1983

Petrology of the Mount Shields Formation (Belt Supergroup) western Montana northern Idaho

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PETROLOGY OF THE MOUNT SHIELDS FORMATION (BELT SUPERGROUP) WESTERN MONTANA NORTHERN IDAHO

By

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B.S., West Virginia University, 1981

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

Date

Barlow, David A., M.S., August 1983 Geology

Petrology of the Mount Shields Formation
(Belt Supergroup)
Western Montana and Northern Idaho (140 pp.)

Director: Dr. Donald Winston

The detrital mineralogy of the Mount Shields Formation is characterized by a moderately sorted, subangular to subrounded fine-grained population (62 to 250 microns) and a poorly sorted, subrounded to well rounded coarse-grained population (25 to 2000 microns). The aerial distribution of grain types reflect source terranes located south, southwest, northeast and north of the Belt basin. The southern terrane contained predominantly granitic rocks and associated igneous injected terranes. Very fine to medium-and coarse-grained chert-bearing quartz sandstone also existed south of the basin. The southwestern terrane contained coarse, chert-bearing quartz sandstone and metaquartzite. Granitic rocks were subordinate. Granitic rocks and associated igneous injected terranes, and coarse, chert-bearing quartz sandstone were exposed northeast of the basin. A very fine to fine-grained chert-bearing quartz sandstone, perhaps the upper Snowslip and lower Shepard, provided grains and rock fragments from the north. Volcanic rock fragments were reworked from the lower Shepard and/or eroded directly from the Purcell lava exposed north of the basin. The composition of the four source terranes remained relatively constant throughout deposition of the sediments which comprise the Mount Shields Formation. Abrupt increase in sandstone content from the Mount Shields I to the Mount Shields II reflect an episode of rapid basin subsidence relative to the surrounding source terranes.

Infered weathering products include smectite and perhaps hematite and chlorite. Carbonate cements in the lower and upper Mount Shields Formation were precipitated in a subaqueous environment. Diagenetic hematite formed from oxidation of biotite, magnetite and ilmenite. Smectite was converted to illite and chlorite and eventually to 2M illite (200°C to 350°C) providing silica for quartz cement growth. Degredation of potassium feldspar and perhaps biotite supplied the constituents necessary for potassium feldspar precipitation.

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INTRODUCTION

Sedimentologic Setting

The Mount Shields Formation is comprised of sediments which were deposited on alluvial aprons in the Middle Proterozoic Belt basin of western Montana, northern Idaho, eastern Washington, and British Columbia (Figs. 1 and 2). These sediments are part of an enormously thick package of conglomerate and coarse, crossbedded quartzite, red, green and black argillite, and dolomite which were deposited in braided stream channels, on sheet wash fans, subaerial and subaqueous mudflats, and shallow water carbonate banks respectively. The Mount Shields Formation consists of red argillite and fine, horizontally laminated quartzite with lesser thicknesses of crossbedded quartzite.

Near Alberton, Montana, the Belt Supergroup reaches a thickness over 20 kilometers (Harrison, 1972). The great thickness of the Belt Supergroup sediments has been attributed to their deposition on slowly sinking tectonic blocks, bounded by high-angle faults (Winston et al., 1982; Harrison et al., 1974). The thickness of these sediments, and more specifically of the Mount Shields sediments, varies regionally and is a reflection of differential subsidence of these tectonic blocks.

Slover (1982) analyzed in detail the fining upward sequences in the lower part of the Mount Shields Formation and proposed that they result from cyclic alternation of abrupt rainy periods followed by gradual increased in aridity. Her thesis requires that the Belt basin was internally drained. Slover's findings support a similar conclusion proposed by Grotzinger (1981).

