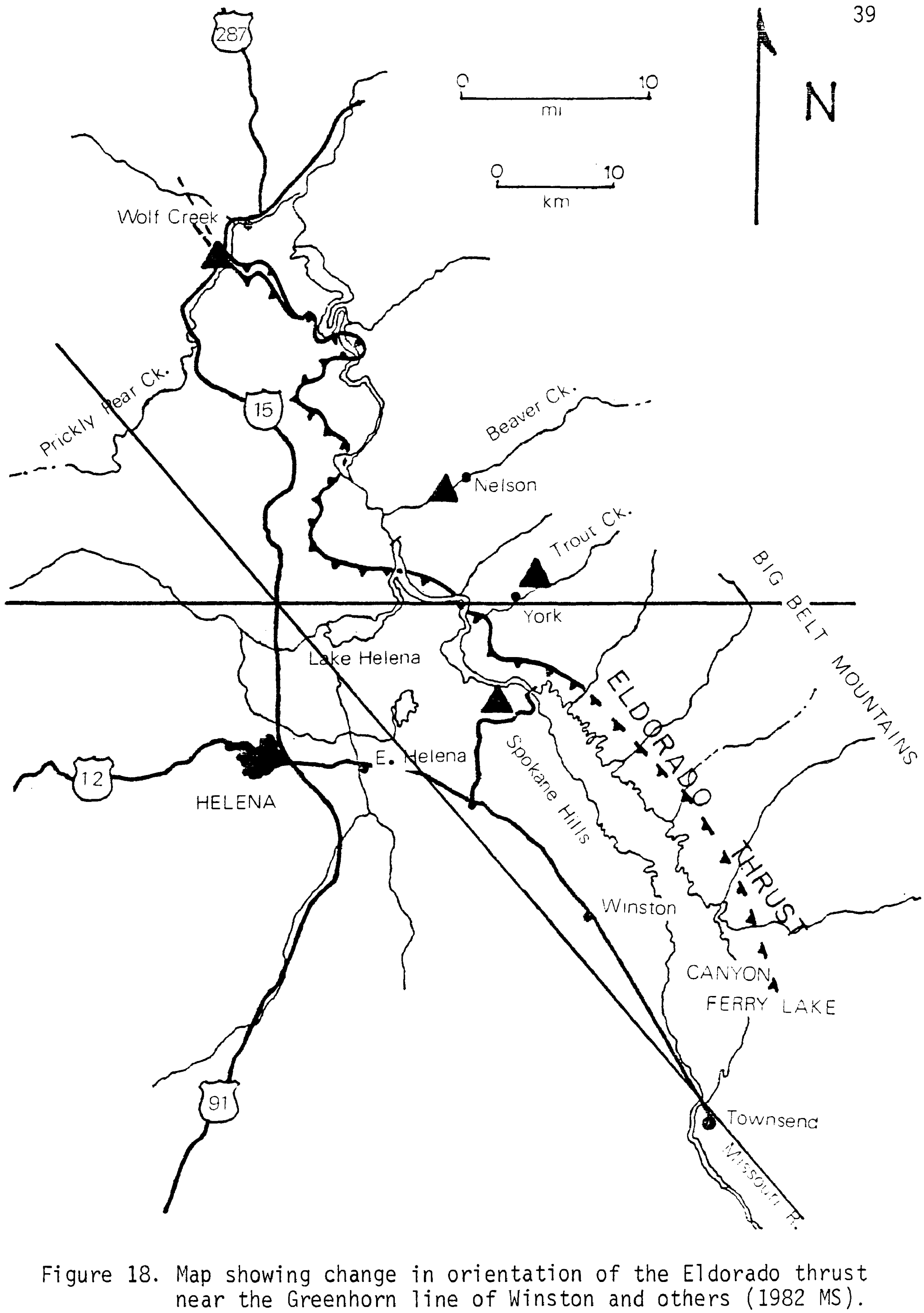


Figure 18. Map showing change in orientation of the Eldorado thrust near the Greenhorn line of Winston and others (1982 MS).

CHAPTER V

CONCLUSIONS

The stratigraphy and sedimentary structures of the Greyson-Spokane transition sequence reflect sedimentation in the intertidal to subtidal zone of a shallow, flat shelf. Rocks in the transition sequence record an overall marine regression including four regressive-transgressive cycles. The four cycles define the transition sequence and are well correlated across the four measured sections. The occurrence of both horizontally-laminated fine sand beds and horizontally-laminated coarse sand beds suggests two source areas. Sheet-wash and fluvial deposits which occur in the Upper Middle Spokane Formation (Whipple, 1980) probably represent the source for the abundant fine sand fraction. Variation in sediment input from this source may explain changes in the proportion of fine sand to silt and clay size material throughout the Greyson-Spokane transition sequence. Coarse sand, possibly reflecting a different source, may have been brought in by longshore currents.

Gravity data in the area encompassing the measured sections generally reflect near surface geology and structure. An anomalous gravity low over Belt rocks on the upper plate of the Scout Camp thrust may be modelled by placing a thin slab of Belt rocks over a nearly horizontal block of lower density, Paleozoic rocks. These results suggest that the Scout Camp thrust is a low-angle, single sheet thrust, and agree with Bregman's (1971, 1976) conclusions about the Eldorado thrust to the west.

Evidence for Proterozoic fault zones from the data in this thesis is similar to data used by Winston and others (1982 ms.). Their primary evidence consists of stratigraphic thickness changes and differential thrusting response across their proposed lines. North of the Greenhorn line and east of the Townsend line, the Greyson-Spokane transition sequence is approximately 100 meters thick. South of the Greenhorn line, in the Helena embayment, the sequence is 220 meters thick. Since the measured sections are located on two different thrust plates, only sections on the same plate may be correlated with known distance between them. Some reconstruction is necessary to compare sections across the Eldorado thrust. Several estimates of shortening from the Idaho-Wyoming and Canadian thrust belts fall very close to 50 percent (Royce and others, 1975). The Trout Creek (120 meters) and Spokane Hills (240 meters) sections lie on opposite sides of the Eldorado thrust approximately 10 kilometers apart. Using the 50 percent shortening value, the minimum distance between two sections which straddle the Greenhorn line increases to 20 kilometers. This displacement value agrees fairly well with Bregman's (1971) estimate of 16.9 kilometers. A slight thickness change south of the Greenhorn line may suggest a higher rate of subsidence however, evidence for faulting seems weak.

An additional conclusion drawn from this study is the suggestion for a mappable contact between the Greyson and Spokane Formation.

Previous workers used the first appearance of red color in the rocks for the contact (Mertie and others, 1951; Durham, 1972). The lowest red beds vary in stratigraphic level from section to section in the transition sequence. A change in primary sedimentary features rather than secondary diagenetic features would be more clearly definable and consistent. For this reason, I propose that the contact be drawn at the top of the last calcareous microlaminated couplet sequence. This would reduce the confusion caused by the irregular diagenetic red and green coloration of the rocks in the Greyson-Spokane transition sequence.

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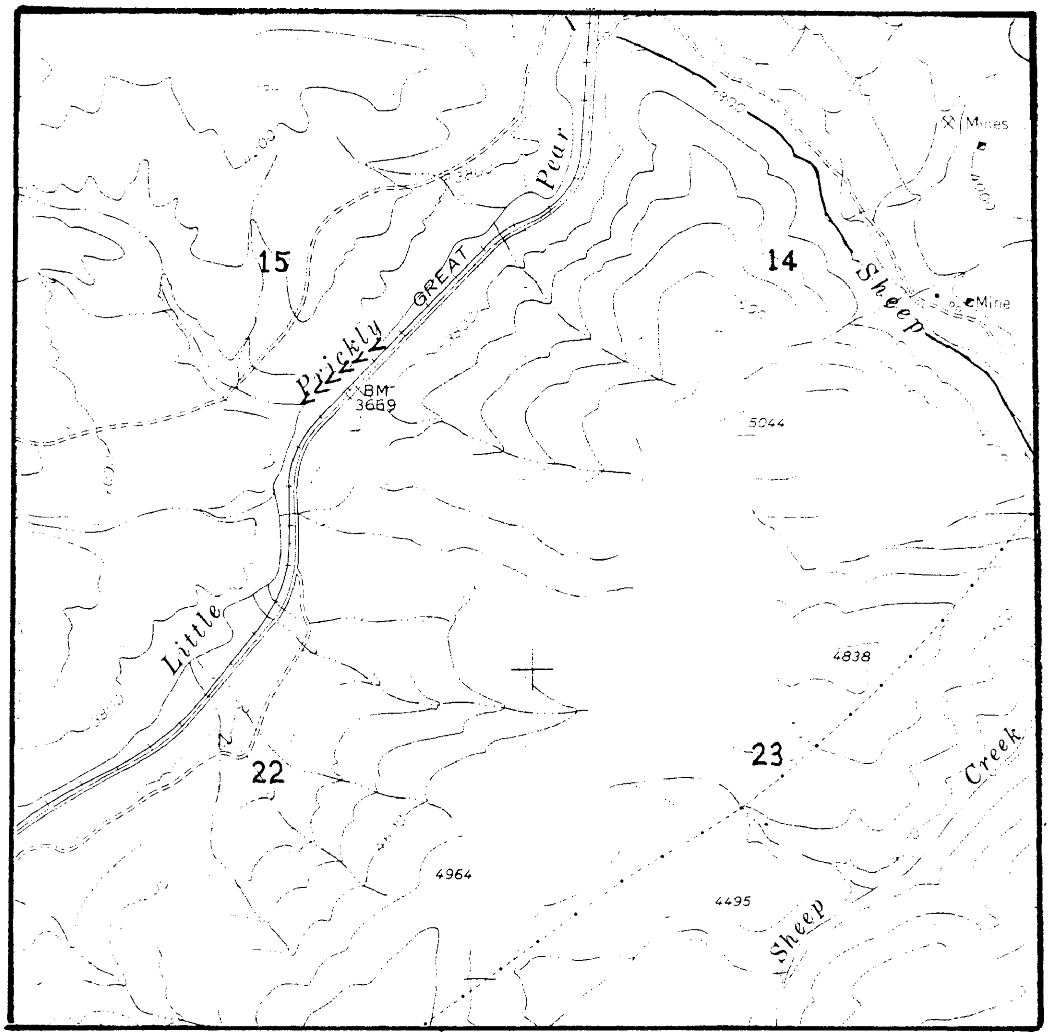
Appendix A

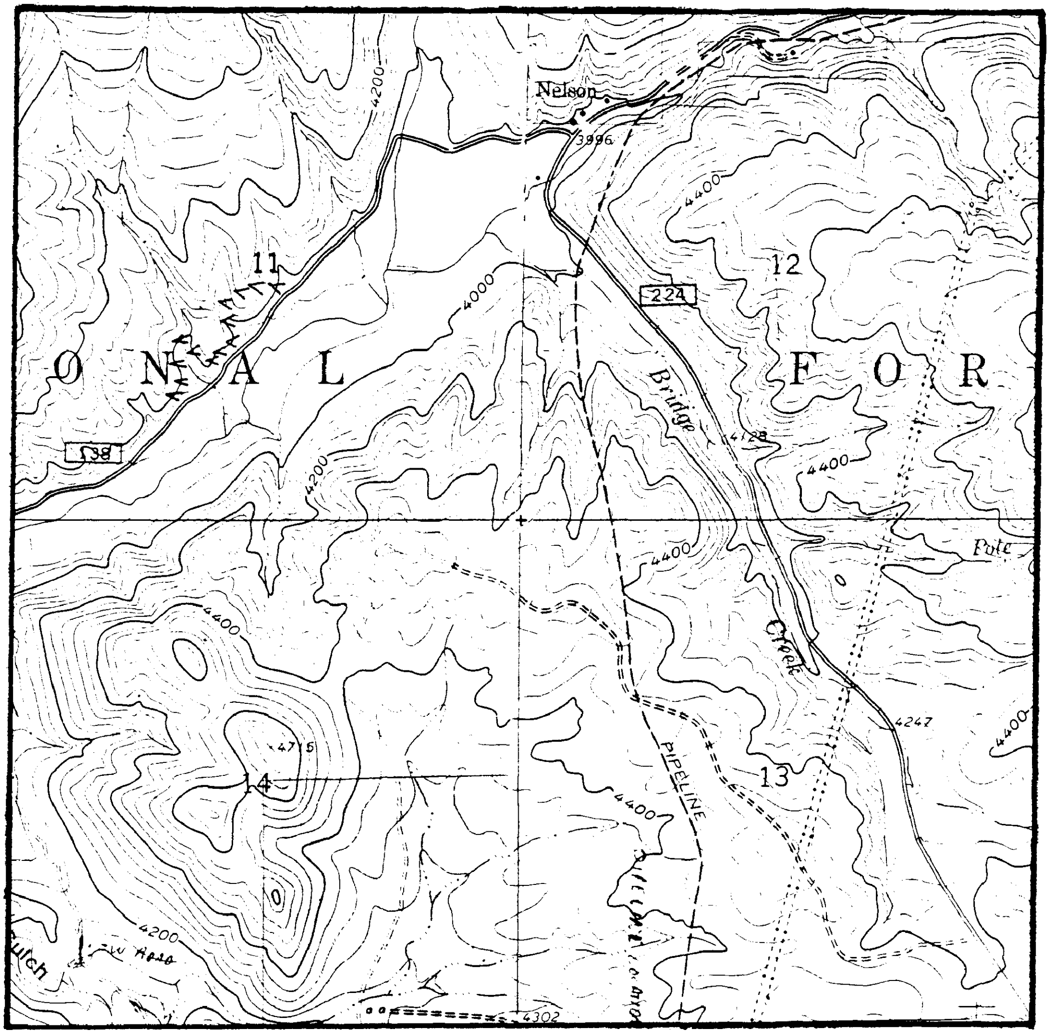
Exact locations of measured sections



WOLF CREEK SECTION

Located in Section 15, T.14 N., R.4 W.

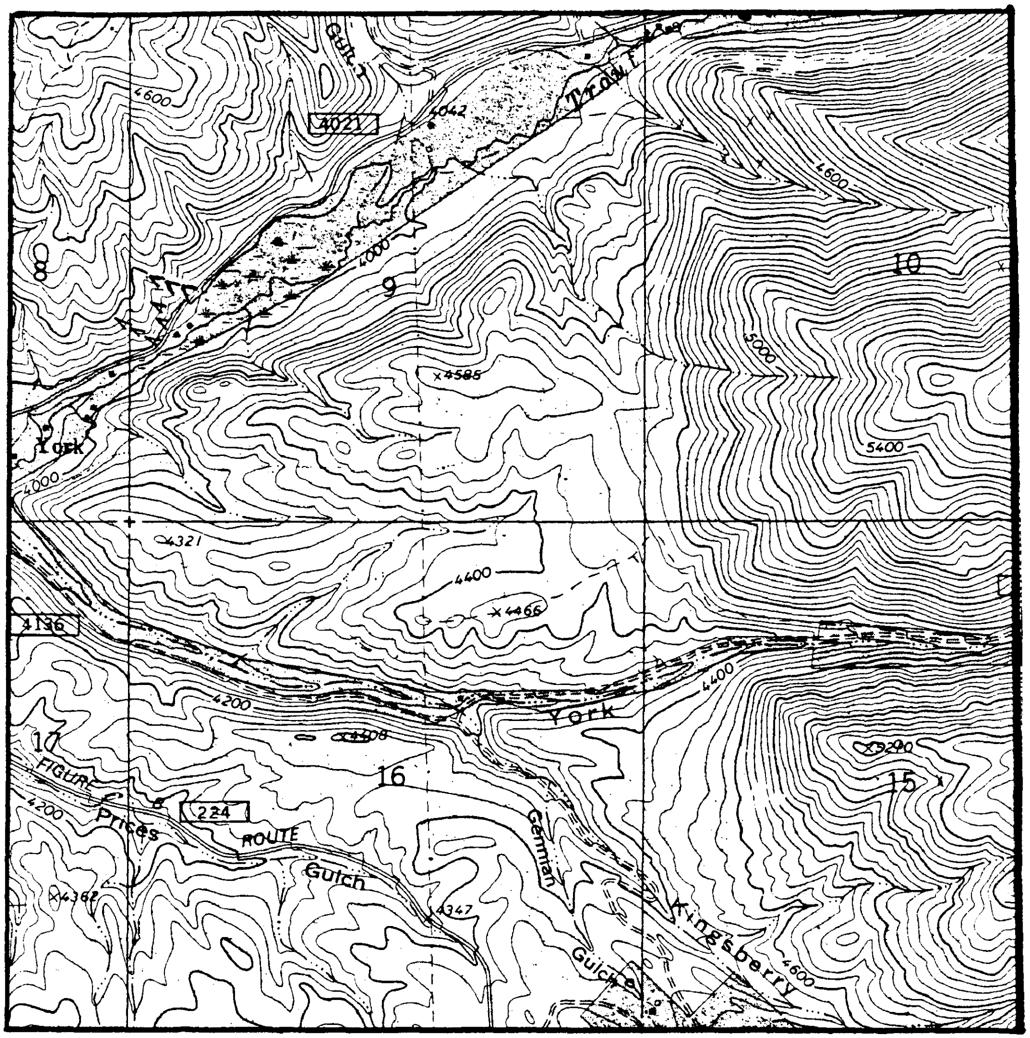
(2.8 miles south on I-15 from Wolf Creek, Montana)



BEAVER CREEK SECTION

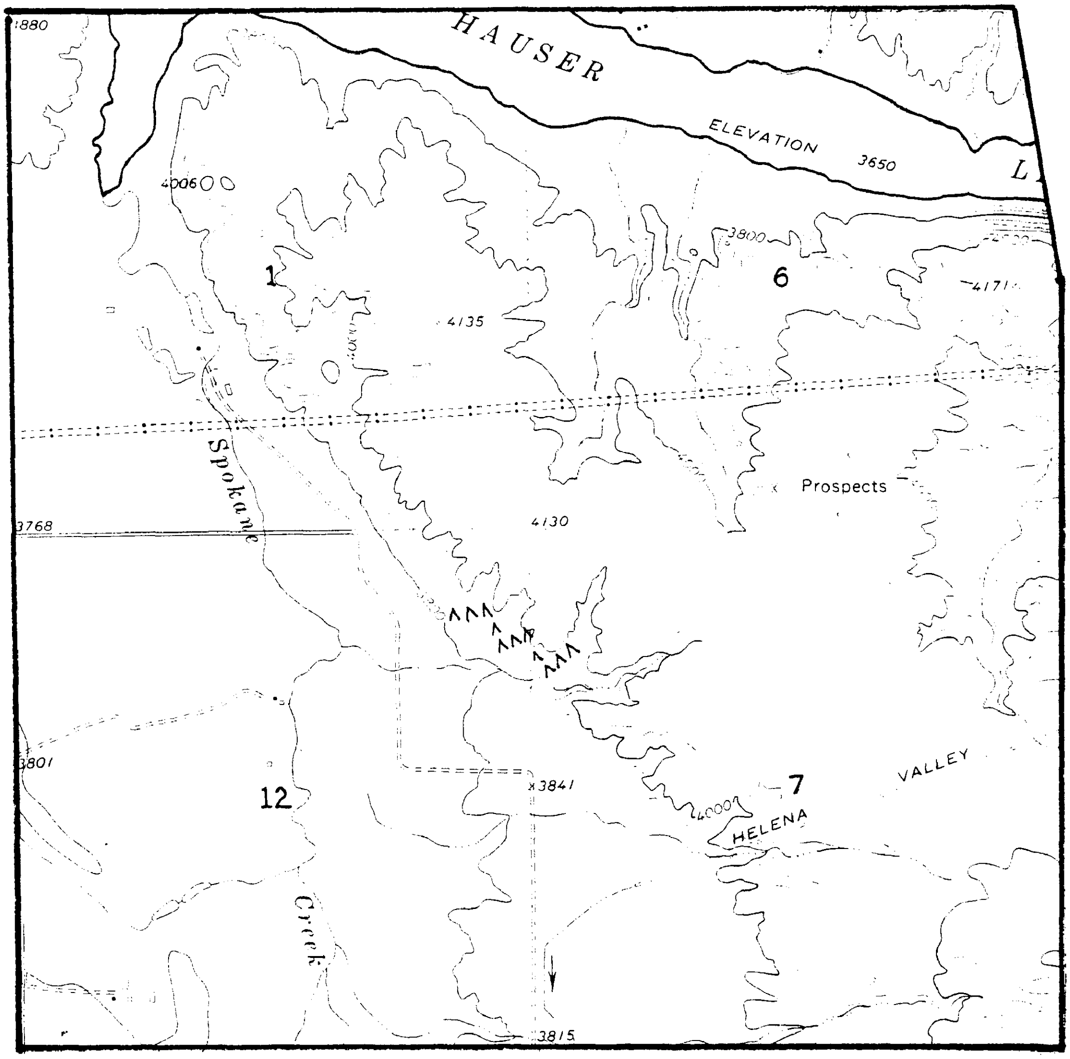
Located in Section 11, T.12 N., R.2 W.

(1.3 miles east from Nelson, Montana)



TROUT CREEK SECTION

Located in Section 9, T.11 N., R.2 W.