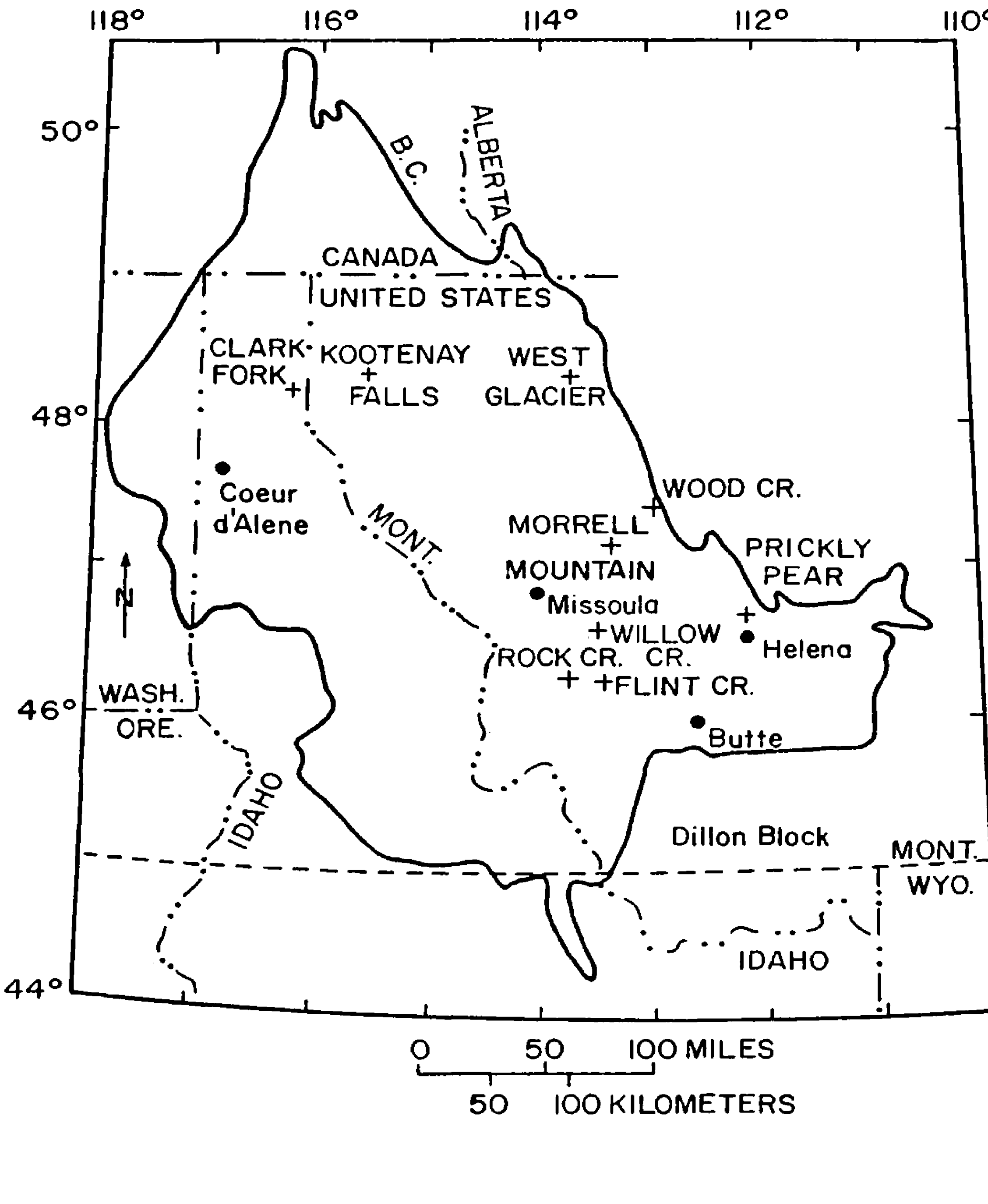


Figure 1. Index map outlining the Belt Basin and locating measured sections (modified after Harrison, 1972).

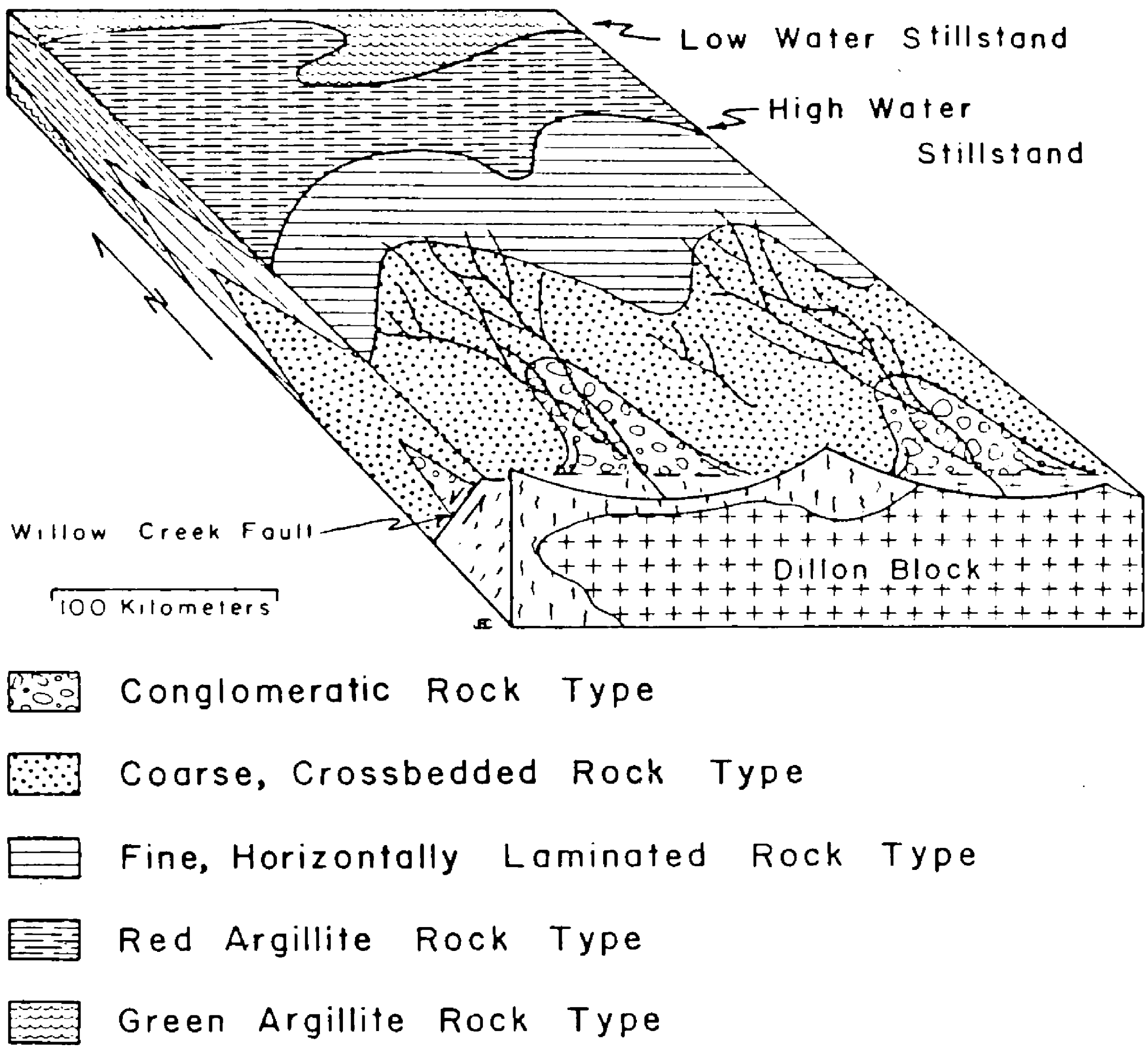


Figure 2. Block diagram showing the facies and corresponding rock types of Belt alluvial fans (Winston, 1978).