SPOKANE HILLS SECTION

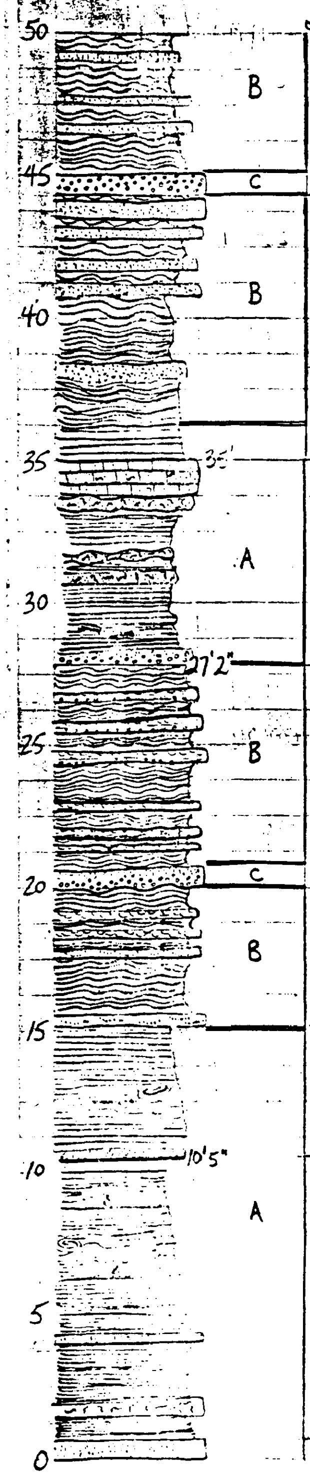
Located in Section 12, T. 10 N., R.2 W.

(on Curly McMaster's property)

Appendix B

Measured Sections

WOLF CREEK SECTION – P. 1



Green horiz. laminated (W9) silt-argillites gradually becoming interbedded horiz and ripple laminated sands with wavy silt-argillite couplets. Horiz sands up to 5cm, X-bedded at top. Sands more dominant at top of 'unit'.

Below 45' 5" coarse horiz. lam sandstone 1.5-2.5ϕ well sorted, sub-well rounded almost exclusively quartz. (W10) Pink + green

Sand below ↑ (W8) is calcareous, contains horiz-bedded rip-ups – very tiny, need hand lens to see

Very fine sandy or clack silty limestone with small 1cm MT (W7)

Coarse 1cm scouring lag overlain by slightly calcareous, black 1mm couplets, some look like RAPLAM with similar soft. sed. def. and rip-ups. Up section, some interbedded very fine MT sands (1-3 cm), beds are irregular with pinch + swell.

Continuous, horizontally laminated green siltite-argillite couplets with some small (2cm) soft-sed def. sed. structures (2cm). Couplets ~1mm (W4). Couplets become larger up section 1mm - 5cm. Interbedded with horiz laminated and ripple-x laminated green, very fine-grained quartzites. Sands > ~1cm are horiz, grading to ripple, < ~1cm are just rippled. Many sands have coarser lag, on scouring base. Sands near 15' contain coarse stringers of subrounded quartz 1.5-1.0 ϕ with ~1% feldspar with some small MT cavities (Another at 17') Coarse sand with scouring base at 20' is 18 cm (W5), slightly calcareous, some mica, mod. sorted, sub rounded 1.0-2.5 ϕ quartz grains with ~1% feldspar, horiz. laminated. The wavy bedding in couplets.

very chloritic layer (separates black RAPLAM from green silt-argillites)

RAPLAM, slightly dolomitic, grey-black, weathers to orange buff, very large soft sed deformation features (W2)

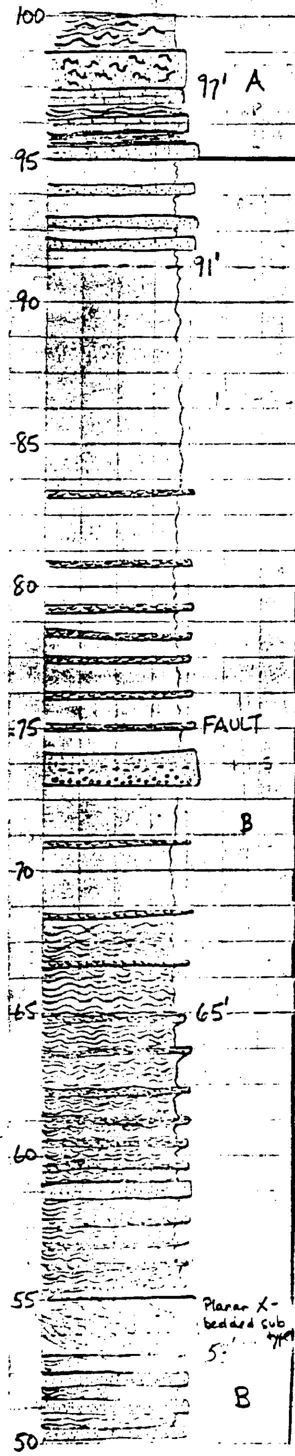
30cm

at 4'7", 8cm massive very fine grained sandstone

at 13", 6" sandy bed with variable size, random MT cav., bedding oriented around them grades into slightly dolomitic RAPLAM, rolling SSD, sed structures, scours, multi-layer rip-ups 14cm, <4ϕ massive sandstone, non-calcareous (W1)

WOLF CREEK SECTION 430 ft.

WOLF CREEK SECTION – P.2



(W13) 13 cm calcareous, horiz.-laminated, scouring, very fine sandstone, then 10 cm black RAPLAM, then another sand w/ wavy bedding, couplets, then 13 cm sand At 97' big MT layer, very random, with bedding around MT, overlain by stratified MT limestone. 19" (W14)

Interbedded 1" horiz-ripple laminated sand with wavy green silt-argillite couplets Becomes predominantly green at 91'

Interbedded horiz-ripple laminated green sands (fairly regularly spaced ~5-8") 2-4" thick into fine pinch + swell red and green couplets. Sand → green, argillite → red, rip-ups, good mudcracks

At 73', 30 cm horiz-laminated sand w/ coarse lag and red rip-ups in middle. FAULT in section ~75' down to the South (W12)

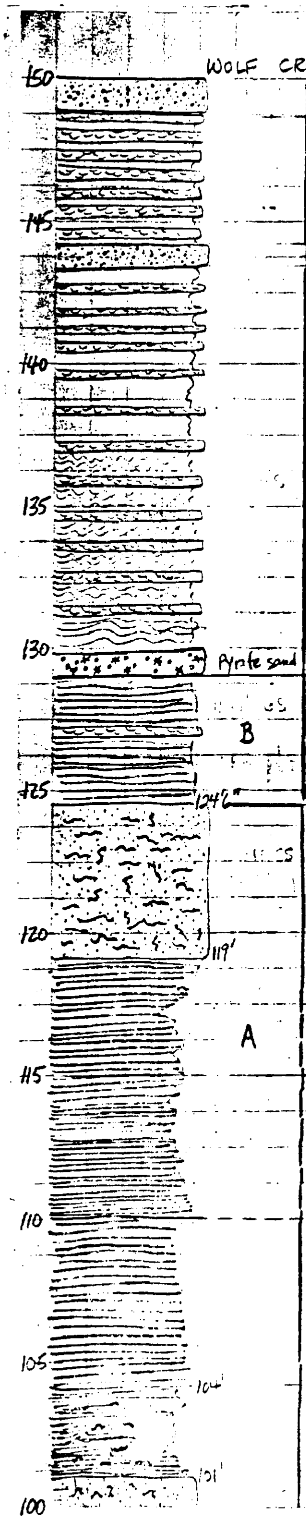
Nearing top of 'unit' sands are thinner ~1" and farther spaced (12"), by 85', no distinguishable sand units, just within couplets, orange weathering. Alot of mudcracks

Interbedded X-bedded 2-3 cm sands and wavy, green silt-argillites, couplets ~1mm not including sand At 52'6", 9 cm horiz. lam. fine grained green quartzite

Pink and green coarse sand, poor-mod sorting, 1.0-3.5 Ø, sub-well rounded 1% feldspar, [illegible] (W11) 54 cm bed. Unidirectional, low ∠, cross beds [illegible] of dip.

Sands become dominant up to 53'3"

WOLF CREEK – P. 3



At 149', 30cm coarse 1.0-2.0 ø mod. sorted, sub-well rounded (some sub-angular) quartzite (W19)

At 144', 12.5cm med. coarse 2.0-2.5 ø well sorted, subrounded quartzite (pinkish) slightly calcareous (W17)

Interbedded ripple-x-laminated green fine quartzite with green, sandy silt-argillite couplets. Bedding slightly wavy, sands farther apart, occassional mud cracks. Upsection -> more sand, larger couplets ~1cm, more ripples, wavy bedding

Above sand at 144', orange very fine-grained sands 2-7cm dominant, fining upward to green argillite (W18)

REPEATED SECTION ↑

Black, horiz. and wavy bedded MT (random but mostly horizontally oriented) sandstone, very fine grained, very calcareous (W16)

Very horiz laminated greenish and black very fine sands <4ø, silts and black argillite 1-2mm couplets, becoming more calcareous up-section (W15)

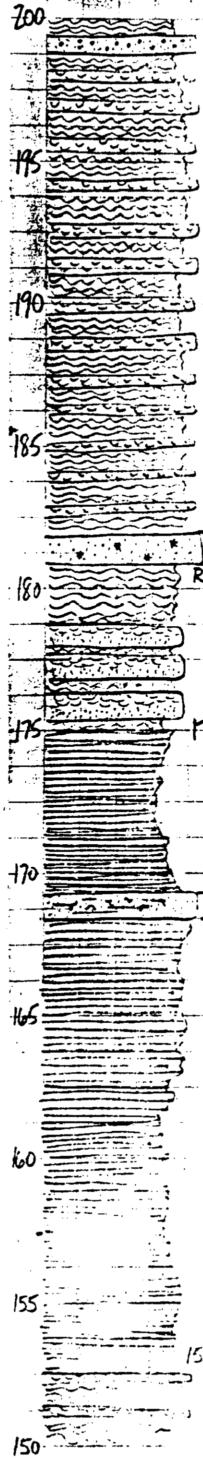
Same but very orange weathering, less calcareous, GREEN

Black 1-2mm couplets of very fine <4.0 ø sand, silt and black argillite, calcareous, MT, ... SSD ... near 104'

Stratified, MT, sandy limestone

WOLF CREEK SECTION 100-150'

WOLF CREEK - P.4



At 198', coarse 2.0-3.0 ϕ, poorly sorted, subrounded, feldspathic sand, horiz laminated ~4½", grades into wavy green couplets and 1" sands (W23) slightly calcareous

B

Interbedded ripple X-laminated sands 1-2" near base, very chloritic, increasing to 3-4", with green, very green couplets. Occassional rip-ups, couplets are black 190-195'

C

Coarse 1.5-2.0 ϕ, calcareous, subround, mod-sorted quartzitic, dominantly green with finer pink stringy beds 4-6 cm (pinch + swell) contains PYRITE (W22)

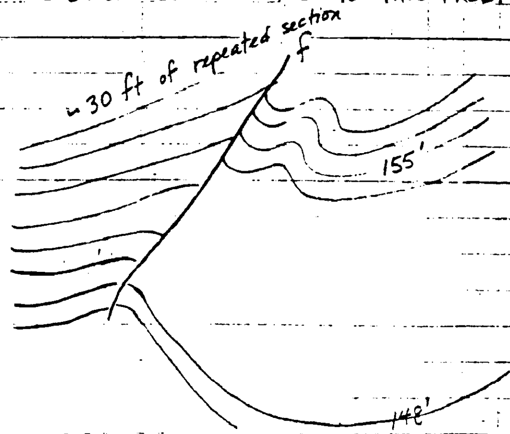
REPEAT ↓

(W21) END OF REPEATED SECTION ↓

At 168', black stratified sand with some MT, 9", followed by fine black couplets

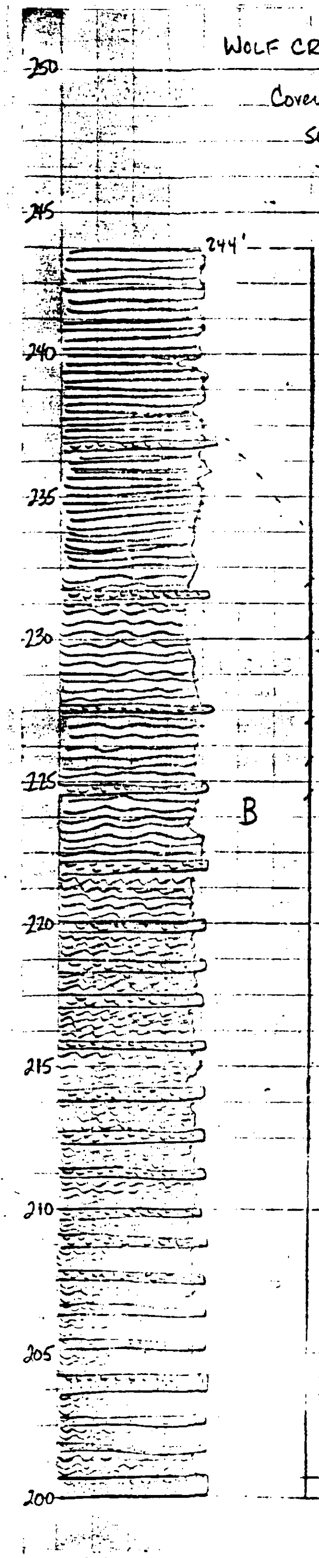
Black, fine-grained, phyllitic argillite, weathers orange, lots of soft-sed deformation bedding on ≤ 1mm scale mudcracks, slightly calcareous (W20)

WEIRD STRUCTURE AROUND 150'
REPEATED SECTION DUE TO THIS FAULT



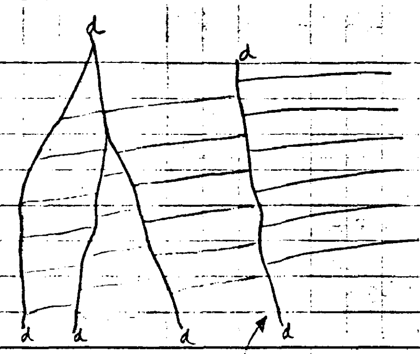
Interbedded green sands and wavy silt-argillite couplets

WOLF CREEK - P.5



Covered with trees, several dikes run through →

at ~245' dikes, covered by trees



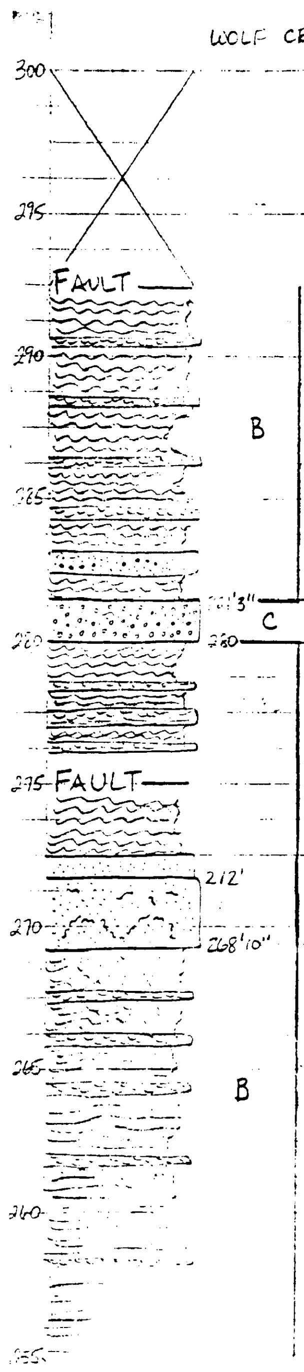
Same except back to green, sand units becoming sparse, green silt-argillite couplets are not as rippled, lots of rip-ups, lots of chlorite from shearing along faults (W25)

Metamorphosed rock near dikes (W26) (dike W27)
Mica in a pinkish and black quartzite

Same as below except some sandy beds are reddish brown & finer couplets, less sand, more rip-ups, becoming more deep maroon up section.

At 200' and 204'*, 10 cm, very fine 3.0-3.5 ϕ, horizontal-laminated greenish-white quartzites which fine into interbedded fine sands with wavy green silt-argillite couplets 2-5 mm; sands 3-8 cm, lots of tectonic deformation. Thin sands are ripple x-bedded, thicker ones are horiz. lam → ripple at top, some mudcracks (W24*)

WOLF CREEK SECTION - P. 6



Same? Too high to be seen by me anyway!

Same only more argillaceous, gouged from FAULT, 17' of movement determined by sighting from road

At 280', 39 cm coarse 1.5-2.5ø, poor-mod sorting, sub-well rounded (W29) quartzite, stringers of coarser sand, mud [illegible], 20 cm above is fine 2.5-3.5 ø calcareous quartzite (W30), stringers of coarser lithic quartz grains. Above is sandy couplets with some horiz-ripple sands, lots of rip-ups, some red argillite near 290'

At 275'-276½' 3-8" horiz-ripple sands with stringers and tops of green argillite, to 280' are sandy, wavy silt-argillite 2-3 mm couplets sands are 1-2"

— Displacement determined by sole marks on underside of sand at 280', 10' of movement

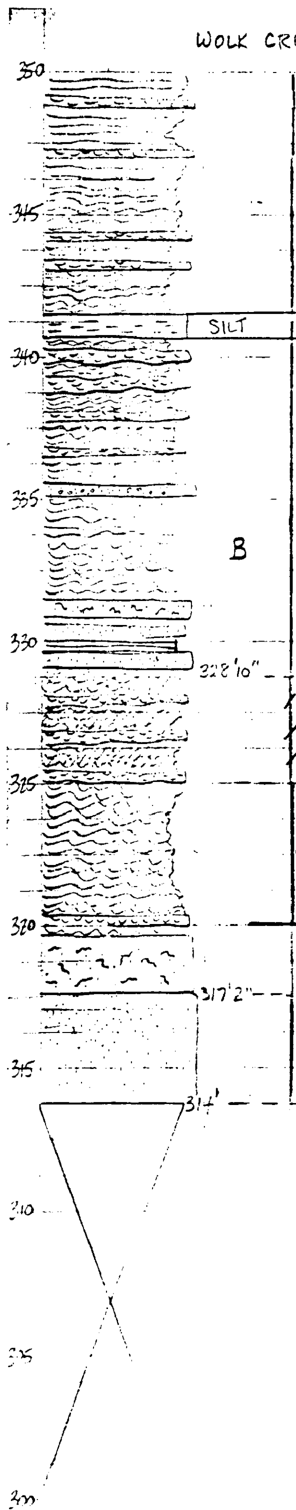
79 cm molar tooth sandstone (W28), black, very fine quartzite → brownish, buff weathering, overlain by 6" calcareous, green fine grained quartzite, overlain by slightly wavy, sandy green couplets 3-5 mm

Interbedded ripple-x-lam. sands and wavy couplets, rip-ups, mud cracks

Reddish sandy, slightly wavy silt-argillite couplets 1-2 mm, caked by intrusion, weathering orange and red although getting very green near 260.

Covered by trees, too high [illegible]

WOLK CREEK SECTION - P.7



½ 'n' ½ red, green couplets, [illegible] sandier (coarser), lots of rip-ups, couplets sometimes [illegible] ~1mm to 5cm, slightly wavy.

Dominantly red sandy couplets ~5mm, sands are greenish, 1" ripple sands are green

~36 cm massive fine-sandy red siltite [illegible] into red couplets
From 333-340', very fine-laminated green silt-argillite couplets, horiz. w/ occassional ripples in sand layers, very green couplets .5mm-1cm, lots of aug, some SSD, beds become more sandy, red w/ mud chips (pinch + swell sands near 34[illegible]

At 335'7", coarse stringers in green sandy couplet (slightly calcareous) (WZ[illegible])

At 333'2" [illegible] 8 cm molar tooth [illegible] (WZ[illegible]) (missing)

9cm fine, calcareous green massive quartzite

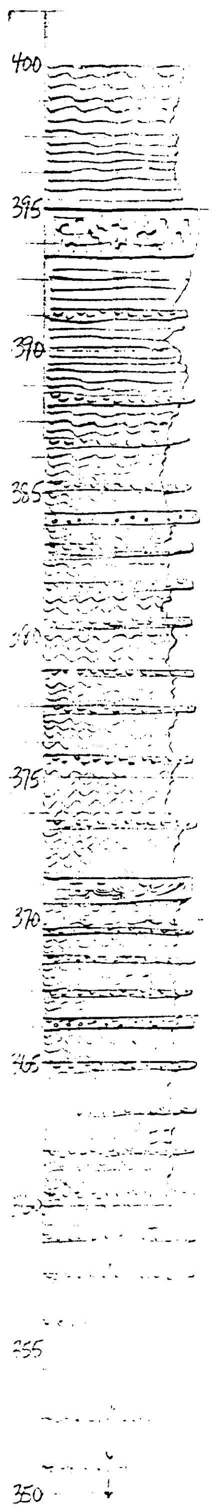
Scouring green, ripple-x-lam. sands with red mudchips, mudcracks, fining up to red argillite

Same as above, less sand, all green

At 314', very fine-grained, green, calcareous massive quartzite, At 317'2" (WZ[illegible]) very large molar-tooth sandstone (like at 120'), the calcareous green [illegible] slightly wavy silt-argillite, 2-5 mm couplets (like Trout Ck on road?)

Same? (from previous page)

WOLF CREEK SECTION – P. 8



Green, sandy slightly wavy green siltite-argillite couplets

At 393'10" calcareous, wavy stratified [illegible] molar tooth sandstone

Same, except at 389', couplets are thinner, more continuous, still wavy sand beds (smaller ≤ 2") [green]

Getting more sandy – 4" ave dominant sands, horiz. ripple, thin mudchips, repeated cycle, 2" coarse stringer sand at 384'

B

Red now

✓Green sandy, wavy silt-argillite and 1-2" sands, couplets <1mm - 3", mud chips, cracks

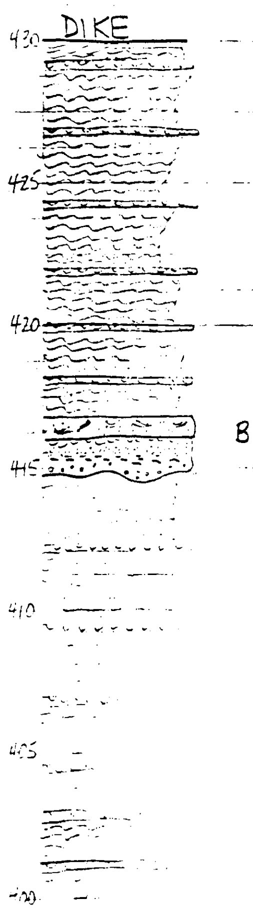
At 370', 20 cm, very fine 4ϕ, well sorted grey-white quartzite, X-beds 1-2 cm, some horiz bedding. (W40)

– At 368' becomes dominantly green, still ripples, slightly wavy, sandy (W39). micaceous, slightly calcareous

At 366', 10½ cm coarse to 1.0ϕ, very poorly sorted well rounded - subround, red, stringers of mud cracked red argillite, some mud chips, overlain sharply by red argillite (W38)

Same; a little more [illegible] ([illegible]), beginning to have a mottled appearance (in bands – discontinuous)

WOLF CREEK SECTION - P. 9 (END)



Dike - end of section

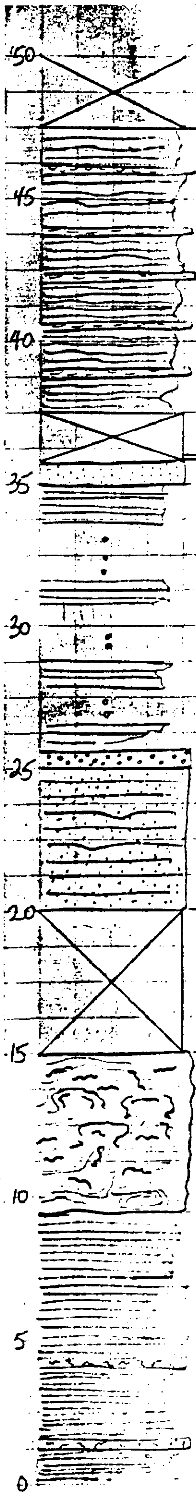
Red and green wavy bedded sand and siltite-argillite, rip-ups, X-bedding, sands 1-3"

At 416'+, 13 cm calcareous, white, 2.0-3.0 ∅ (fine) quartzite with 3" trough X-bedding some horiz. bedding (W41)

At 415', coarse stringer sand is overlain and deeply scoured by another similar one containing large rip-ups, fixed over (red) then green, turning into green X-bedded sand 8.15"

Green, sandy slightly wavy [illegible] becoming red, mottled look because [illegible] green [illegible] beds, [illegible] to ≤1", still mud-cracks, rip-ups. Becomes mostly [illegible] to 415'

BEAVER CREEK SECTION – P. 1



COVERED

B — Interbedded thin 5mm–2cm, slightly wavy black sandy silt-argillite couplets with 2-10 cm sandy (dolomitic) beds

COVERED

At 35', ~12 cm massive, very fine-grained green quartzite, slightly calcareous (B4)

S-A-F — thin, 1-3 mm horiz. lam. black silt-argillite, poor exposure, covered by scattered soil

A

At 25', < 10 cm coarse, 1.0-2.5 ϕ poorly sorted, sub ang–sub round, calc. dirty SS (B3)

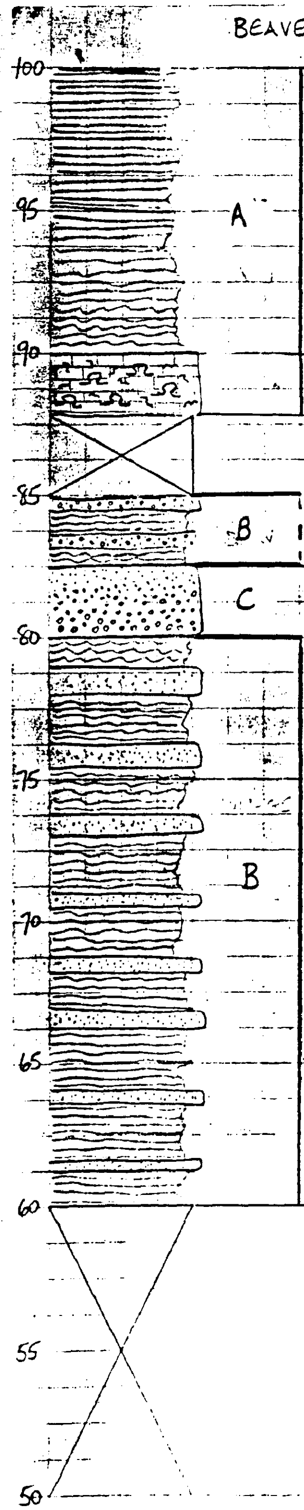
Horizontally bedded 4ϕ dolomitic quartzite, some ripple X-laminae, some cut and fill, all < 4 cm, greenish or grey, weathers buff. (B2)

COVERED

Thinly laminated 2mm couplets, large 5-6 cm molar-tooth gaps, stromatoforms SSD, ← 3-4cm

A — Interbedded 3-5mm sandy, black, dolomitic argillite (very horiz. continuous) with 3-7 cm continuous beds of (B1) calcareous stratified MT SS, molar tooth ripups, sharp base gradational top Increasing in carbonate up-section

BEAVER CREEK SECTION – P.2



Wavy, 1-2cm queen sitt-argillites grade into very flat, horizontally bedded argillites becoming increasingly sandy and dolomitic

At 28'6", 40cm stromatolitic limestone with large molar-tooth cavities ←5cm, grades into thin-bedded 5mm, queen arg couplets (B6)

COVERED

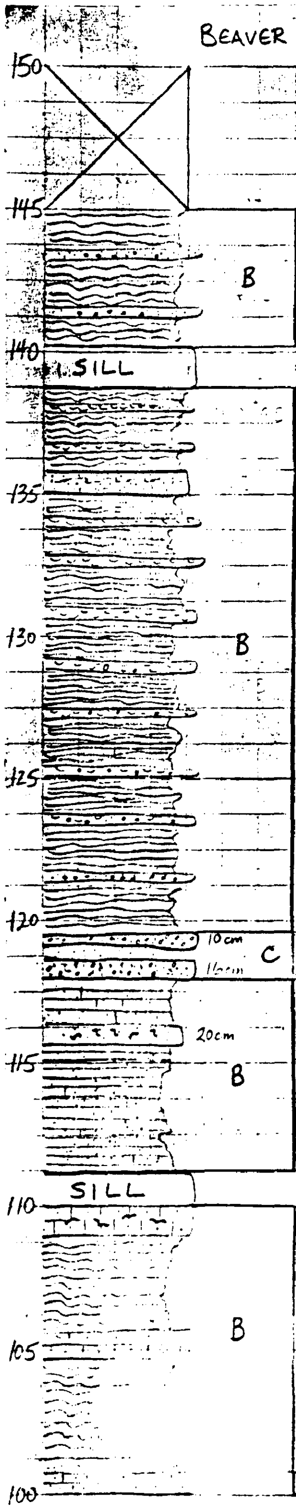
22 cm of queen arg., pinch + swell 2-12 cm coarse, poorly sorted sand

At 80', 80cm med-coarse 1.5-3.0 Ø, poorly sorted, subrounded, <1% feldspar quartzite, slightly calcareous w/ calcite in fractures, fines upward (same source) horiz. laminated. (B5)

Interbedded queen, less calcareous, sandy siltite-argillite couplets bedding 1mm-3cm, wavy, with 10-40cm horiz. fine-grained sands

COVERED

BEAVER CREEK SECTION - P.3



150–145: COVERED

145–140 (B): Interbedded wavy green silt-argillite couplets 1cm with some 5-10 cm sandy rippled beds, some coarse stringers

SILL: 38 cm

fine black micaceous quartzite, some places poorly sorted, fairly straight crested assymmetrical ripple marks, slighty calcareous 2.0-2.5 ϕ

(B): Interbedded slightly wavy green sandy silt-argillites with small 2x5cm pinch and swell sands, couplets <1mm - 3cm with fine-grained green quartzite containing less and less stringers of coarse, poorly sorted, subrounded clasts, interference ripple marks.

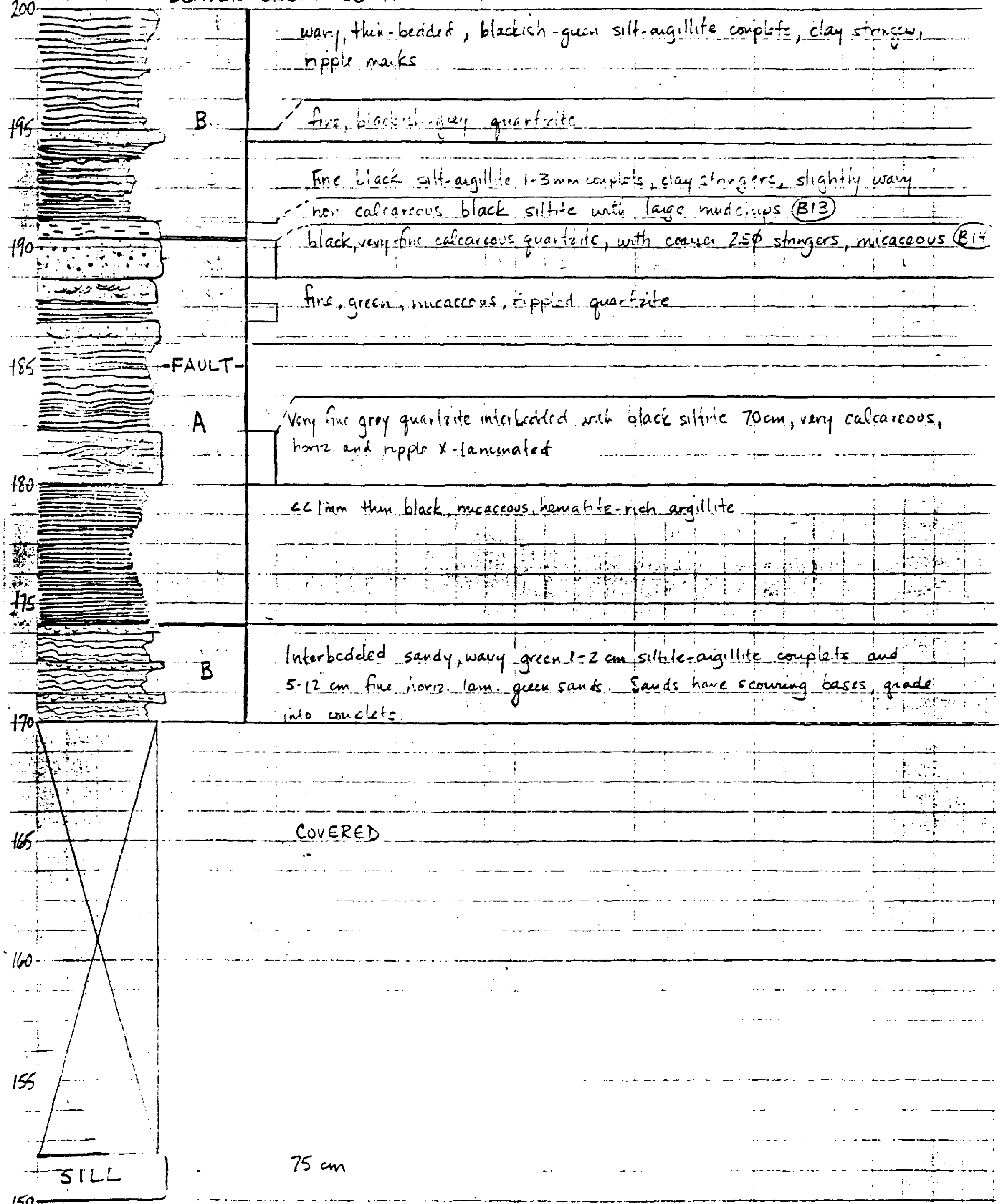
(C): 2 Horiz. lam., calcareous 1.0-2.5ϕ, angular-rounded green quartzite, poorly sorted (B9) (B10)

(B): Finely laminated, horiz. fine dolomitic sands with some limestone layers 20cm with MT cavities.

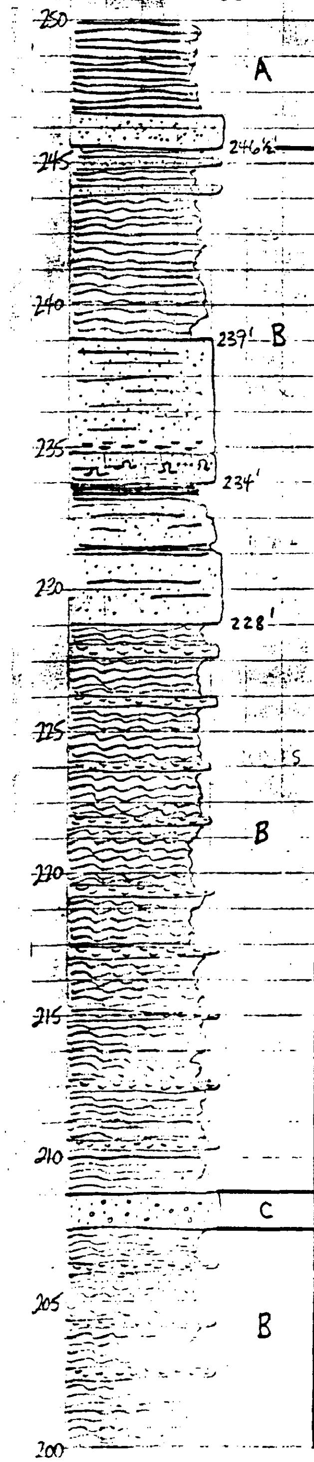
SILL: 27 cm porphyritic basalt (E8)

(B): Interbedded sandy, micaceous, green wavy siltite-argillite couplets with 3 sandy limestones, irregular bedding, soft-sed deformation (E7), 3rd one has lots of MT, cavities. Each limestone is ≈20 cm

BEAVER CREEK SECTION - P.4



BEAVER CREEK SECTION - P.5



<1mm - 2cm thin-bedded, sandy black silt-argillite couplets, irregular bedding, some ripple marks (E17)

43cm conchoidal fracture, very fine-grained black quartzite, calcareous

black, sandy, wavy silt-arg. couplets 5mm-2cm, with rip-ups grade into same interbedded with 3-20cm black, horiz. ripple quartzites, mudcracks, too.

Dominantly horiz. bedded black quartzite and siltite, rip-ups of limy mud little ripples, scours in sand near limestone

At 234', 25cm stromatoform, stratified sandy limestone (E16)

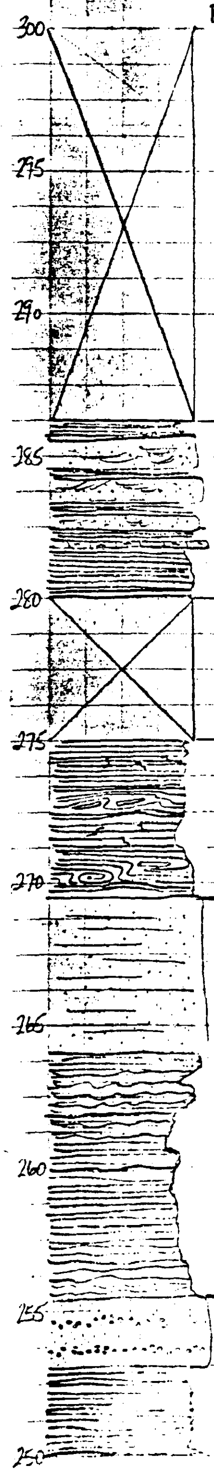
Horizontally lam. sand, coarse, fining upward and interbedded with black siltite and argillite beds and stringers

Interbedded fine sands ~8cm with black wavy silt-argillite couplets, mica-rich 5mm, dolomitic

70cm med coarse 1.5-3.0 ϕ, poorly sorted, sub-ang.-subrounded quartzite (quartz) (E15)

Interbedded sandy gray silt-argillite couplets, and fine quartz ripple X-laminated and horiz. lam. sands

BEAVER CREEK SECTION - P.6



COVERED

A — 5-20 cm low ∠ planar and 2-3 cm ~~trough~~ X-bedded 3.5-4.0 ø quartzite, black and gray color, calcareous, interbedded w/ black argillite (B20)

thin 5 cm, MT, stromatoform limestone dolomitic RAPLAM

COVERED

A — Unit below grades into calcareous, MT, rap lam, pinch & swell, roll-over soft-sed def., large rip-ups (intraclasts), slumping and scour marks

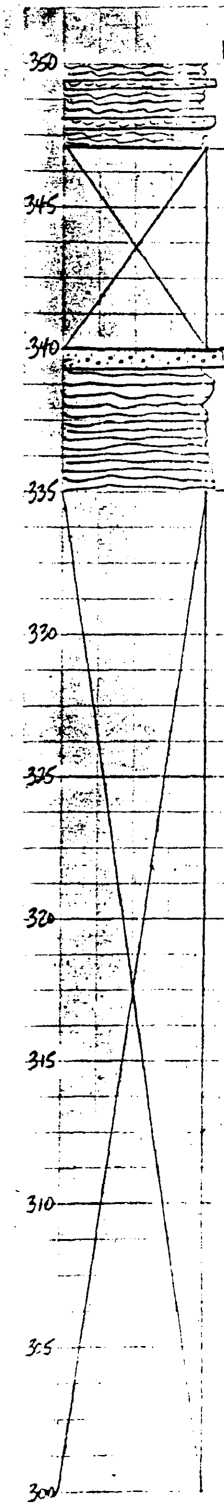
1.5 meter, very fine 7.4 ø, horiz. laminated black quartzite with some small, broad ripples (calcareous) (B19)

B — Unit below fines upward to wavy, sandy mudcracked surface and is further over lain by 2mm - 1cm bedded, fining upward into black, sandy, slightly wavy argillite

C — 72 cm poorly sorted quartzite with coarse (to 6.0 ø) sub-ang to rounded clasts very slightly calcareous (due to secondary calcite veins) black (B18) horiz. lam. (contains <<1% pyrite)

A — Same grading into more horizontal .5 cm bedded finer black couplets

BEAVER CREEK SECTION - P. 7



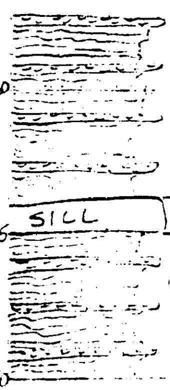
B	Interbedded wavy green silt-argillite couplets ~1 cm bedding with sandy layers, pinch and swell, ripple marks, X-bedding
	COVERED
C	15 cm or > coarse (to 0.5 ϕ) poorly sorted, ~~sub ang - rounded, felaspathic quartzite~~ calcareous (outcrops like Flathead quartzite) (321)
B	5mm - 2cm green silt-argillite couplets, clay rip-ups, slightly wavy bedding, some red argillites
	COVERED

BEAVER CREEK SECTION - P. 8 (LAST PAGE)