Stratigraphic Setting

Winston et al. (1982) have constructed stratigraphic columns for the different tectonic blocks they have proposed for the Belt basin (Fig. 3). These structural blocks are discussed more fully in the following section. The importance of these stratigraphic relationships and their tectonic implications will become evident to the reader when the results of this study are discussed and interpreted.

The Mount Shields Formation was subdivided into four units in the Jocko Mountains, Montana. Winston and Jacob (1977) have informally named them: 1) Mount Shields I (interbedded fine-grained feldspathic quartzite and red argillite), 2) Mount Shields II (fine- and medium-grained feldspathic quartzite), 3) Mount Shields III (red argillite and abundant salt casts), and 4) Mount Shields IV (green argillite). The Mount Shields Formation is correlative with the Striped Peak Formation of the Coeur d'Alene district in northern Idaho (Fig. 3). At Clark Fork, Idaho (Harrison and Jobin, 1963) the Mount Shields I and II are correlative with the Striped Peak I; the Mount Shields III correlates with part of the Striped Peak II and III (Winston, 1977). In the northern, eastern and western sections of the Mount Shields Formation a stromatolite bed or calcareous beds mark the base of the Mount Shields III, and form an important stratigraphic marker. Extending below the stromatolite bed and the calcareous beds is a coarse-grained interval of the Mount Shields II ranging from a few centimeters thick at the northwestern sections to several meters thick in the south. These coarse grained beds occur in all sections of this