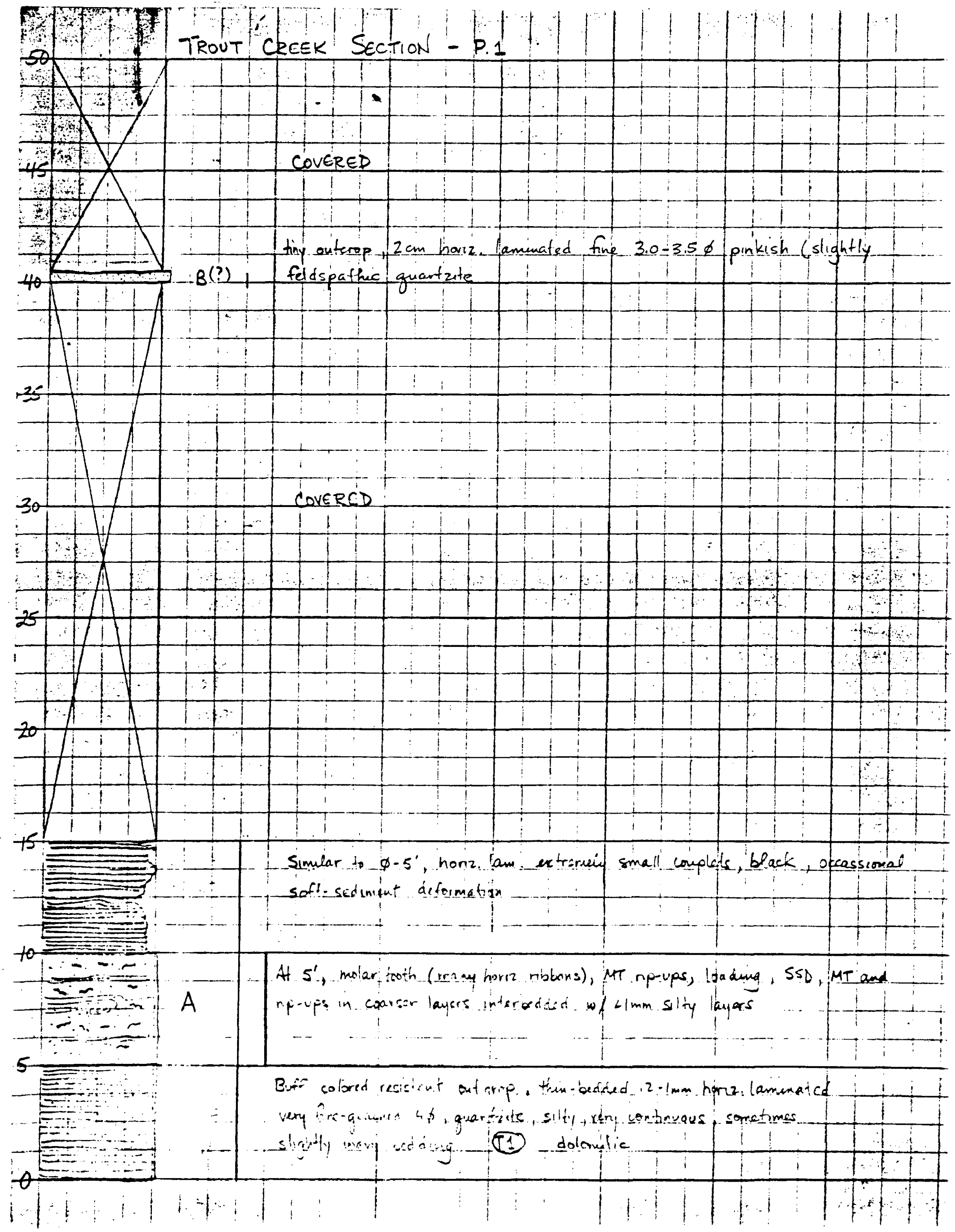
370

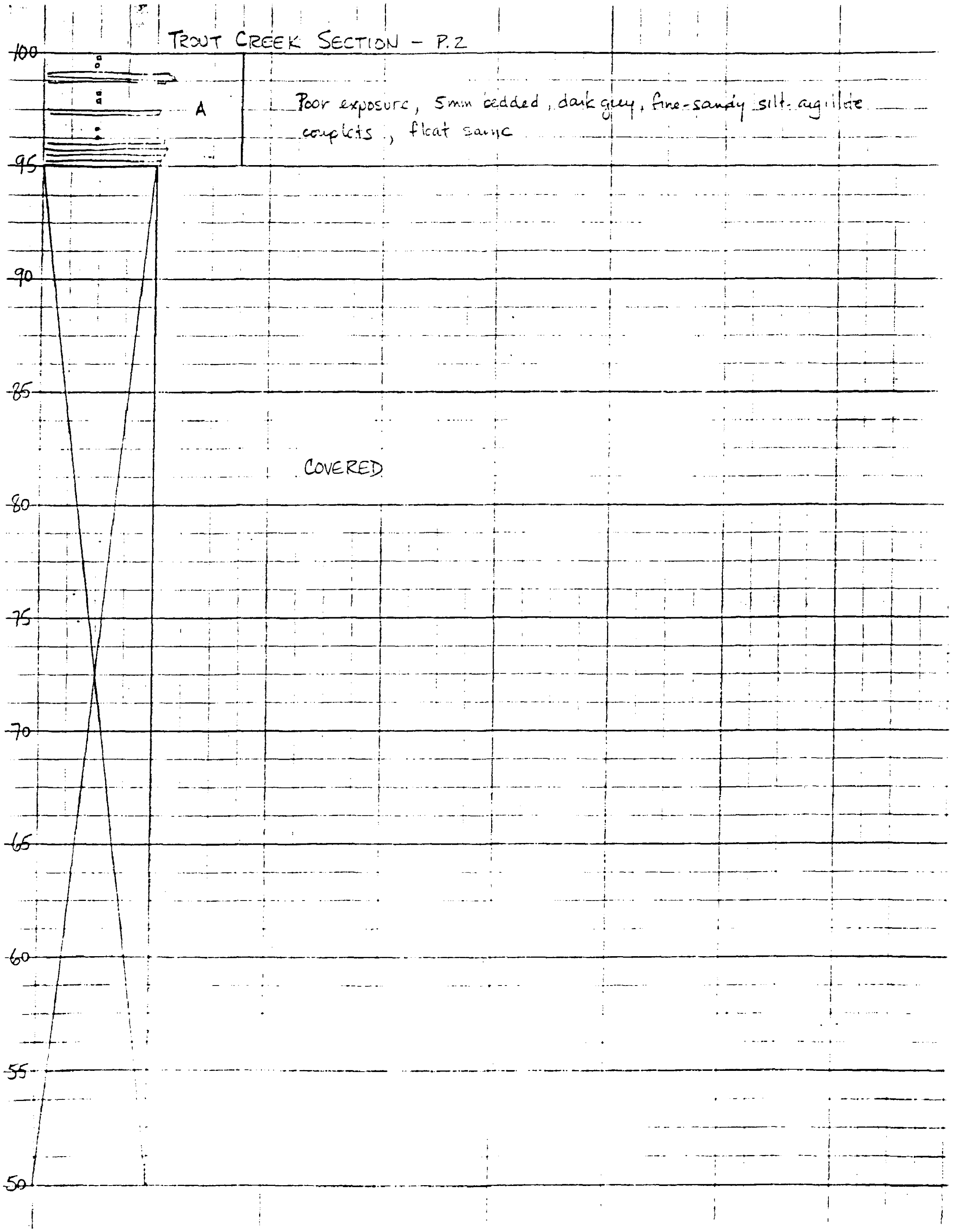
RED INCREASES

365

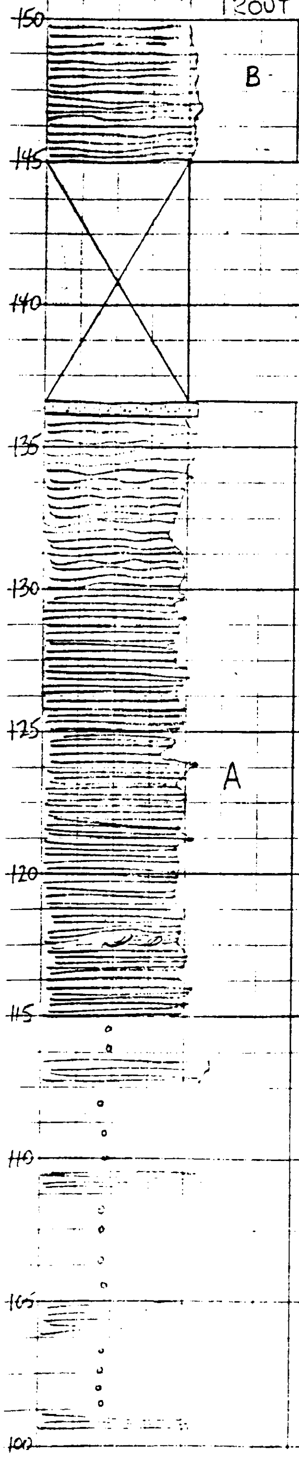


360	B	Interbedded 2-5 cm horiz but mainly ripple sands fining upward to argillite, couplets 7-12 cm total, argillites → red, sands black, weather reddish green, lots of mudcracks
355	SILL	~40 cm (B22)
350	B	Same


TROUT CREEK SECTION - P. 1
50
45
COVERED
tiny outcrop, 2cm horiz. laminated fine 3.0-3.5 ø pinkish (slightly feldspathic quartzite
B(?)
40
35
COVERED
30
25
20
15
Similar to ø-5', horiz. lam. extremely small couplets, black, occassional soft-sediment deformation
10
A
At 5', molar tooth (many horiz ribbons), MT rip-ups, loading, SSD, MT and rip-ups in coarser layers interbedded w/ <1mm silty layers
5
Buff colored resistant outcrop, thin-bedded .2-1mm horiz. laminated very fine-grained 4 ø, quartzite, silty, very continuous, sometimes slightly wavy bedding (T1) dolomitic
0


TROUT CREEK SECTION - P.2
100
A
Poor exposure, 5mm bedded, dark grey, fine-sandy silt-argillite couplets, float same
95
90
85
COVERED
80
75
70
65
60
55
50

TROUT CREEK SECTION - P.3



very fine-grained, sandy grey silt-argillite couplets 1-5mm, load structures, bedding sometimes wavy

COVERED

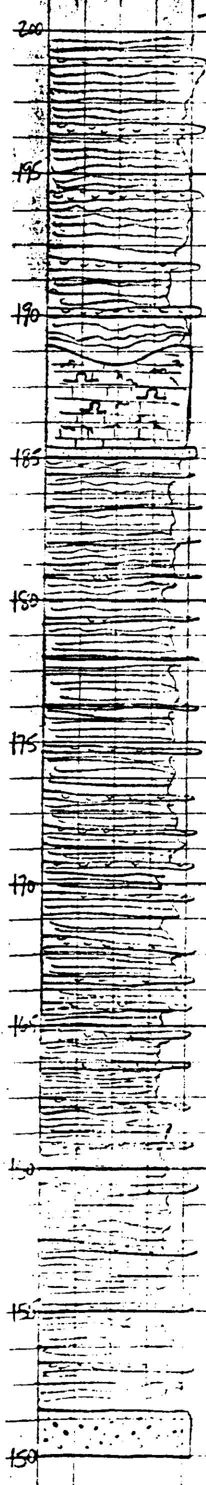
fine-grained, reddish-black silty quartzite (T4)

Becomes slightly wavy, larger scale bedding

RAPLAM, mostly very continuous bedding, some odd soft-sediment deformation occurs in one 5 cm bed, all others flat (T3) very sandy

Same as below

TROUT CREEK SECTION - P.4

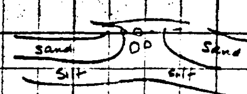


Interbedded green silt-argillite couplets and sand, some ripple-X-laminae in sand 2cm high

4cm sand unit, then thin-bedded limestone with molar tooth cavities, [illegible] forms, some real MT, unit pinches and swells 10-40 cm

Thin-bedded <1mm - 10mm horiz. or wavy bedded sand, silt-argillite couplets, rip-ups, interbedded with fining-upward horiz and ripple-lam. sands 3-7 cm, avg 4 cm (green)

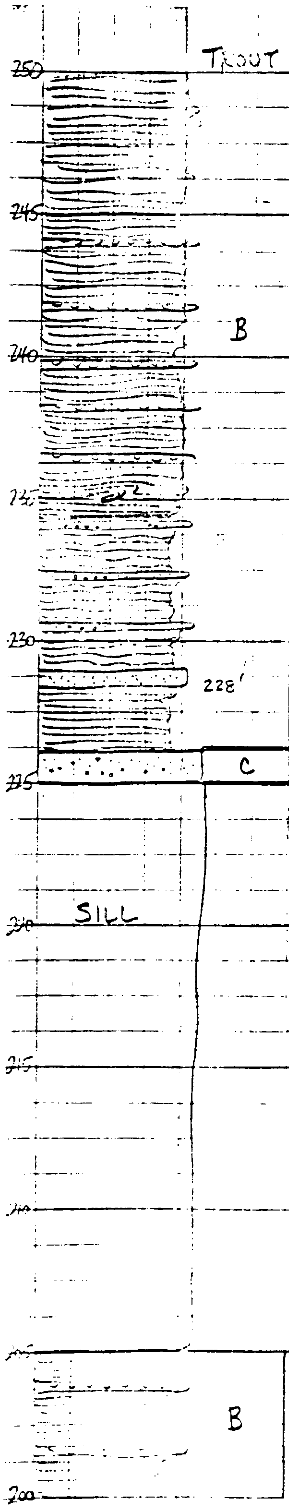
Some weird soft-sediment deformation



Sand units decrease in size, are closer together up-section

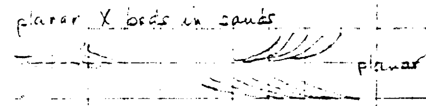
40 cm 2.5-3.0 Ø quartzite, subround - subangular clasts, some silt, black grains, feldspar, 2mm horiz bedding, coarse stringers (T5)

TROUT CREEK SECTION - P.5



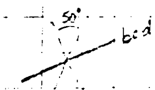
just green argillites NO BANDS

Same, very sli. no trough and planar X beds in sands
more ssd



Interbedded green silt-argillite couplets 2-8 mm and 7cm continuous but pinch + swell sands (fining-upward), irregular soft-sed def.

Diagonal shearing 50° from bedding



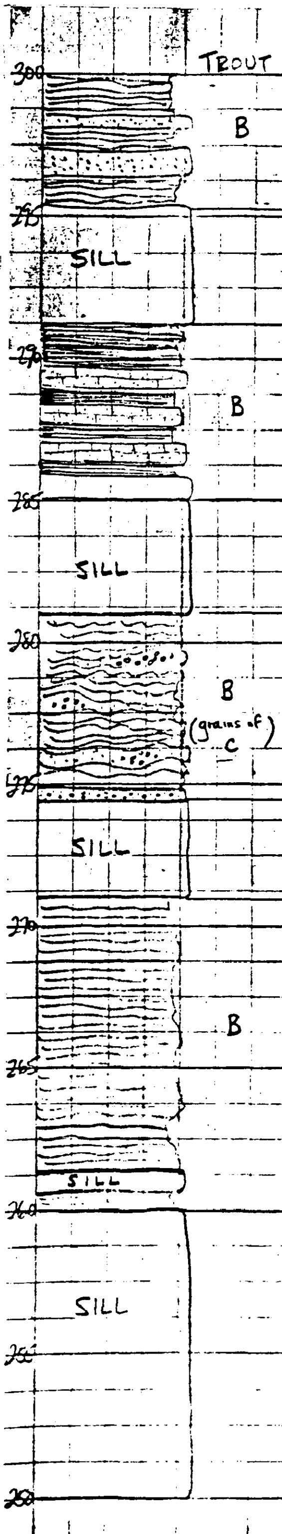
Horiz and ripple laminated sandy green silt-argillite couplets with sand. Sands have organic fingers, grade into clay, have mudchips, cracks, micaceous, At 228' 10 cm resistent to shearing sand bed, couplets < 1 mm - 1 cm
↓

At 225' horiz bedded, 1.5 - 2.5 ϕ green quartzite, subang-rnd (T7) ~25 cm

SILL - very altered → chloritic (T6)

[illegible]

TROUT CREEK SECTION – P.6



Thinbedded wavy green silt-argillite couplets, mud chips and mudcracks with sharp scouring massive or horiz. green quartzites

Interbedded intraclastic, calcareous very fine sandstone and thin-bedded 1mm–1cm calcareous siltite limestone 4-5 cm (sometimes 1-2) every 2-3 cm apart. Many large horizontal ribbons, strange soft-sed deformation, sharp bases on cal. ss, many large 5-4cm rip-ups near base. Seem to grade quickly into very thinly laminated siltite, mostly siltite last 3 ft.

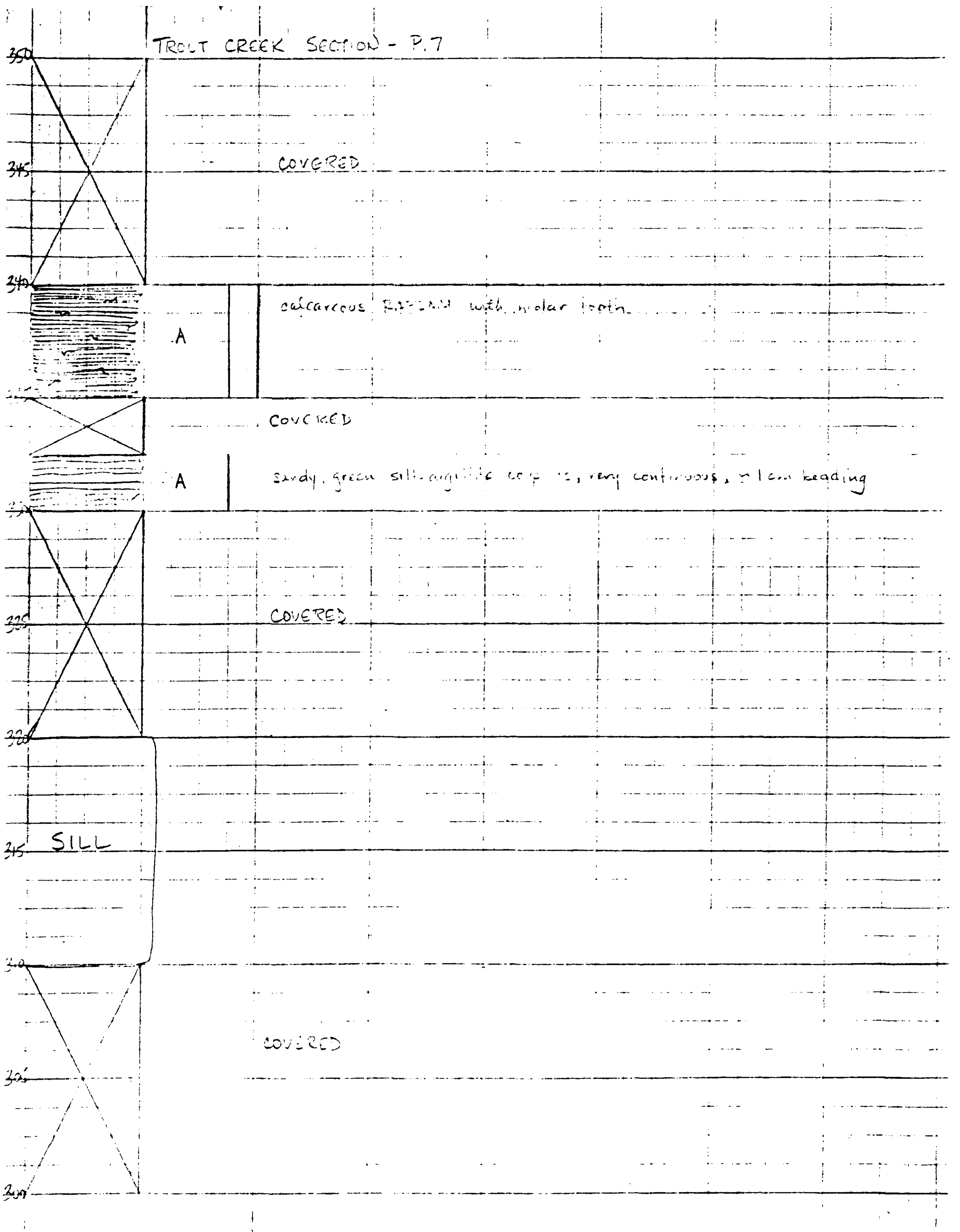
green silt-argillite couplets 1-2mm scale interbedded with stringers and lenses of very coarse → 0.0 ϕ, very poorly sorted, large sub-ang. grains of quartz + feldspar, many lithic fragments. couplets and fine sands are X-bedded (T-8 (2)), mudcracks up section in argillite. At 277' horiz. lam. med. coarse sand with very coarse lens 1-3cm thick, ½-2ft wide, scouring base, fines cont. upward to 280'

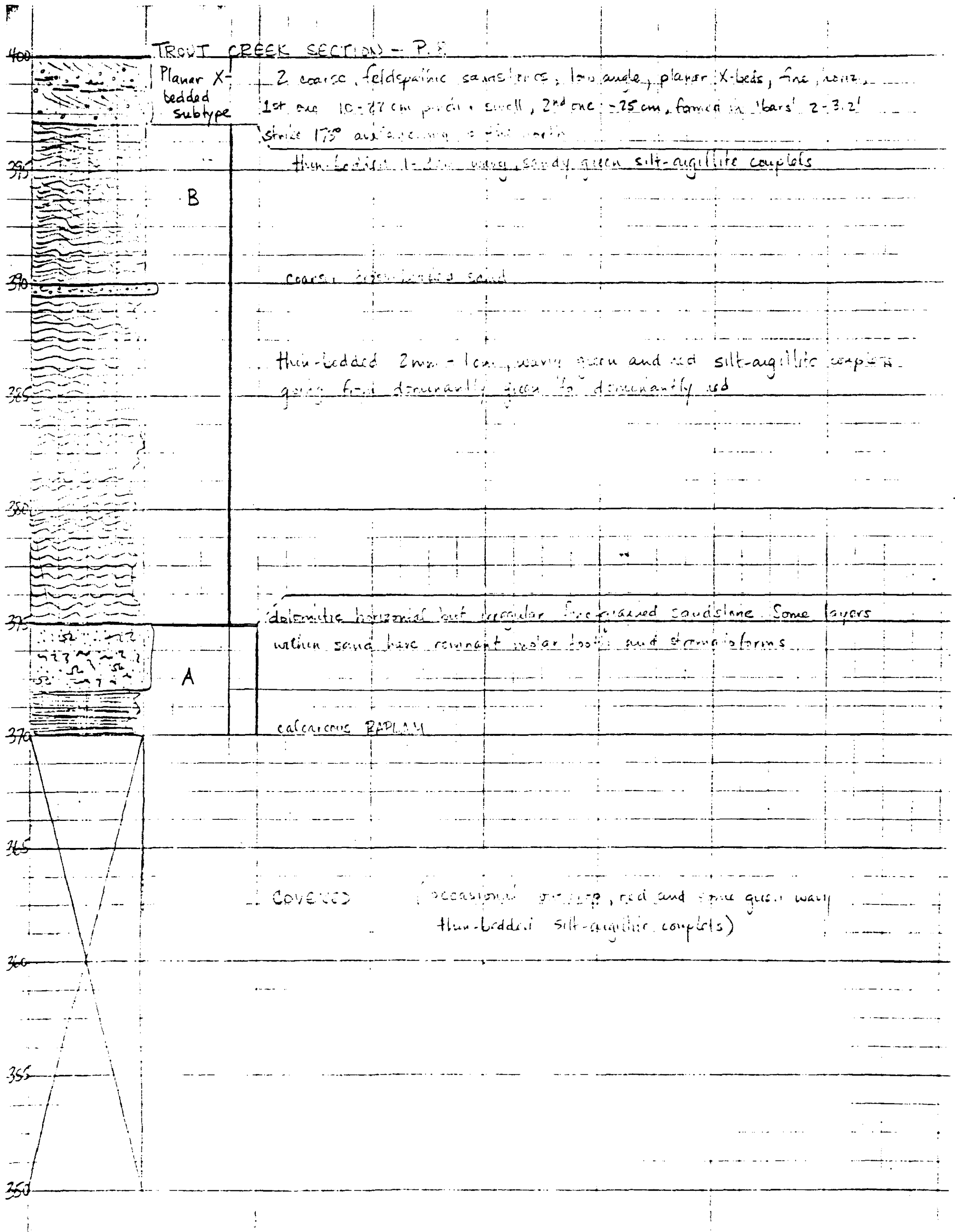
271–274'

Very fine silt-argillite couplets, trough X-beds < 1 cm high, mud rip-ups, fine upward to 1mm thick mud then scouring base of silt (horiz. lam.)

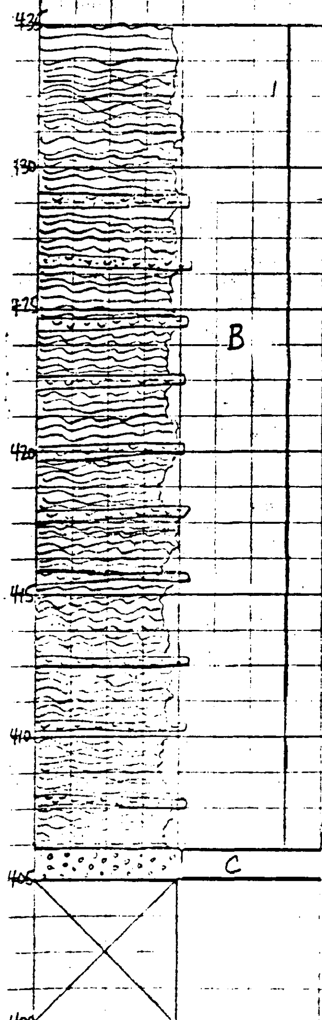
40 cm, same as above

250–260'


TROUT CREEK SECTION - P.7
350
COVERED
345
340
calcareous
with molar tooth
A
COVERED
A
sandy, green
very continuous
beading
COVERED
320
SILL
315
COVERED
300


TROUT CREEK SECTION – P.
400
395
390
385
380
375
370
365
360
355
350
Planar X-bedded subtype
B
A
2 coarse, feldspathic sandstones, low angle, planar X-beds, fine,
1st one 10-27 cm , 2nd one ~25 cm, formed in 'bars' 2-3.2'
strike 175°
thin-bedded wavy, sandy, green silt-argillite couplets
coarse sand
thin-bedded 2mm - 1cm, wavy green and red silt-argillite couplets
going from dominantly green to dominantly red
dolomitic horizontal but irregular fine-grained sandstone. Some layers
within sand have remnant and stromatolites
calcareous
COVERED
(occasional , red and green wavy
thin-bedded silt-argillite couplets)

TROUT CREEK SECTION - P.9



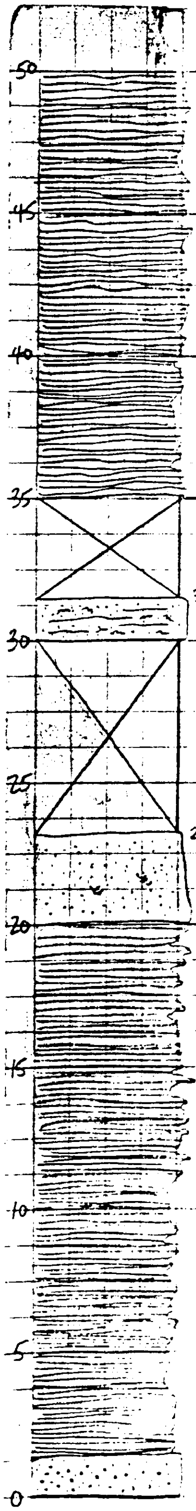
thin-bedded ~1 cm sandy wavy, red silt-argillite couplets

Interbedded 2-5 cm wavy green sands with dominantly red sandy silt-argillite couplets, mud chips

Coarse (to 1.0 ø) sand, >25% feldspar, subrounded - rounded, massive but possibly horizontally laminated

COVERED

SPOKANE HILLS SECTION – P. 1 (Curly's section)



A — very thin, microcompleted, horiz. green sandy silt-argillites slightly wavy, many times due to slumping, very continuous (C5) (C6) Almost like RAPLAM except for absence of familiar soft-sed. def., lam are not black either

COVERED

31.5' A — 1.5 ft (45 cm) molar-tooth, occasionally stratified brown sandstone, some soft sediment deformation

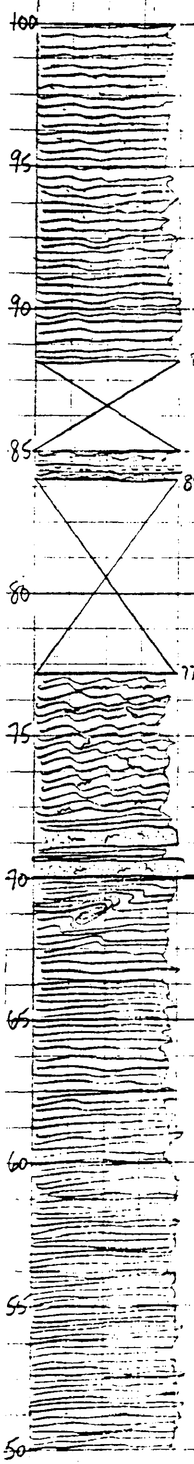
COVERED

23' A — 3 ft (0.9 meters) very fine >4ϕ massive brown sandstone, ripple X-bedding in some places (C3)

A — thin-bedded, ≤1mm brown, sandy, dolomitic silt-argillite couplets, very continuous bedding, some areas slightly wavy (C2)

massive, slightly calcareous, med-fine 2.5ϕ sandstone (C1) (forms rigid outcrop on west side of 1st gulch)

SPOKANE HILLS SECTION – P. 2



B

very slightly wavy, sometimes horizontal sandy green silt-argillite couplets. couplets 1-2mm (C10)

COVERED

B

1-2mm bedded, slightly wavy, sandy green silt-argillite with 1-2 cm sand s

COVERED

B

2-3 cm very wavy, molar tooth cavities, larger soft-sed. deformation (C9)

grades into massive, very fine-grained greenish buff sands interbedded with muddy stringers and molar tooth

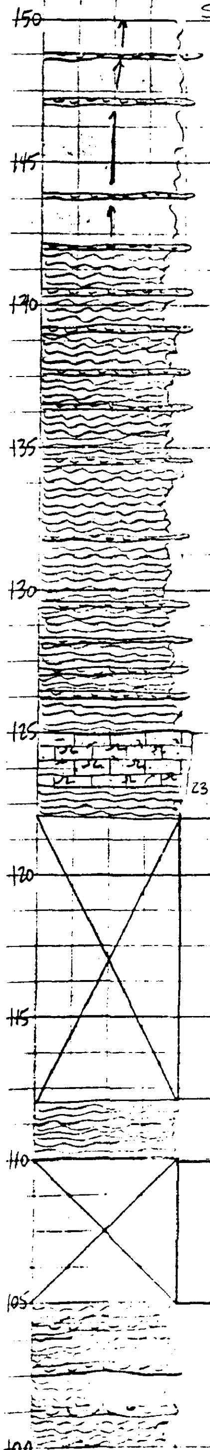
A

(C8)

same with increased soft sediment deformation up section
looks more like RAPLAM now with the bed forms.

(C7)

SPOKANE HILLS SECTION - P. 3



B

Sand becoming dominant, 2-4 cm beds with couplets go from silt dominant, back to sand dominant

less sand, just small ripples, scouring bases on ≤1 cm couplets
rip-ups common

interbedded horiz. and rippled sands 2-5 cm with wavy green silt-argillite couplets ~1 cm

2 ft (60 cm) stromatolitic limestone, molar tooth, large wavy structures with λ of 4 ft.

wavy green silt-argillite couplets

COVERED

B

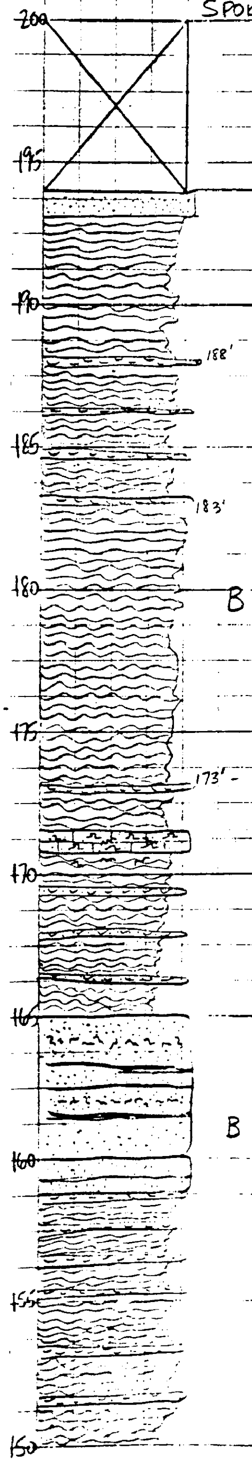
very thin <1 mm bedded sandy green silt-argillite couplets, many tiny mud rip-ups, scour and fill (C-11)

COVERED

B

Same as below, slightly more sandy

SPOKANE HILLS SECTION- P.4



COVERED

35 cm fine 3.0-3.5 ϕ clean green quartzite, well sorted, subrounded clasts horiz. laminations and massive (C13)

same as 173-183'

same as below except 1-5 cm rippled green sands

very fine sandy, slightly wavy, very continuous green silt-argillite couplets 2-5 mm

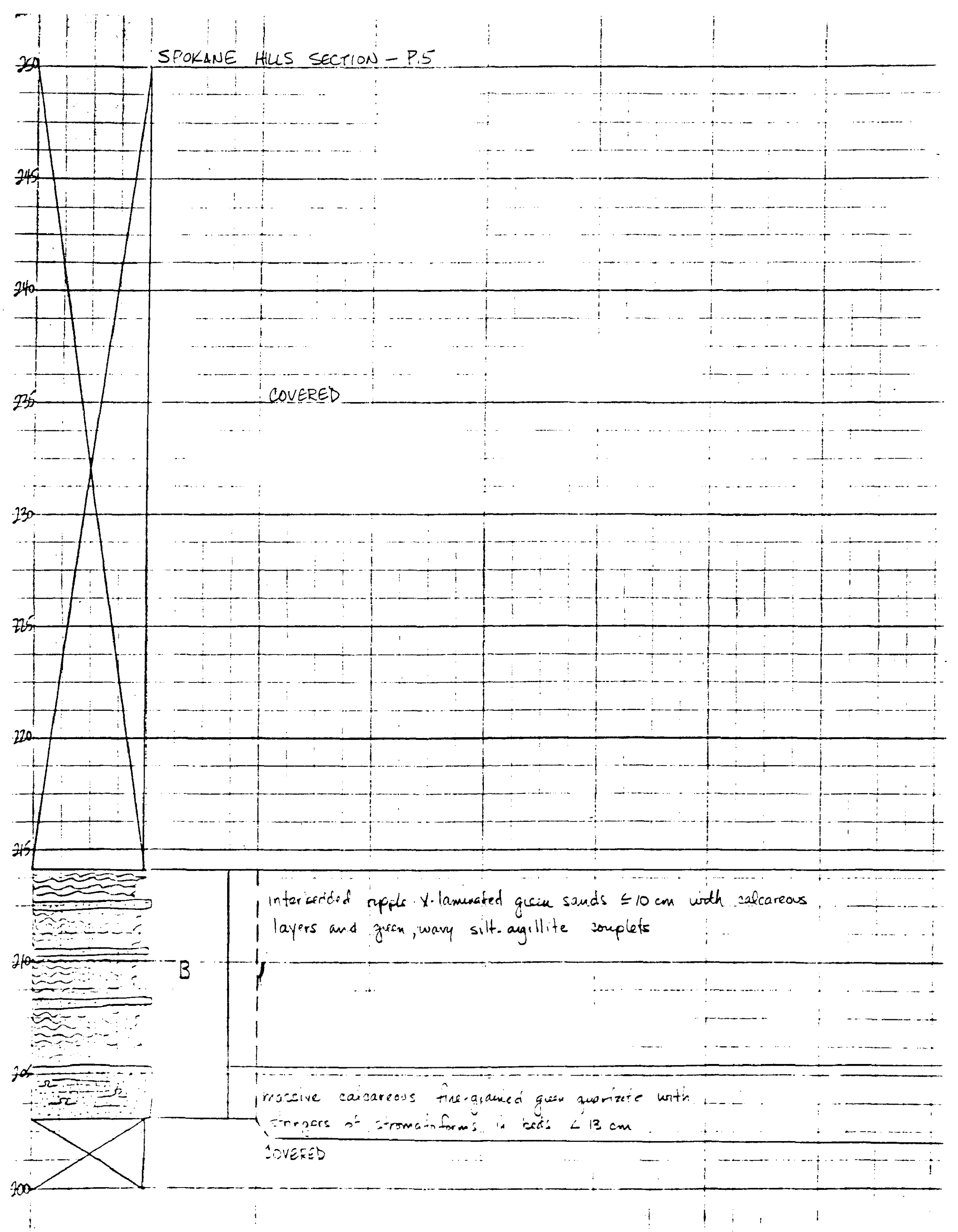
same as 165-171'

20 cm stromatolitic, molar tooth, sandy limestone

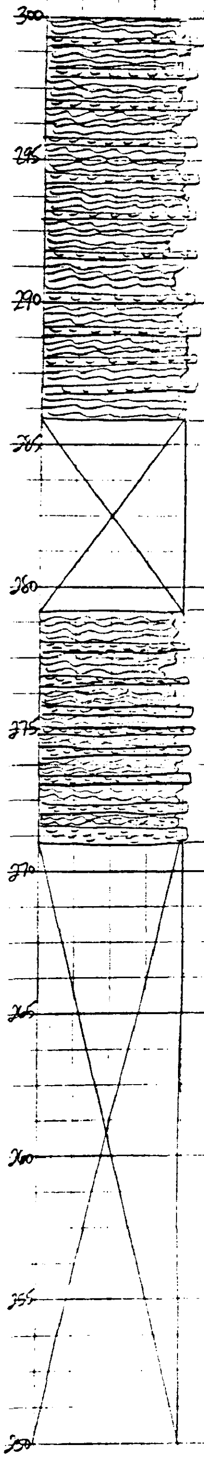
ripple X-laminated sands 1-25 cm interbedded with green silt-argillite couplets 2-3 mm, sand dominant, some molar tooth above 170'

massive, very fine grained >4ϕ greenish white quartzite with some clay and silt beds and stringers, some very dense 10 cm molar tooth layers near 165' (C12)

same as below


SPOKANE HILLS SECTION – P.5
250
245
240
235
COVERED
230
225
220
215
interbedded ripple X-laminated green sands ≤10 cm with calcareous layers and green, wavy silt-argillite couplets
210
B
205
massive calcareous fine-grained green quartzite with stringers of stromatoforms in beds < 13 cm
COVERED
200

SPOKANE HILLS SECTION - P. 6



B — similar to below, but fairly regular fine green sands 3-7 cm fining upward into very wavy, rippled, mud cracked, rip-up red argillite

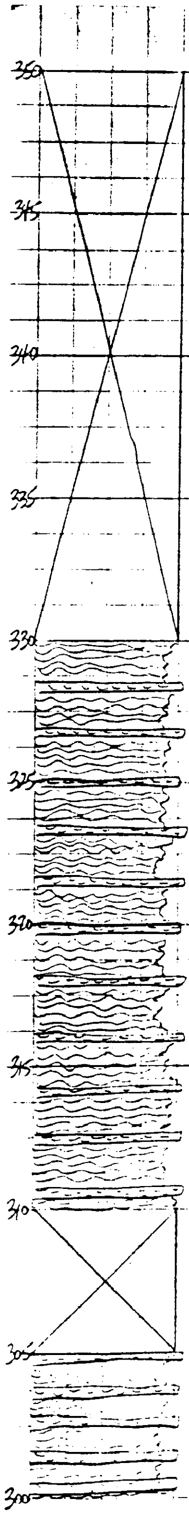
same as below, but green, many mudchips possible salt casts? mudcracks, lots of scours, ripple marks (C16) micaceous

COVERED

B — dominantly green ripple X-laminated fine sands with silt-argillite couplets 2-3mm and stringers of clay, after 275', same but becoming maroon colored (silt) and mud chips present (C15)

COVERED

SPOKANE HILLS SECTION - P.7



COVERED with green sandy silt-argillite float

interbedded fine green sands with silt-argillite couplets, small rip-ups are red, larger rip-ups are green, gradual color change over ~1ft

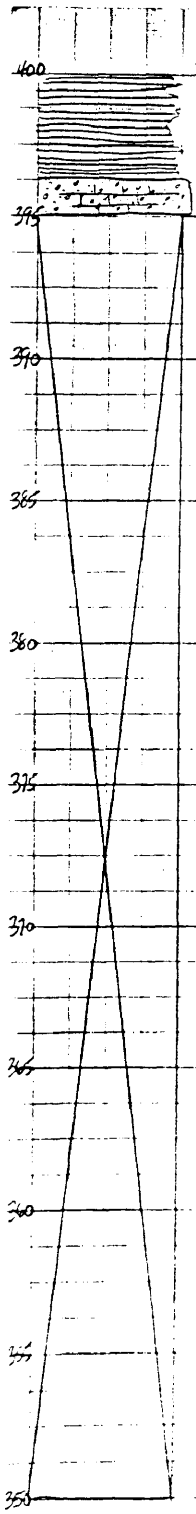
B

COVERED

B

Similar, but much less wavy, only a few rip-ups, very correlative to change in color to green

SPOKANE HILLS SECTION - P.8

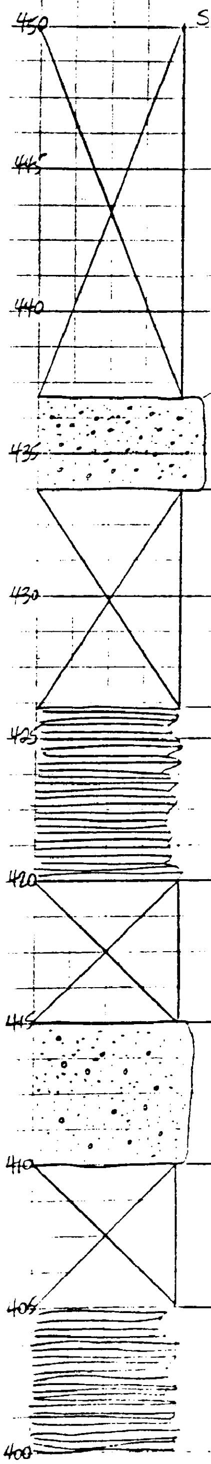


A — thin bedded 1-3mm ionz. green silt-argillite couplets

33cm very fine, very calcareous quartzite, massive

COVERED with green float (same as below)

SPOKANE HILLS SECTION – P.9



COVERED

C — 3ft. very prominant ridge forming quartzite (looks like Flathead) 2.5-3.0 ø, well sorted, rounded quartzite massive, very white (C19)