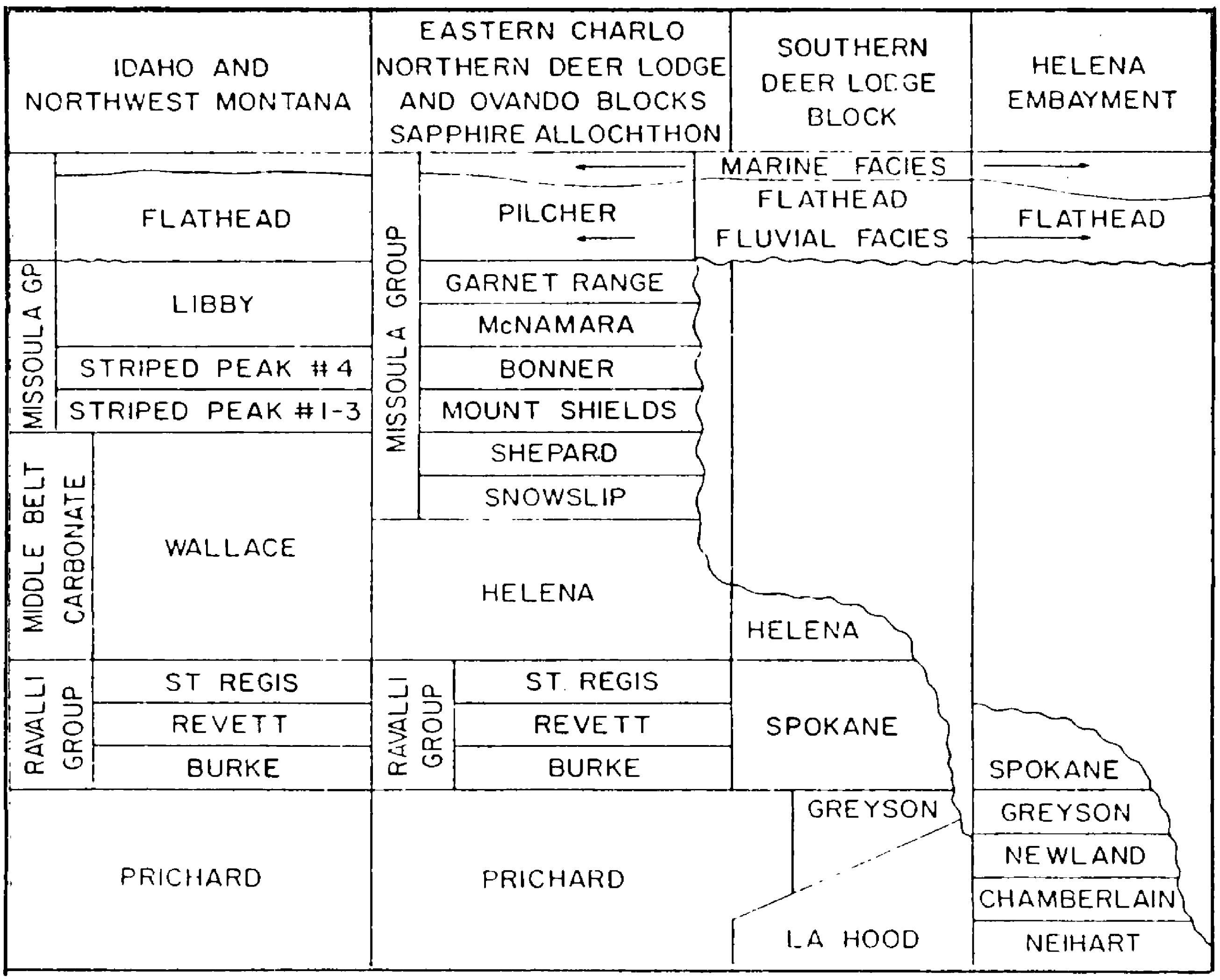


Figure 3. Stratigraphic sections of the Belt Supergroup for each of the proposed tectonic blocks of the Belt basin (Winston et al., 1982).

study except at Clark Fork, Idaho where the grains are medium. The significance of this course interval will be discussed in a following section.

Structural Setting

As mentioned above, the Belt Supergroup sediments were deposited in a block faulted basin. Winston et al. (1982) have proposed three zones of high-angle block faults which they call lines. These lines are in addition to the previously described east-west trending Perry line which bounds the south edge of the Belt basin and the north edge of the Dillon block (Fig. 4). The Perry line and the nearly east-west trending Greenhorn and Jocko lines are intersected on the east by the northwest-southeast trending Townsend line which marks the eastern boundary of the Deer Lodge, Ovando, and Charlo blocks, and the western end of the Helena Embayment (Fig. 4). Winston et al. (1982) have proposed that the western boundary of these blocks be marked by a western thrust belt. Harrison et al. (1972) have proposed that the Hope fault (Clark Fork, Idaho) coincides with a Proterozoic fault zone, and McMannis (1963) studied the Willow Creek Precambrian fault which lies along the Perry line.

The tectonic blocks proposed by Winston et al. (1982) not only controlled the structure of the Belt basin but may have acted as buttresses and ramps for Late Cretaceous thrusting. Winston et al. (1982), as well as other geologists (Harrison et al., 1974) speculate that the emplacement of other structures, such as the Idaho and Boulder

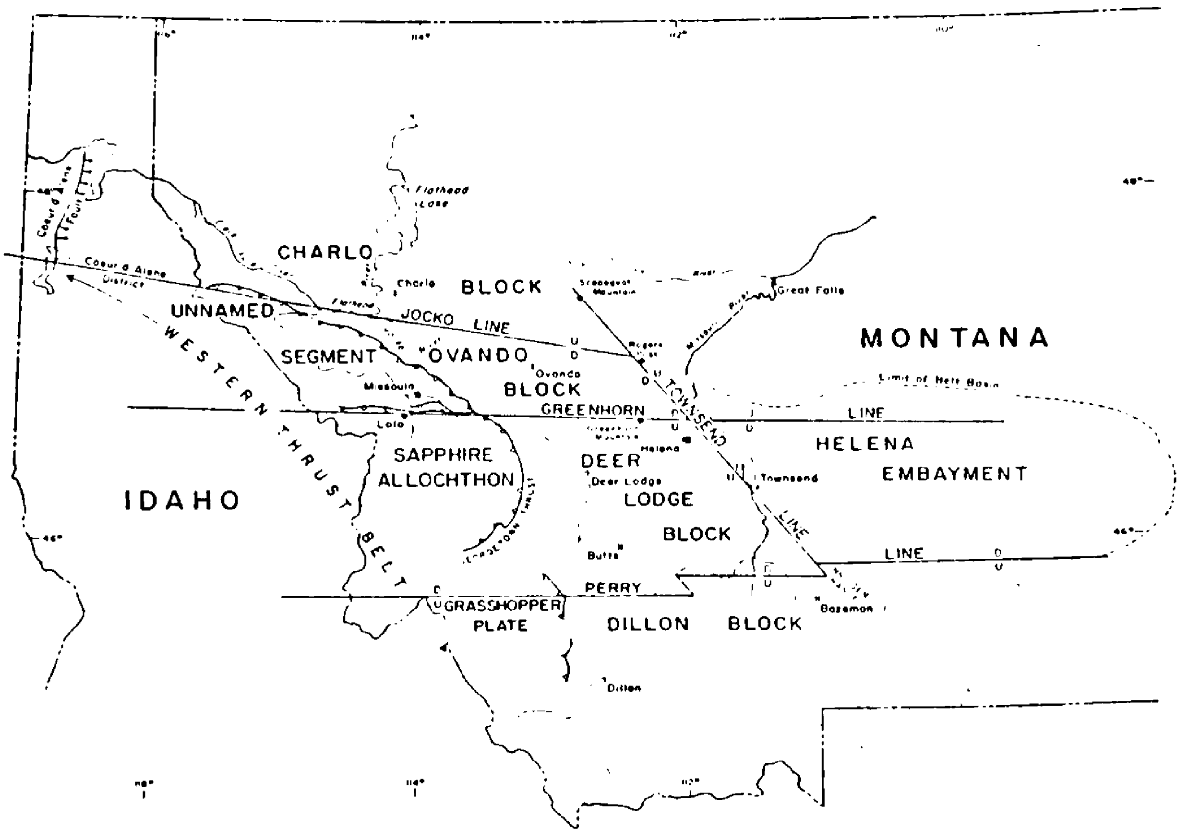


Figure 4. Proposed Precambrian tectonic blocks of western Montana and northern Idaho (Winston et al., 1982).