COVERED

A — thin bedded 2-3 mm, horz. continuous green sandy silt-argillite couplets

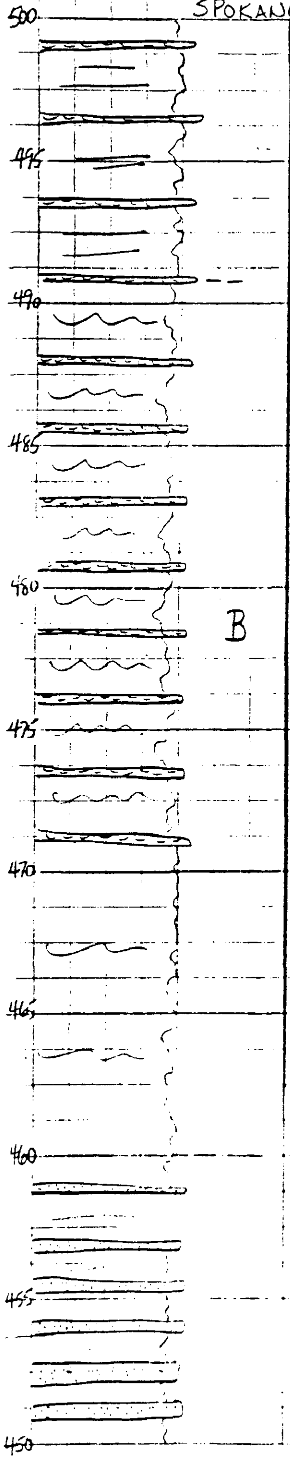
COVERED

? could be very dirty sandstone, more likely a SILL (C18)

COVERED

A — same as below

SPOKANE HILLS SECTION — P. 10



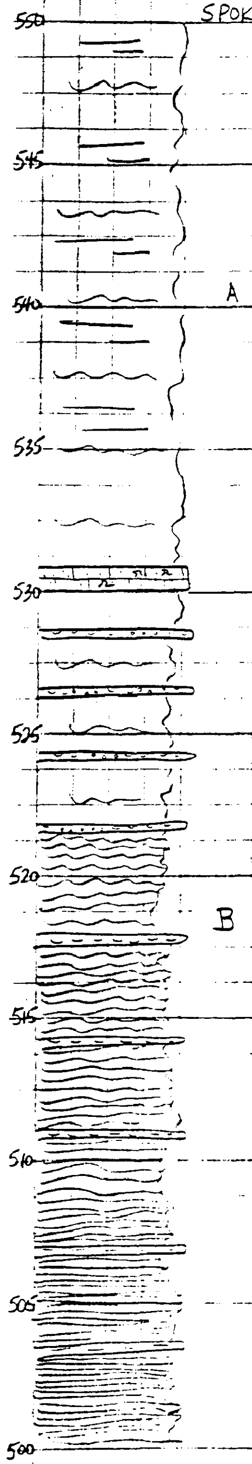
same but losing ripples, clay very dominant, occurring in 5mm beds RED near 500

then, wavy green silt-argillite couplets interbedded with green fine sands with much planar and trough X bedding, all directions. Layers of rippled material are surrounded by continuous beds that curve around ripples

thin bedded 1-3mm wavy green silt-argillite couplets

interbedded fine horizontal or massive quartzites with thin 2-3mm wavy buff colored silt-argillite couplets, sands 10-12 cm

SPOKANE HILLS SECTION - P. 11



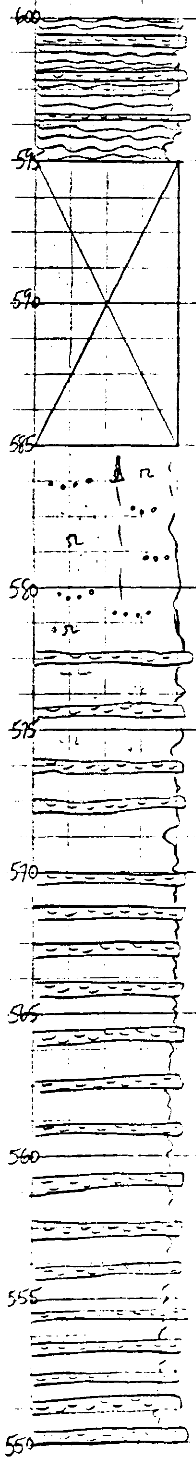
horizontal - slightly wavy green silt-argillite couplets 2-3 mm

10 cm sandy stromatolitic limestone

thin, horizontal laminated sands with some ripple X-laminations containing much coarser material interbedded with green silt-argillite couplets with some rip-ups, coarse material up to 10-20 ø, poorly sorted, subangular-rounded clasts, mostly quartz

same with ≤5 cm sand layers

SPOKANE HILLS SECTION - P. 12



B — interbedded X-bedded and horizontal sands with silt-argillite couplets
red and green sands 2-10 cm, red near top

COVERED

blocky outcrop, same calcic green, stromatoforms, little coarse stringers

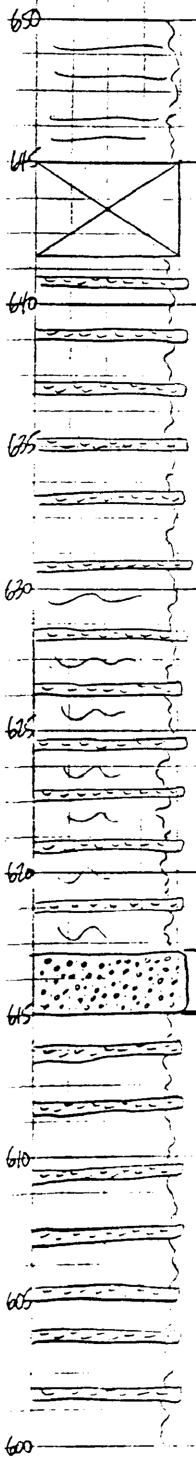
becomes calcareous, 'chalky'

B

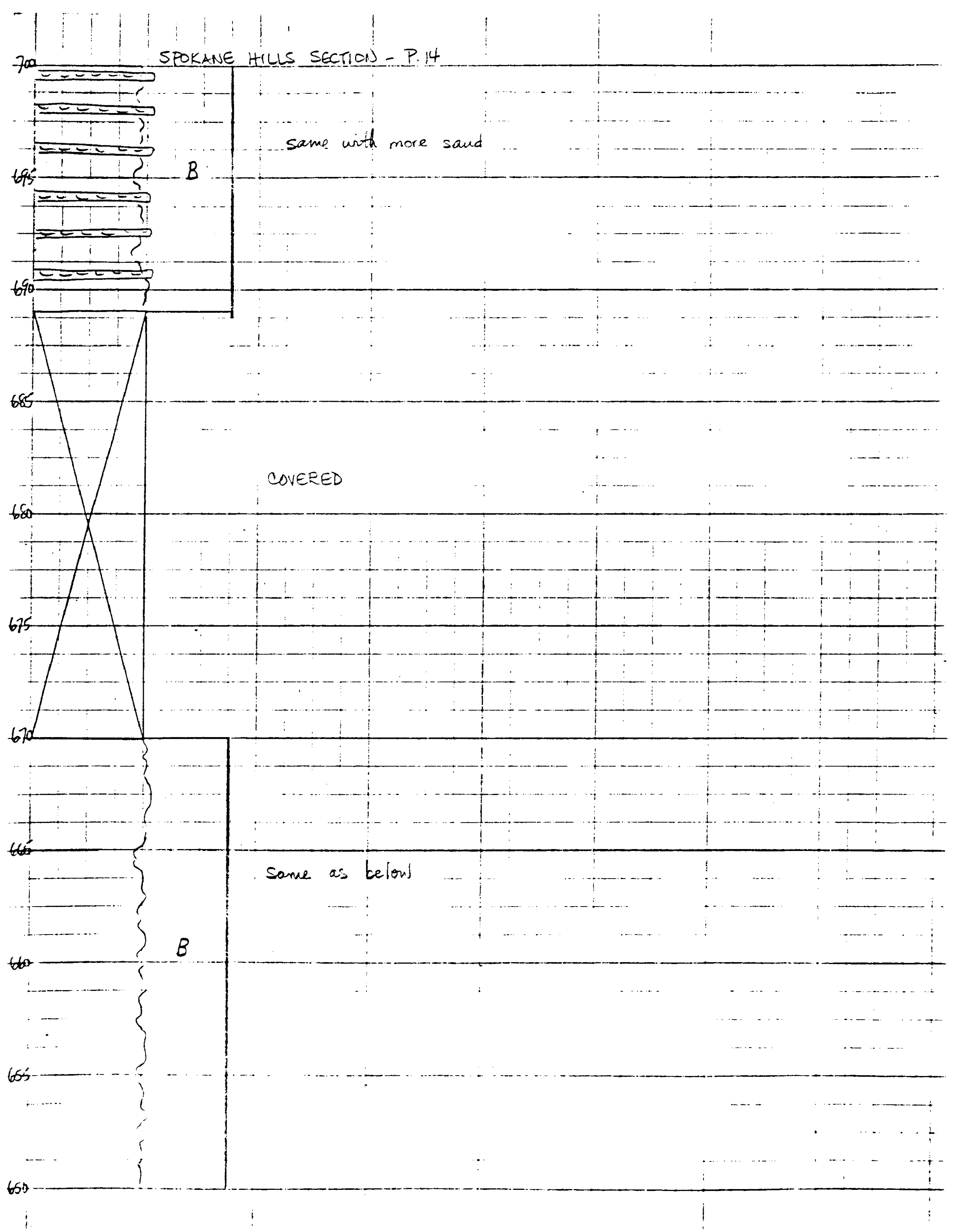
horizontal sand dominant

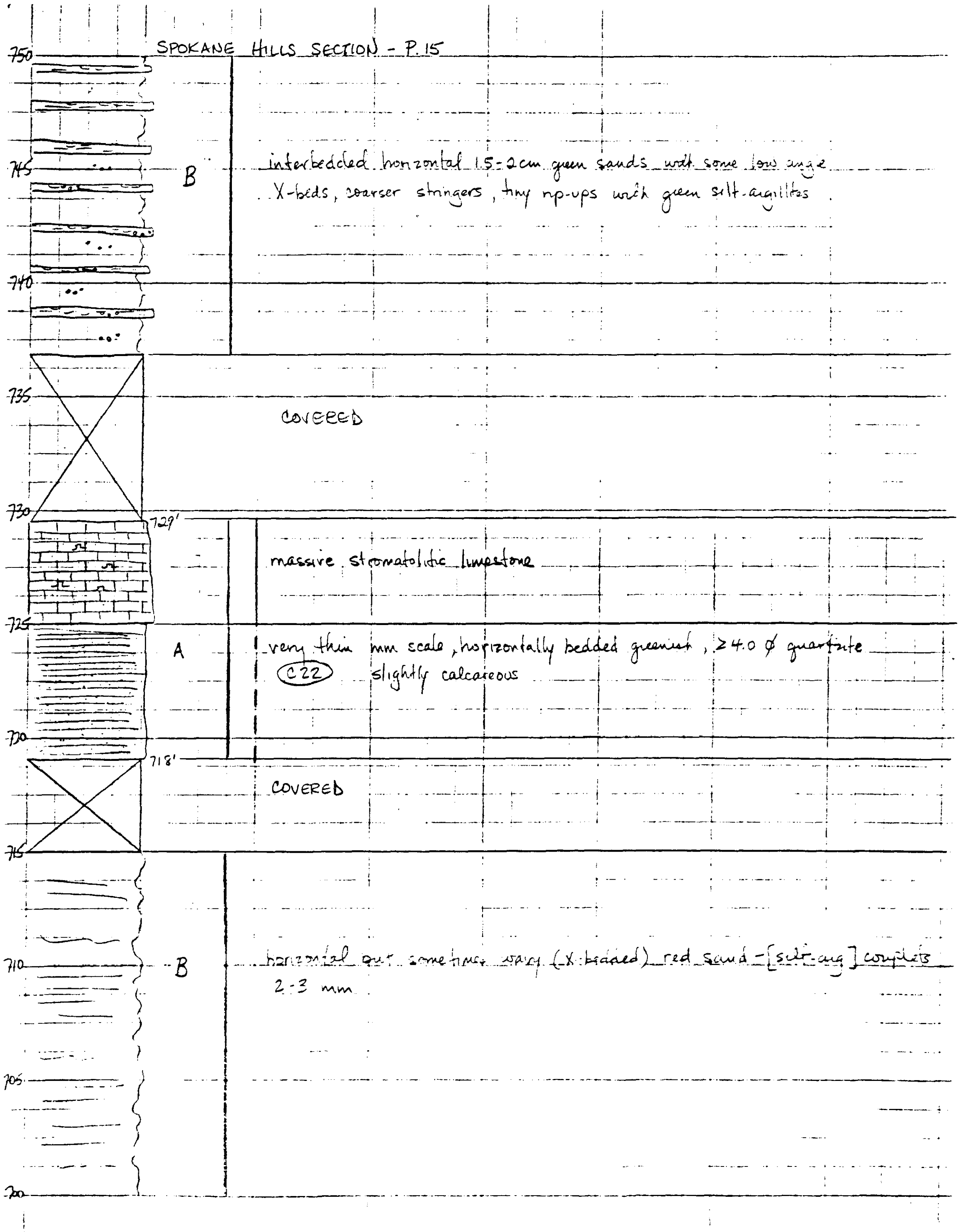
same as below, getting very sandy

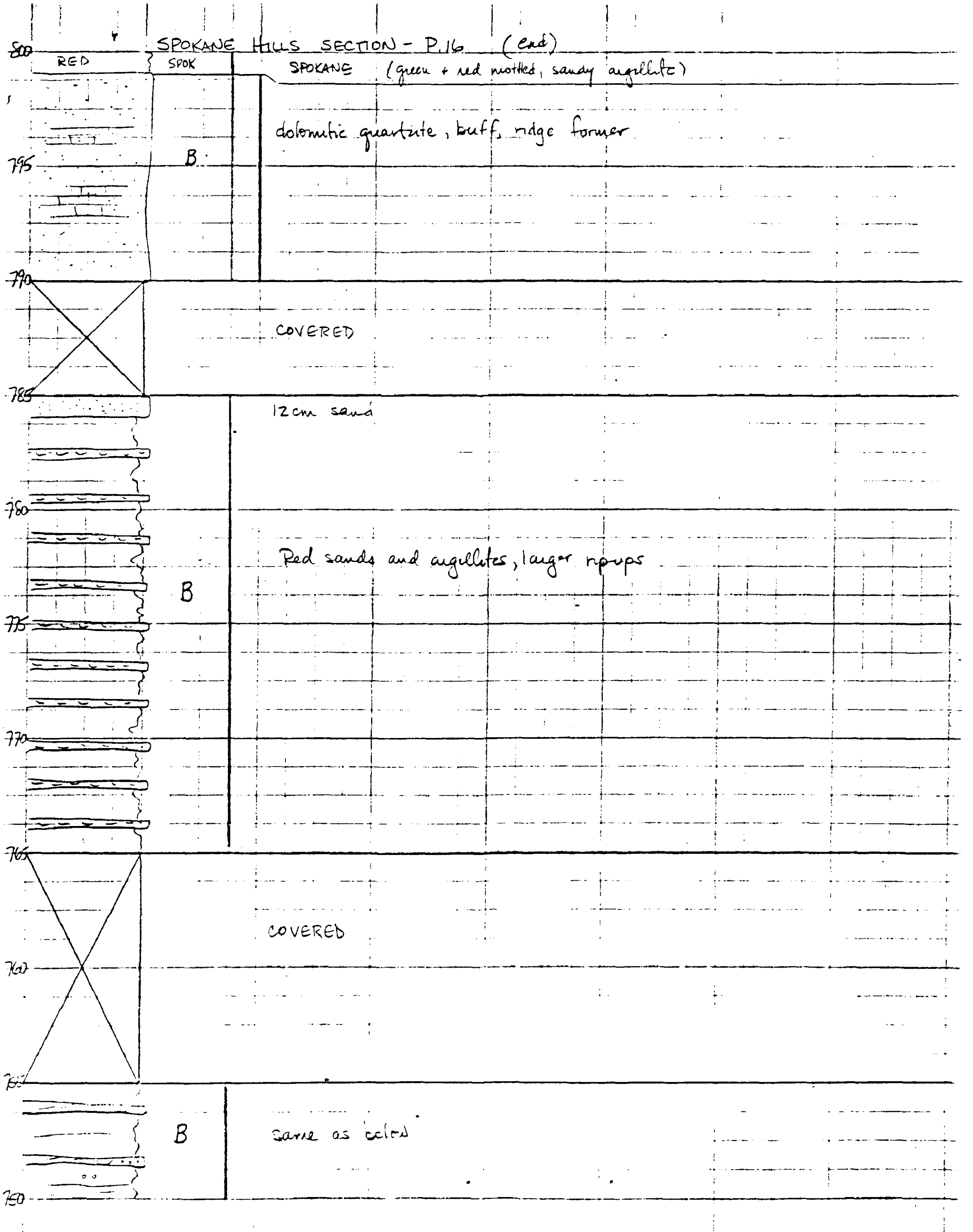
SPOKANE HILLS SECTION - P. 13



B	thin-bedded, calcareous green silt-argillite couplets ~1 cm some outcrop covered but appears continuous
	COVERED
B	interbedded wavy 2cm bedded green silt-argillite couplets with ≤12cm horiz and ripple X-lam fine sands with mudchip intervals; sands become coarser and clays redden near 640'
C	75 cm coarse, poorly sorted (0.0-3.0 ϕ) rounded-well rounded slightly feldspathic quartzite, fining upward (C21)
B	Same as below


SPOKANE HILLS SECTION - P. 14
700
same with more sand
695
B
690
685
COVERED
680
675
670
665
Same as below
B
660
655
650


SPOKANE HILLS SECTION - P. 15
750
745
B
interbedded horizontal 1.5-2cm green sands with some low angle X-beds, coarser stringers, tiny rip-ups with green silt-argillites
740
735
COVERED
730
729'
massive stromatolitic limestone
725
A
very thin mm scale, horizontally bedded greenish, ≥4.0 ϕ quartzite
C22
slightly calcareous
720
718'
COVERED
715
710
B
horizontal but sometimes wavy (X-bedded) red sand-[silt-arg] couplets 2-3 mm
705
700


SPOKANE HILLS SECTION - P.16 (end)
800
RED
SPOK
SPOKANE (green + red mottled, sandy argillite)
dolomitic quartzite, buff, ridge former
B
795
790
COVERED
785
12cm sand
780
Red sands and argillites, larger ripups
B
775
770
765
COVERED
760
B
Same as below
750

Appendix C

Gravity data

Lat.	Long.	Elev.	Obs. grav.	F.A.A.	S.B.A.
47.0027	-112.1963	1568.2	980336.12	19.80	-155.50
47.0053	-112.0412	1079.6	980441.38	-25.70	-146.60
47.0067	-112.0700	1084.8	980437.57	-27.90	-149.30
47.0083	-112.0650	1085.1	980437.49	-28.20	-149.60
47.0100	-112.0650	1099.4	980436.12	-25.40	-148.40
47.0148	-112.5475	1492.6	980349.64	6.30	-158.00
47.0200	-112.9443	1316.1	980384.99	-10.60	-157.60
47.0202	-112.9850	1298.1	980367.72	-33.40	-178.70
47.0388	-112.2392	1649.0	980332.66	38.00	-146.40
47.0460	-112.5453	1544.4	980351.31	23.70	-148.90
47.0463	-112.9635	1341.1	980373.68	-16.50	-166.60
47.0483	-112.4300	1542.0	980348.77	20.30	-152.10
47.0490	-112.9213	1338.0	980376.08	-15.30	-165.00
47.0517	-112.1300	1295.4	980400.37	-4.30	-149.30
47.0535	-112.7463	2422.8	980174.65	117.40	-153.50
47.0538	-112.8905	1458.4	980350.61	1.90	-161.30
47.0552	-112.8323	2369.8	980172.40	98.70	-156.30
47.0560	-112.7533	2547.8	980152.69	131.80	-152.40
47.0600	-112.5462	1574.6	980348.64	29.30	-146.70
47.0630	-112.7200	2425.6	980174.71	117.50	-153.70
47.0663	-112.9520	1356.3	980379.81	-7.50	-159.30
47.0710	-112.8252	2431.0	980164.91	108.70	-163.20
47.0725	-112.7765	2644.7	980134.89	144.50	-151.30
47.0742	-112.6610	2209.5	980228.03	103.10	-143.90
47.0768	-112.9363	1715.1	980307.63	29.90	-161.80
47.0775	-112.3700	1709.6	980325.07	45.70	-145.60
47.0780	-112.7583	2452.1	980171.20	120.80	-153.40
47.0783	-112.6220	1634.6	980349.86	36.20	-144.60
47.0812	-112.8632	2401.8	980170.87	104.70	-163.90
47.0817	-112.0650	1176.2	980435.07	-14.10	-145.70
47.0868	-112.5995	1692.2	980331.17	45.50	-143.70
47.0877	-112.5325	2034.2	980259.98	79.80	-147.70
47.0880	-112.6132	1703.2	980330.98	48.60	-141.80
47.0903	-112.6417	1634.9	980342.37	36.70	-144.10
47.0950	-112.3550	1650.2	980329.27	30.00	-154.50
47.0970	-112.7307	2513.0	980162.41	129.10	-151.90
47.0983	-112.6830	2238.1	980219.94	101.70	-148.60
47.1002	-112.8713	2443.2	980168.53	113.40	-159.80
47.1033	-112.7675	2548.4	980147.20	124.30	-160.70
47.1112	-112.0643	1254.6	980418.22	-4.50	-144.90
47.1127	-112.8470	2214.6	980223.58	96.80	-150.80
47.1133	-112.6090	2062.2	980253.29	79.40	-151.20
47.1147	-112.5272	2368.6	980189.72	110.30	-154.60
47.1147	-112.5277	2368.6	980189.28	109.80	-155.00
47.1150	-112.1683	1352.7	980392.37	-0.40	-151.70
47.1167	-112.7380	2868.4	980071.97	146.60	-174.20
47.1170	-112.8103	1812.3	980308.53	57.20	-145.40
47.1200	-112.8998	2466.7	980153.04	104.00	-171.80
47.1218	-112.5913	2419.2	980187.27	122.90	-147.70
47.1225	-112.5812	1765.9	980338.10	72.30	-125.30
47.1272	-112.6700	2263.4	980221.28	108.20	-144.80
47.1278	-112.4663	1673.0	980336.59	41.60	-145.40
47.1302	-112.8315	2432.6	980175.61	114.50	-157.50
47.1317	-112.7278	2554.2	980154.68	132.00	-154.60
47.1330	-112.6160	1855.0	980306.20	65.60	-140.80
47.1347	-112.1758	1414.5	980389.17	13.60	-144.60
47.1370	-112.5133	2300.9	980195.07	111.30	-152.70
47.1385	-112.4565	1698.9	980333.79	45.50	-144.40
47.1386	-112.5392	2024.7	980266.91	91.20	-145.20
47.1395	-112.5603	2289.9	980212.73	106.30	-149.30
47.1404	-112.3200	1371.3	980390.57	1.20	-152.10
47.1413	-112.9130	2555.1	980139.60	115.50	-170.20
47.1422	-112.7710	2245.7	980220.24	100.40	-150.70
47.1430	-112.5670	2277.1	980216.99	106.80	-147.80

47.1453	-112.8207	2490.5	980161.36	116.80	-151.70
47.1465	-112.6825	2068.5	980263.09	89.00	-142.30
47.1500	-112.0850	1242.1	980420.47	-9.40	-148.50
47.1550	-112.2133	1257.0	980415.47	-10.40	-151.00
47.1550	-112.6033	2381.4	980193.98	114.30	-151.50
47.1562	-112.8398	1752.6	980322.23	48.90	-147.00
47.1580	-112.6990	2564.5	980138.38	115.50	-171.30
47.1630	-112.5830	2434.1	980188.66	125.10	-147.10
47.1673	-112.9672	2545.3	980141.12	111.40	-173.20
47.1687	-112.4535	1920.2	980293.61	71.00	-143.70
47.1703	-112.5532	2441.8	980183.63	120.50	-151.50
47.1712	-112.5033	2478.6	980170.41	119.80	-157.30
47.1772	-112.7225	2203.1	980236.77	100.60	-145.70
47.1790	-112.9248	1524.0	980356.08	10.20	-150.20
47.1805	-112.7713	2298.5	980211.33	104.80	-152.20
47.1815	-112.6740	2428.0	980181.89	114.80	-156.70
47.1852	-112.8037	2141.2	980250.30	94.30	-145.10
47.1883	-112.5730	2668.5	980124.27	130.60	-157.70
47.1885	-112.5272	2150.6	980246.64	93.30	-147.20
47.1893	-112.8500	2033.6	980268.33	78.90	-148.60
47.1932	-112.5963	2637.1	980137.62	134.00	-150.90
47.1933	-112.0933	1174.7	980433.22	-16.50	-148.00
47.2002	-112.2722	1294.7	980417.88	-0.50	-145.40
47.2002	-112.7950	2524.3	980164.38	125.30	-157.90
47.2065	-112.7427	2514.3	980171.56	128.80	-152.40
47.2085	-112.8613	2015.9	980273.07	77.10	-148.30
47.2097	-112.7705	2616.4	980147.13	135.60	-157.00
47.2098	-112.9630	2137.5	980239.25	78.90	-160.10
47.2117	-112.5217	1585.0	980361.45	31.50	-145.70
47.2138	-112.0562	2195.1	980240.26	98.40	-147.10
47.2167	-112.1117	1205.8	980430.97	-16.30	-151.30
47.2187	-112.4760	1366.7	980300.66	63.20	-147.90
47.2203	-112.6967	2349.7	980211.74	115.90	-145.80
47.2207	-112.9048	2334.5	980202.94	94.20	-163.50
47.2222	-112.2267	1279.7	980424.01	-1.30	-144.40
47.2222	-112.8432	2330.5	980206.79	105.90	-154.70
47.2232	-112.4378	1668.3	980343.82	35.70	-147.90
47.2232	-112.8133	2551.1	980159.39	126.50	-158.80
47.2245	-112.7630	2545.3	980164.57	129.80	-154.80
47.2257	-112.0873	1216.9	980428.80	-15.90	-152.10
47.2267	-112.5650	2199.7	980229.74	88.10	-157.80
47.2270	-112.8200	2438.4	980131.34	113.30	-159.40
47.2280	-112.8815	2251.2	980218.84	93.00	-158.70
47.2308	-112.3250	1363.0	980407.98	7.80	-144.70
47.2310	-112.4790	1585.0	980365.48	33.80	-143.40
47.2350	-112.6433	2155.9	980241.59	85.70	-155.30
47.2386	-112.9227	2171.0	980229.30	77.70	-165.00
47.2423	-112.6530	2108.6	980256.56	85.50	-150.30
47.2457	-112.3512	1368.1	980406.91	6.90	-146.10
47.2465	-112.8113	2357.6	980204.09	110.00	-153.60
47.2467	-112.2250	1272.2	980426.77	-2.60	-145.10
47.2478	-112.7452	2599.9	980144.55	124.50	-156.20
47.2482	-112.7550	2419.0	980168.60	102.00	-171.90
47.2488	-112.9685	1918.1	980274.90	44.30	-170.10
47.2553	-112.2227	1284.7	980424.49	-2.30	-145.80
47.2638	-112.4823	1467.6	980378.03	7.10	-156.90
47.2650	-112.5467	1639.8	980352.96	35.10	-148.20
47.2667	-112.8717	2517.6	980174.27	127.10	-154.40
47.2667	-112.9333	2255.5	980219.84	91.60	-150.40
47.2667	-112.9883	1825.4	980298.68	37.90	-156.10
47.2700	-112.6750	2014.7	980275.49	72.60	-152.40
47.2717	-112.9383	2374.1	980180.31	38.40	-177.10
47.2733	-112.8983	2192.1	980261.08	82.60	-151.90
47.2733	-112.9450	2407.0	980137.66	98.80	-170.40
47.2750	-112.8250	2246.3	980226.98	95.40	-155.80
47.2765	-112.4817	1435.5	980387.56	5.70	-154.60

47.2768	-112.3865	1423.3	980394.49	3.70	-150.40
47.2783	-112.7250	2346.5	980209.68	108.70	-153.70
47.2805	-112.4060	1424.7	980385.48	2.60	-156.50
47.2833	-112.5517	2290.7	980203.63	86.80	-170.30
47.2850	-112.5133	1554.5	980368.27	22.30	-151.50
47.2883	-112.1583	1273.0	980423.72	-7.80	-150.80
47.2900	-112.1600	1265.8	980424.37	-11.60	-152.70
47.2900	-112.6157	2198.5	980236.43	88.70	-157.10
47.2927	-112.1667	1271.9	980423.74	-10.10	-152.40
47.2933	-112.7467	2180.8	980238.41	85.00	-158.90
47.2933	-112.7917	2405.7	980195.17	111.10	-157.90
47.2933	-112.9717	1960.4	980281.62	60.10	-159.10
47.2950	-112.6600	2176.8	980238.85	83.90	-159.50
47.3058	-112.8467	2610.5	980141.59	119.70	-172.20
47.3065	-112.4115	1409.7	980395.61	4.90	-154.50
47.3092	-112.2585	1341.3	980413.99	3.00	-150.00
47.3100	-112.8667	2615.1	980141.42	120.50	-172.00
47.3100	-112.9283	2576.4	980146.50	113.60	-174.50
47.3108	-112.6456	2610.6	980150.92	128.50	-163.50
47.3115	-112.1085	1239.9	980433.05	-12.30	-151.10
47.3133	-112.7500	2189.9	980237.57	85.00	-159.60
47.3133	-112.8300	2635.0	980142.74	127.60	-167.10
47.3138	-112.4752	1487.4	980377.65	6.30	-158.00
47.3150	-112.7117	1758.7	980331.76	46.10	-150.50
47.3150	-112.7600	2169.3	980238.33	79.40	-163.20
47.3168	-112.1055	1255.6	980429.34	-11.70	-152.20
47.3183	-112.9917	2413.1	980176.50	92.00	-177.40
47.3217	-112.7833	1892.8	980296.37	51.50	-150.10
47.3227	-112.8150	2334.5	980213.95	95.10	-155.60
47.3262	-112.4407	1425.5	980391.05	1.50	-157.80
47.3275	-112.3888	1388.7	980402.26	1.20	-154.00
47.3285	-112.2233	1290.1	980422.00	-9.40	-153.80
47.3313	-112.7297	1797.1	980320.21	44.90	-156.10
47.3317	-112.8767	2703.8	980119.97	124.40	-178.00
47.3330	-112.4652	1460.2	980383.27	3.80	-159.50
47.3333	-112.7717	2312.2	980215.93	39.30	-159.20
47.3333	-112.8333	2493.2	980161.81	101.00	-177.80
47.3343	-112.5805	1509.0	980367.41	2.90	-155.90
47.3350	-112.2183	1306.7	980420.77	-6.00	-152.30
47.3357	-112.7133	2136.9	980250.16	79.30	-159.60
47.3358	-112.3805	1385.9	980402.53	-0.10	-155.00
47.3367	-112.7700	2376.2	980196.29	99.10	-166.60
47.3417	-112.7667	1986.4	980284.26	66.40	-155.70
47.3417	-112.9100	2767.5	980096.82	120.00	-189.50
47.3433	-112.8083	2342.6	980208.19	100.00	-151.90
47.3450	-112.8917	2530.1	980154.42	104.00	-179.90
47.3455	-112.3350	1360.9	980409.46	-1.70	-153.90
47.3467	-112.6883	1836.4	980312.87	48.20	-157.10
47.3467	-112.8150	2356.4	980200.77	96.60	-166.90
47.3467	-112.9333	2581.7	980152.49	117.90	-170.80
47.3533	-112.4850	1413.4	980392.37	-3.30	-161.30
47.3592	-112.5217	1425.8	980386.51	-3.80	-163.40
47.3617	-112.8500	2491.1	980167.61	103.60	-174.90
47.3627	-112.2667	1341.8	980411.83	-6.70	-156.90
47.3633	-112.5417	1537.7	980365.29	7.00	-164.90
47.3642	-112.0508	1252.9	980437.29	-8.80	-149.00
47.3650	-112.9250	2484.1	980170.00	103.60	-174.20
47.3683	-112.7600	2418.5	980188.19	101.20	-159.20
47.3705	-112.4982	1377.7	980403.17	-5.00	-159.10
47.3722	-112.4477	1375.3	980403.48	-5.50	-159.40
47.3733	-112.6267	1576.7	980355.24	4.10	-158.20
47.3767	-112.8583	2478.9	980158.64	99.60	-177.60
47.3783	-112.2933	1360.6	980411.07	-3.10	-155.30
47.3783	-112.2850	1291.1	980425.42	-10.20	-154.60
47.3800	-112.3000	1352.1	980417.69	-6.20	-157.50
47.3822	-112.1235	1352.0	980409.92	-7.20	-158.50

47.3843	-112.4480	1359.7	980426.37	-8.60	-150.60
47.3883	-112.9217	2336.7	980185.74	85.30	-150.90
47.3900	-112.7700	2482.6	980172.09	102.90	-174.70
47.3913	-112.1992	1282.4	980424.41	-15.10	-158.60
47.3917	-112.5467	1677.3	980335.86	18.10	-159.40
47.3958	-112.6297	1539.9	980364.26	3.70	-158.50
47.3967	-112.8433	1770.8	980317.48	23.10	-159.90
47.3997	-112.3235	1297.2	980422.31	-13.40	-158.50
47.4017	-112.7967	2474.9	980171.50	98.90	-177.80
47.4017	-112.9433	2425.2	980174.99	87.00	-184.20
47.4050	-112.5950	1487.4	980374.12	-3.40	-159.70
47.4060	-112.3925	1289.3	980422.83	-15.80	-160.20
47.4067	-112.7550	1697.7	980336.94	24.10	-155.70
47.4100	-112.7083	1571.2	980368.14	16.00	-159.70
47.4117	-112.1315	1193.3	980445.60	-21.60	-155.70
47.4130	-112.5788	1487.8	980375.33	-2.70	-159.20
47.4133	-112.9200	2485.0	980167.97	97.50	-186.40
47.4168	-112.2302	1239.[illegible]	980435.80	-19.40	-158.70
47.4197	-112.2563	1236.6	980436.11	-20.00	-158.40
47.4200	-112.7867	1780.9	980322.40	34.00	-165.00
47.4217	-112.8500	1737.6	980325.42	21.40	-172.10
47.4223	-112.4640	1310.9	980415.87	-17.50	-164.20
47.4233	-112.3417	1275.3	980430.14	-14.30	-157.10
47.4233	-112.8950	1747.1	980320.59	21.50	-173.80
47.4250	-112.4750	1312.3	980414.17	-18.90	-165.80
47.4250	-112.5550	1357.3	980400.06	-19.30	-171.20
47.4250	-112.6333	1386.8	980395.36	-14.90	-170.10
47.4250	-112.8717	2241.8	980218.58	72.00	-178.70
47.4258	-112.8142	2370.1	980192.82	85.80	-179.30
47.4300	-112.6767	1525.5	980378.67	17.60	-159.90
47.4338	-112.1333	1175.[illegible]	980451.60	-24.60	-156.10
47.4367	-112.8033	1779.1	980324.61	34.30	-161.60
47.4388	-112.0500	1173.9	980459.34	-17.90	-149.30
47.4392	-112.4588	1300.8	980418.28	-19.60	-165.40
47.4408	-112.5233	1318.3	980424.73	-15.00	-155.50
47.4417	-112.3450	1291.1	980430.[illegible]7	-11.20	-155.60
47.4427	-112.5263	1322.8	980413.17	-18.50	-166.50
47.4470	-112.8205	1723.5	980331.82	23.30	-169.50
47.4483	-112.8167	1744.1	980331.75	29.60	-155.40
47.4483	-112.9133	1712.1	980330.66	18.50	-172.90
47.4500	-112.9900	2472.2	980168.60	90.20	-186.20
47.4517	-112.4423	1282.6	980425.20	-19.60	-163.10
47.4517	-112.8917	2442.9	980168.66	91.70	-191.40
47.4518	-112.3592	1253.9	980435.85	-17.90	-158.20
47.4533	-112.8917	2462.5	980168.42	87.40	-198.00
47.4547	-112.6575	1454.9	980388.79	-3.10	-165.90
47.4550	-112.8551	2115.3	980251.45	63.50	-173.60
47.4583	-112.8383	1723.0	980337.97	28.30	-164.30
47.4583	-112.9983	2347.0	980201.53	84.40	-178.00
47.4633	-112.8733	1670.3	980351.11	24.70	-162.00
47.4683	-112.9083	2349.4	980191.82	74.50	-188.20
47.4693	-112.5930	1382.2	980400.93	-14.80	-169.40
47.4700	-112.2572	1239.6	980442.92	-16.30	-155.50
47.4717	-112.9250	1669.3	980334.49	7.00	-179.60
47.4717	-112.9283	1663.6	980338.60	9.40	-176.60
47.4733	-112.8583	1689.2	980346.57	25.40	-153.40
47.4750	-112.4167	1255.2	980435.37	-18.90	-159.40
47.4807	-112.4700	1311.6	980420.56	-16.20	-164.80
47.4898	-112.3910	1241.1	980443.31	-17.30	-156.70
47.4932	-112.3967	1243.6	980442.44	-18.10	-157.30
47.4950	-112.1856	1169.3	980456.96	-27.50	-153.70
47.4950	-112.8883	1622.8	980360.[illegible]2	16.10	-155.30
47.4985	-112.2418	1173.1	980461.58	-21.20	-152.50
47.5000	-112.1450	1173.5	980462.[illegible]7	-21.70	-152.00
47.5022	-112.1207	1159.7	980463.00	-24.30	-154.10
47.5033	-112.2583	1176.2	980400.95	-21.30	-152.90

47.5050	-112.2383	1161.9	980468.27	-18.50	-148.50
47.5059	-112.2567	1187.2	980461.77	-17.90	-150.80
47.5053	-112.9653	2592.1	980183.25	129.80	-170.10
47.5052	-112.2287	1166.8	980462.28	-23.10	-153.70
47.5067	-112.0138	1124.4	980475.08	-23.60	-149.40
47.5075	-112.7262	1760.2	980337.62	35.00	-161.80
47.5100	-112.3008	1194.8	980456.04	-19.10	-152.80
47.5117	-112.3600	1235.1	980449.52	-15.40	-153.60
47.5117	-112.3650	1224.1	980449.85	-16.40	-155.40
47.5133	-112.3690	1235.1	980451.37	-14.60	-152.80
47.5138	-112.5958	1433.8	980396.75	-7.70	-168.20
47.5212	-112.3603	1250.9	980451.42	-9.50	-119.50
47.5235	-112.5808	1408.2	980400.69	-11.80	-169.40
47.5238	-112.4573	1276.8	980437.13	-16.00	-153.90
47.5240	-112.9180	1969.9	980284.27	44.90	-175.40
47.5283	-112.4583	1273.1	980440.87	-14.50	-157.00
47.5315	-112.9552	2245.7	980241.97	87.00	-164.20
47.5368	-112.5992	1433.0	980398.74	-7.40	-157.70
47.5447	-112.9437	1959.8	980302.28	57.90	-161.30
47.5458	-112.4717	1260.5	980441.85	-15.40	-157.50
47.5483	-112.3633	1213.1	980458.29	-16.60	-152.40
47.5578	-112.4975	1280.7	980440.16	-14.80	-158.20
47.5587	-112.9205	1524.0	980377.71	-2.30	-172.70
47.5650	-112.3483	1253.5	980453.87	-10.90	-150.30
47.5663	-112.9397	1849.5	980316.13	35.80	-171.10
47.5667	-112.8733	2224.1	980241.38	76.70	-172.00
47.5683	-112.2352	1265.3	980447.78	-12.70	-154.40
47.5813	-112.0627	1203.7	980461.41	-19.50	-154.20
47.5817	-112.3315	1304.1	980445.64	-4.30	-150.20
47.5817	-112.5255	1334.1	980426.47	-14.10	-163.40
47.5818	-112.8533	1938.8	980297.06	43.80	-173.10
47.5865	-112.1563	1319.3	980437.70	-8.[illegible]	-155.60
47.5867	-112.9920	2585.3	980161.64	106.50	-182.70
47.5870	-112.9792	2388.7	980203.29	87.50	-179.70
47.5923	-112.5742	1368.9	980418.57	-12.10	-165.30
47.5928	-112.1565	1301.5	980441.73	-10.00	-155.60
47.5962	-112.2417	1353.9	980435.78	-0.10	-151.60
47.6000	-112.2412	1349.0	980438.29	0.40	-150.40
47.6003	-112.8515	1925.7	980303.60	43.70	-171.70
47.6013	-112.9417	2225.9	980236.69	71.40	-177.60
47.6023	-112.7607	1441.7	980407.76	-1.60	-162.90
47.6028	-112.9068	2123.8	980257.01	58.00	-179.40
47.6033	-112.9237	2123.8	980265.49	66.50	-171.10
47.6042	-112.6008	1322.5	980428.97	-17.30	-165.30
47.6100	-112.7400	1367.0	980422.57	-10.30	-153.20
47.6132	-112.9820	2567.9	980166.32	105.50	-181.80
47.6145	-112.7923	1441.7	980409.53	-0.90	-162.10
47.6160	-112.6605	1349.7	980428.48	-10.50	-161.50
47.6167	-112.6217	1332.3	980428.27	-16.00	-165.10
47.6177	-112.6950	1361.3	980426.43	-9.10	-161.40
47.6192	-112.8797	1463.0	980403.01	-1.30	-164.90
47.6208	-112.8508	1680.0	980358.94	21.40	-166.50
47.6217	-112.2783	1348.4	980445.67	5.70	-144.90
47.6227	-112.9885	2115.3	980276.34	72.90	-163.60
47.6238	-112.7373	1414.3	980415.04	-3.70	-161.90
47.6267	-112.2683	1342.3	980446.12	3.70	-146.30
47.6280	-112.9625	2151.9	980278.76	58.40	-172.20
47.6292	-112.5987	1374.1	980416.69	-16.80	-159.40
47.6302	-112.8507	1449.3	980406.56	-2.60	-154.70
47.6350	-112.0067	1152.4	980487.27	-21.20	-150.20
47.6355	-112.9942	1536.1	980387.16	3.90	-167.90
47.6357	-112.6468	1365.5	980423.16	-12.50	-155.40
47.6372	-112.6333	1364.1	980424.43	-13.20	-155.40
47.6392	-112.3482	1443.5	980434.29	10.00	-147.00
47.6458	-112.4380	1431.4	980429.37	4.10	-152.60
47.6503	-112.9663	1941.0	980312.01	52.30	-154.60

47.6515	-112.8523	1776.0	980345.29	34.60	-154.00
47.6552	-112.9272	2174.1	980277.31	53.30	-173.70
47.6625	-112.5817	1343.7	980429.51	-15.70	-156.00
47.6682	-112.8627	1494.4	980400.55	1.40	-155.70
47.6695	-112.6433	1476.5	980406.71	2.00	-153.10
47.6707	-112.0930	1168.3	980485.63	-14.30	-115.00
47.6763	-112.1237	1174.1	980487.08	-11.50	-142.90
47.6806	-112.2417	1398.1	980445.47	15.60	-149.70
47.6803	-112.3525	1297.5	980460.69	-0.10	-145.30
47.6815	-112.9870	2427.4	980211.39	99.00	-172.50
47.6823	-112.8080	2506.3	980189.71	101.60	-178.70
47.6842	-112.0292	1150.0	980494.60	-12.00	-140.70
47.6842	-112.7733	2479.5	980191.55	95.00	-132.30
47.6858	-112.8775	1717.4	980361.45	25.50	-164.40
47.6872	-112.2335	1392.3	980445.94	13.60	-142.10
47.6875	-112.9183	1651.4	980371.65	19.30	-155.40
47.6897	-112.8005	2476.5	980201.62	103.60	-173.40
47.6953	-112.0533	1150.0	980500.57	-7.10	-135.60
47.6967	-112.2175	1386.8	980449.93	15.00	-140.10
47.6989	-112.9872	2130.5	980270.85	71.40	-156.90
47.7008	-112.8875	1624.8	980380.40	18.50	-163.10
47.7072	-112.9335	1830.0	980337.97	38.90	-165.80
47.7080	-112.9727	1845.5	980339.46	45.10	-161.30
47.7130	-112.5917	1405.9	980424.77	-5.50	-162.90
47.7132	-112.7762	2432.3	980218.60	104.90	-167.20
47.7217	-112.5867	1492.0	980413.40	8.70	-158.10
47.7230	-112.8768	1741.3	980359.44	31.60	-163.20
47.7322	-112.8117	2545.6	980139.61	109.20	-175.60
47.7343	-112.3655	1250.4	980479.50	-9.80	-149.70
47.7392	-112.4997	1377.9	980438.77	-2.60	-156.80
47.7398	-112.6533	1635.2	980384.21	22.10	-159.80
47.7474	-112.7773	2600.5	980177.42	112.60	-178.40
47.7500	-112.2250	1220.7	980489.37	-1.50	-133.00
47.7510	-112.9852	1820.5	980351.31	45.90	-157.70
47.7552	-112.9368	1670.6	980379.51	25.90	-157.90
47.7600	-112.1050	1150.6	980517.86	4.40	-124.30
47.7640	-112.8432	1744.9	980364.26	33.80	-161.30
47.7667	-112.1992	1170.1	980501.75	-6.20	-137.10
47.7695	-112.5632	1448.7	980427.52	5.20	-156.80
47.7697	-112.9748	1675.1	980380.36	27.60	-159.80
47.7698	-112.5967	1491.3	980420.08	10.90	-155.90
47.7707	-112.2633	1223.8	980487.35	-4.40	-141.40
47.7710	-112.1148	1148.2	980516.60	1.40	-127.00
47.7732	-112.7768	2563.3	980192.10	113.40	-173.30
47.7759	-112.7767	2322.9	980248.75	95.00	-164.90
47.7775	-112.3478	1263.7	980474.91	-5.30	-146.70
47.7783	-112.9965	2134.5	980289.36	78.40	-150.40
47.7813	-112.2857	1252.1	980481.82	-2.20	-142.30
47.7849	-112.5633	1437.1	980432.87	5.70	-155.00
47.7850	-112.8055	2086.3	980301.34	74.40	-159.00
47.7883	-112.8647	2145.7	980287.80	78.90	-161.10
47.7895	-112.9395	1622.1	980393.48	22.90	-158.60
47.7908	-112.7697	2345.7	980249.49	102.40	-159.90
47.7913	-112.4007	1297.2	980469.69	-1.30	-146.40
47.7918	-112.2357	1230.9	980490.11	-1.40	-139.10
47.7960	-112.3965	1679.5	980377.86	24.00	-153.70
47.7967	-112.5470	1410.3	980440.55	3.90	-153.80
47.8042	-112.7847	2701.1	980153.49	124.50	-177.60
47.8055	-112.8130	2458.5	980226.02	112.00	-153.90
47.8065	-112.6575	1750.2	980372.39	43.20	-155.50
47.8080	-112.9390	1706.8	980378.07	31.90	-159.00
47.8100	-112.1600	1164.3	980505.92	-7.70	-138.00
47.8117	-112.1333	1163.4	980506.27	-7.70	-137.90
47.8117	-112.8512	1874.5	980344.17	44.40	-160.20
47.8133	-112.1750	1163.4	980506.03	-8.10	-138.30
47.8133	-112.1517	1164.3	980506.29	-7.60	-137.90

47.8197	-112.4695	1368.5	980455.53	3.90	-149.10
47.8202	-112.5053	1357.5	980458.14	0.90	-150.10
47.8202	-112.5432	1378.0	980457.56	1.80	-152.30
47.8212	-112.9143	1632.8	980394.08	23.90	-158.70
47.8252	-112.4228	1371.6	980459.67	8.50	-144.90
47.8270	-112.5623	1397.8	980446.99	3.70	-152.00
47.8293	-112.8117	2554.2	980205.32	118.70	-167.00
47.8317	-112.1992	1177.2	980506.41	-5.20	-136.90
47.8402	-112.5730	1405.4	980446.35	4.30	-152.90
47.8403	-112.5075	1409.7	980449.42	8.60	-149.00
47.8460	-112.5793	1410.0	980445.74	4.50	-153.10
47.8475	-112.7813	1747.7	980371.14	34.00	-161.40
47.8503	-112.8255	2499.3	980219.34	114.00	-165.60
47.8530	-112.9913	1760.6	980374.72	41.20	-155.80
47.8542	-112.7757	1734.0	980379.02	37.10	-156.90
47.8552	-112.0250	1133.2	980526.56	-1.80	-127.00
47.8552	-112.1553	1181.7	980511.44	-0.90	-133.20
47.8568	-112.3258	1270.7	980489.08	3.90	-138.20
47.8580	-112.5890	1437.4	980441.34	7.50	-153.20
47.8589	-112.9650	1725.7	980381.10	36.50	-155.50
47.8590	-112.2415	1276.0	980492.24	-13.00	-147.90
47.8592	-112.2412	1266.1	980506.88	1.60	-133.30
47.8638	-112.7573	1686.4	980392.52	35.10	-153.50
47.8663	-112.8850	1760.9	980369.79	37.80	-159.10
47.8678	-112.7125	1647.8	980407.43	25.30	-154.50
47.8678	-112.7322	1641.5	980401.14	29.50	-154.10
47.8698	-112.0910	1153.5	980521.33	-1.10	-130.10
47.8705	-112.6473	1512.4	980429.51	17.70	-151.40
47.8720	-112.6950	1575.8	980416.19	23.80	-152.40
47.8727	-112.5943	1457.5	980439.81	8.70	-153.50
47.8768	-112.2633	1222.0	980516.20	6.20	-130.40
47.8795	-112.5312	1482.8	980435.32	13.50	-152.20
47.8805	-112.9305	1737.0	980371.75	27.40	-166.90
47.8827	-112.6782	1519.4	980431.21	20.50	-149.40
47.8830	-112.8302	2371.3	980257.15	109.30	-155.90
47.8832	-112.6107	1460.9	980439.35	10.50	-152.80
47.8843	-112.3297	1259.7	980498.92	7.90	-133.00
47.8848	-112.6639	1504.1	980430.72	15.10	-153.10
47.8850	-112.5395	1406.3	980452.56	6.70	-150.50
47.8852	-112.4803	1360.0	980467.12	7.00	-145.10
47.8857	-112.7185	1550.6	980420.19	18.90	-154.60
47.8858	-112.4242	1317.0	980479.88	6.40	-140.90
47.8862	-112.5617	1423.7	980456.03	9.50	-149.80
47.8867	-112.6413	1488.9	980435.00	14.50	-152.00
47.8867	-112.7042	1554.4	980422.58	22.30	-151.50
47.8885	-112.6520	1495.9	980433.86	15.40	-151.90
47.8892	-112.3663	1278.6	980491.30	5.70	-137.30
47.8963	-112.7242	1569.1	980418.70	22.10	-153.40
47.8995	-112.2640	1227.4	980501.67	-0.50	-137.90
47.8992	-112.2633	1226.8	980511.44	9.90	-128.20
47.8997	-112.8847	2359.1	980255.89	102.80	-151.10
47.9017	-112.8443	1749.6	980388.65	47.40	-148.20
47.9033	-112.8408	2433.8	980238.57	108.20	-164.10
47.9068	-112.7263	1590.4	980415.70	24.70	-153.20
47.9130	-112.9750	1761.7	980386.05	41.40	-155.70
47.9135	-112.5788	1457.1	980442.67	9.90	-153.00
47.9172	-112.7417	1614.5	980413.48	29.30	-151.60
47.9175	-112.5940	1467.3	980442.36	10.30	-153.10
47.9193	-112.8043	1659.2	980371.15	62.00	-145.90
47.9205	-112.6555	1623.0	980409.77	27.60	-153.90
47.9215	-112.7598	1734.3	980385.76	37.90	-156.10
47.9213	-112.8885	2451.5	980236.94	110.30	-163.40
47.9233	-112.6443	1543.3	980424.55	19.30	-153.80
47.9250	-112.8983	2255.5	980257.74	69.70	-182.60
47.9257	-112.7633	1632.5	980409.43	29.70	-152.80
47.9262	-112.6275	1504.3	980414.50	-4.60	-172.90

47.9265	-112.8367	2314.0	980275.71	106.20	-152.60
47.9282	-112.3597	1408.2	980455.37	6.20	-151.30
47.9285	-112.4167	1230.6	980493.13	7.30	-136.90
47.9322	-112.5422	1537.7	980429.80	20.30	-151.70
47.9342	-112.7412	1093.4	980401.23	39.60	-149.80
47.9357	-112.8035	1903.1	980358.66	61.60	-151.30
47.9363	-112.9190	2464.6	980231.10	107.20	-158.50
47.9395	-112.8923	2405.7	980250.07	107.70	-161.40
47.9417	-112.0475	1148.5	980536.90	6.40	-122.90
47.9423	-112.1560	1164.9	980535.05	9.60	-120.70
47.9425	-112.2875	1208.2	980523.56	11.40	-123.60
47.9427	-112.3075	1204.6	980523.77	10.50	-124.20
47.9433	-112.2850	1208.8	980523.64	11.60	-123.50
47.9447	-112.9505	2371.3	980250.09	96.70	-158.60
47.9458	-112.8048	1777.5	980393.30	40.60	-152.30
47.9462	-112.6602	1627.6	980414.29	31.20	-150.80
47.9482	-112.6893	1912.6	980361.92	66.60	-147.30
47.9530	-112.9182	2484.4	980228.67	109.60	-158.30
47.9533	-112.1548	1162.4	980538.10	10.80	-119.10
47.9577	-112.8198	1734.0	980386.53	35.30	-158.70
47.9633	-112.9912	1771.8	980389.62	49.50	-148.70
47.9692	-112.8985	2356.1	980264.08	103.80	-159.80
47.9713	-112.6152	1458.0	980448.31	10.60	-152.40
47.9720	-112.3045	1207.0	980525.60	10.40	-124.60
47.9767	-112.3150	1211.0	980528.41	14.00	-121.30
47.9782	-112.8472	2704.1	980174.96	121.20	-181.30
47.9783	-112.3100	1210.4	980528.96	14.30	-121.0
47.9800	-112.3133	1210.4	980529.47	14.60	-120.60
47.9867	-112.2650	1191.3	980534.73	13.50	-119.60
47.9867	-112.2867	1201.2	980532.52	14.20	-120.00
47.9867	-112.3083	1211.3	980530.10	14.90	-120.40
47.9867	-112.3300	1219.2	980527.42	14.70	-121.60
47.9867	-112.3517	1230.2	980523.18	13.80	-123.60
47.9867	-112.3625	1234.7	980521.47	13.50	-124.50
47.9867	-112.3733	1246.1	980518.54	13.80	-125.30
47.9867	-112.3960	1253.9	980514.75	12.70	-127.50
47.9867	-112.3967	1255.9	980514.00	12.40	-127.80
47.9867	-112.4133	1264.9	980510.34	12.20	-129.10
47.9867	-112.4267	1274.1	980507.73	11.90	-130.50
47.9867	-112.4383	1278.6	980505.36	11.40	-131.40
47.9867	-112.4492	1286.3	980503.46	11.40	-132.30
47.9867	-112.4583	1292.7	980500.19	10.10	-134.30
47.9870	-112.4590	1292.6	980500.27	10.20	-134.40
47.9882	-112.9192	2359.1	980267.18	106.10	-157.80
47.9900	-112.4758	1306.4	980495.78	9.60	-136.30
47.9940	-112.5967	1418.5	980460.52	8.60	-150.00
47.9942	-112.4983	1327.4	980489.36	9.30	-139.00
47.9942	-112.5128	1339.6	980484.42	8.20	-141.50
47.9942	-112.5357	1360.6	980476.99	7.20	-144.80
47.9942	-112.5565	1378.9	980477.95	6.80	-147.40
47.9943	-112.5565	1378.9	980471.03	6.90	-147.20

Appendix D

Two-dimensional gravity modeling program

```
      DIMENSION XX(300),X(51),Z(51),GSUM(300),XA(51),ZA(51)
        DIMENSION POLY(51)
        TAN(X)=SIN(X)/COS(X)
      PI=3.1415927
      OPEN(UNIT=1),DEVICE='DSK',ACCESS='SEQOUT',FILE='GRAVO.DAT')
        TYPE 790
790     FORMAT(' ENTER NUMBER OF POLYGONS IN MODEL'/)
        ACCEPT 791,NPOL
791     FORMAT(I)
        TYPE 802
802     FORMAT(' ENTER NUMBER OF POINTS IN PROFILE'/)
        ACCEPT 803,KKK
803     FORMAT(I)
      TYPE 806
  806 FORMAT(' ENTER DISTANCE (IN M) INTERVAL BETWEEN PROFILE POINTS'/)
      ACCEPT 807, CO
  807 FORMAT(F)
C...ZERO THE POLY ARRAY
        DO 925 I=1,KKK
925     POLY(I)=0.
      GEE=6.67E-3
C...NOW LOOP THROUGH COMPUTATIONS FOR NPOL TIMES
        DO 650 NCO=1,NPOL
        TYPE 799,NCO
799     FORMAT(' POLYGON NUMBER ',I5)
        TYPE 800
  800 FORMAT(' ENTER NUMBER OF SIDES OF POLYGON'/)
      ACCEPT 801,N
  801 FORMAT (I)
      TYPE 804
  804 FORMAT(' ENTER THE DENSITY CONTRAST'/)
      ACCEPT 805, DENS
  805 FORMAT(F)
      TYPE 809
809     FORMAT(' READ IN COORD.(M) IN CLOCKWISE FASHION,ONE
        1X,Z PAIR PER LINE'/)
      DO 900 I=1,N
      ACCEPT 810, X(I),Z(I)
  810 FORMAT(2F)
  900 CONTINUE
      DO 20 I=1,N
      XA(I)=X(I)
      ZA(I)=Z(I)
   20 CONTINUE
      X(N+1)=X(1)
      Z(N+1)=Z(1)
        DIST=-CO
C...ZERO THE GRAVITY ARRAY
        DO 920 I=1,KKK
920     GSUM(I)=0.

      DO 600 K=1,KKK
        DIST=DIST+CO
        XX(K)=DIST
  496 FORMAT(/)
   25 DO 500 I=1,N
      J=I+1
      A=X(I)
      B=X(J)
      C=Z(I)
      D=Z(J)
      GO TO 49
   50 GZ=0.0
      PHI=0.
```

```
      GO TO 499
C  THE FOLLOWING LOGIC TESTS FOR SPECIAL CASES
   49 IF(A) 71,51,71
   51 IF(C)52,50,52
   52 IF(B) 53,50,53
   53 IF (C-D) 110,130,110
   71 IF(B) 72,81,72
   72 THETA1=ATAN(C/A)
      THETA2=ATAN(D/B)
      IF (THETA1-THETA2) 73,50,73
   73 IF (A-B) 74,140,74
   74 IF (C-D) 160,130,160
   81 IF(C-D) 82,130,82
   82 IF(D-B) 120,50,120
C   COMPUTATION FOR CASE ONE
  110 CALL APCHEC(A,B,C,D,PHI)
      CALL ATERM(A,B,C,D,PHI,AA)
      CALL A2CHEK(B,D,T2)
      ALPHA=T2-PI/2.0
      TPHI=((D-C)/(B-A))
      BETA=TPHI*ALOG(COS(T2)*(TAN(T2)-TPHI))
  490 GZ=AA*(ALPHA+BETA)*(-1.0)
      GO TO 499
C   COMPUTATION FOR CASE TWO
  120 CALL APCHEC(A,B,C,D,PHI)
      CALL ATERM(A,B,C,D,PHI,AA)
      CALL A1CHEC(A,C,T1)
      ALPHA=T1-PI/2.0
      TPHI=((D-C)/(B-A))
      BETA=TPHI*ALOG(COS(T1)*(TAN(T1)-TPHI))
      GZ=AA*(ALPHA+BETA)
      GO TO 499
C  COMPUTATION FOR CASE THREE
  130 IF(A) 131,132,131
  131 IF(B) 134,133,134
  132 T1=PI/2.0
      CALL A2CHEK(B,D,T2)
      GO TO 135
  133 T2=PI/2.0
      CALL A1CHEC(A,C,T1)
      GO TO 135
  134 CALL A1CHEC(A,C,T1)
      CALL A2CHEK(B,D,T2)
  135 GZ=C*(T2-T1)
      PHI=0.0
      GO TO 499
C   COMPUTATION FOR CASE FOUR
  140 CALL A1CHEC(A,C,T1)
      CALL A2CHEK(B,D,T2)
      GZ=A*ALOG(ABS((COS(T1))/(COS(T2))))
      PHI=0.0
      GO TO 499
C   COMPUTATION FOR THE GENERAL CASE
  160 CALL APCHEC(A,B,C,D,PHI)
      CALL ATERM(A,B,C,D,PHI,AA)
      CALL A1CHEC(A,C,T1)
      CALL A2CHEK(B,D,T2)
      ALPHA=T1-T2
      TPHI=((D-C)/(B-A))
      R1=COS(T1)*(TAN(T1)-TPHI)
      R2=COS(T2)*(TAN(T2)-TPHI)
      R=R1/R2
      BETA=TPHI*ALOG(R)
      GZ=AA*(ALPHA+BETA)
  499 GSUM(K)=GZ*2.0*DENS*GEE+GSUM(K)
  500 CONTINUE
```

```
      NN=N+1
      DO 10 I=1,NN
      X(I)=X(I)-CO
   10 CONTINUE
  600 CONTINUE
C  FOR HORIZONTAL DISTANCE OUTPUT IN METERS, DROP THIS DO LOOP
        DO 12 K=1,KKK
      XX(K)=XX(K)/1000.0
   12 CONTINUE
        TYPE 905
        DO 792 K=1,KKK
        TYPE 910,XX(K),GSUM(K)
        POLY(K) = POLY(K) + GSUM(K)
792     CONTINUE
650     CONTINUE
        IF(NPOL.LE.1)GO TO 607
        TYPE 904,NPOL
904     FORMAT(//' COMBINED GRAVITY EFFECT OF //'I3,//' POLYGONS//')
      TYPE 905
  905 FORMAT(' X (IN KM.)   G (IN MGAL.)'//)
      DO 607 K=1,KKK
      TYPE 910, XX(K),POLY(K)
  910 FORMAT(F11.4,2X,F12.3)
      WRITE(10,906) XX(K),POLY(K)
906   FORMAT(F11.4,2X,F12.3)
  607 CONTINUE
      STOP
      END
      SUBROUTINE ATERM (AX,BX,CX,DX,P2,AA)
      A1=BX+(DX*((BX-AX)/(CX-DX)))
      AA=A1*SIN(P2)*COS(P2)
      RETURN
      END
      SUBROUTINE A1CHEC (XA,XC,T1)
      PI=3.1415927
      IF (XC/XA) 2,4,4
    2 T1=ATAN(XC/XA)+PI
      GO TO 11
    4 T1=ATAN(XC/XA)
   11 CONTINUE
      RETURN
      END
      SUBROUTINE A2CHEK (XB,XD,T2)
      PI=3.1415927
      IF (XD/XB) 5,6,6
    5 T2=ATAN(XD/XB)+PI
      GO TO 11
    6 T2=ATAN (XD/XB)
   11 CONTINUE
      RETURN
      END
      SUBROUTINE APCHEC (XA,XB,XC,XD,PHI)
      PI=3.1415927
      IF ((XD-XC)/(XB-XA)) 7,8,8
    7 PHI=ATAN((XD-XC)/(XB-XA))+PI
      GO TO 11
    8 PHI=ATAN((XD-XC)/(XB-XA))
   11 CONTINUE
      RETURN
      END
```