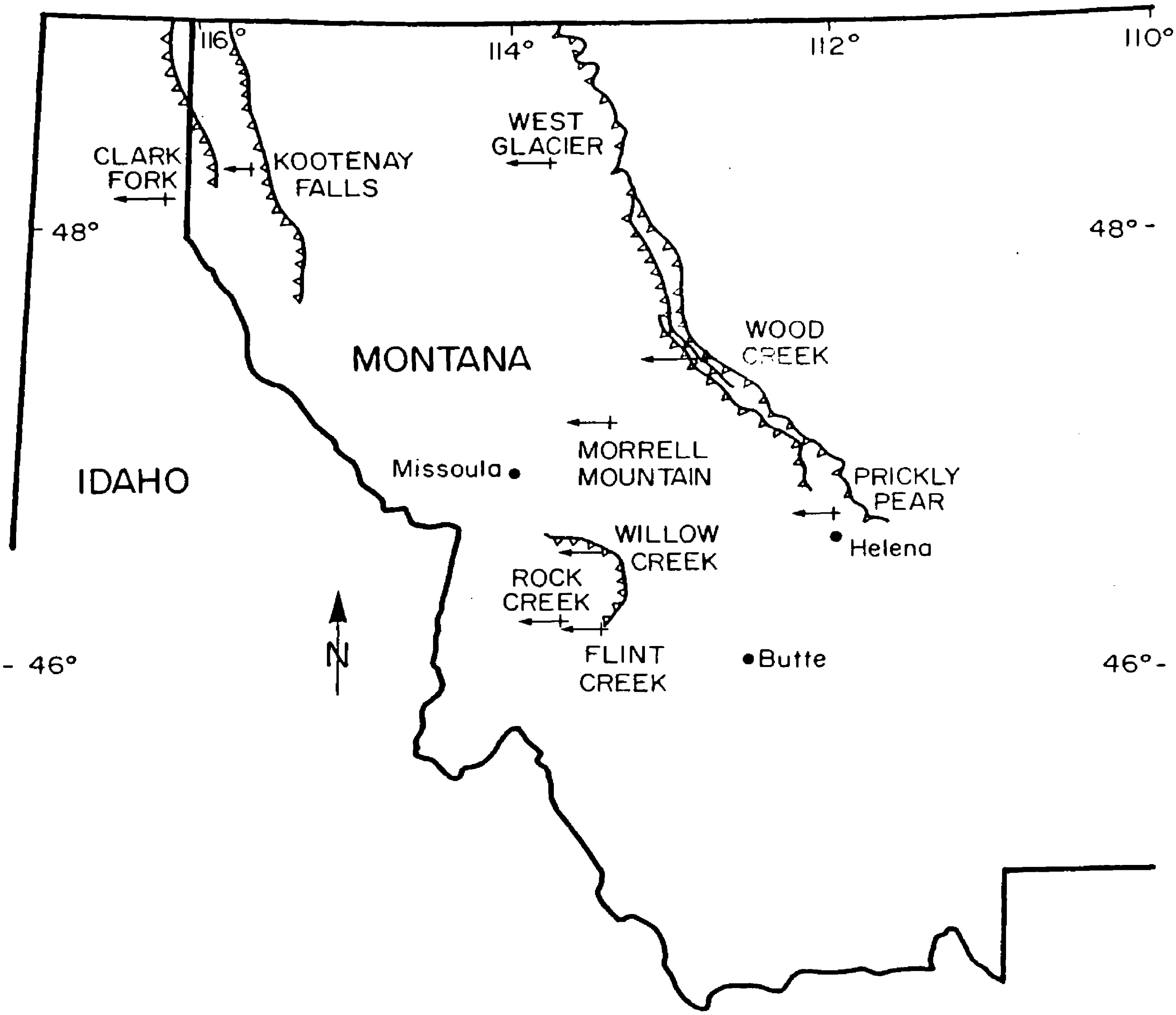


Figure 5. The spatial relationships of the nine measured sections with the major thrust faults of western Montana. The arrows indicate the direction of the original locations of these sections (modified after Winston et al. 1982).

batholiths and Late Cretaceous extensional faults, was controlled by inhomogeneities and faults in the Precambrian basement.

Figure 5 shows the locations of the nine measured sections and their relationships with some of the major thrust faults in the region. The arrows extending west from each section indicate the direction but not necessarily the distance to their original location. The present east-west relationships of the measured sections are the same as the original relationships that is, the Clark Fork section is the furthest west today and was probably the western-most section prior to thrusting. The original north-south relationships are also the same as today. The mineralogical and textural trends presented in this study are therefore valid for interpretation of source terrane locations in their relation to the measured sections.

Purpose of Study

Previous workers (Fenton and Fenton, 1937; Ross, 1963; Harrison, 1972; and others) have proposed several source terranes for the sediments of the Belt Supergroup (including the Mount Shields Formation) on the basis of regional facies relationships. One source area is northeast of the basin, another is south or southwest of the basin. These workers, however, have not systematically analyzed the mineralogy and textures in the Belt rocks for further evidence of source rock locations and compositions. Harrison and Grimes (1970) examined and mineralogy and geochemistry of the Belt Supergroup but only sampled the rocks in the Mission Mountains, Montana and Pend

Oreille, Idaho. This thesis is a systematic study of the mineralogy and textures of the lower part of the Mount Shields Formation throughout most of the Belt basin and will therefore propose solutions to several interesting questions not necessarily answered by previous workers. Some of these questions are:

1. Where were the source terranes for the Mount Shields Formation sediments?

2. Did these source rocks have similar or different compositions and textures?

3. Was there a significant change in source terranes during deposition of the Mount Shields sediments?

4. What do the mineralogical and textural trends in the Mount Shields Formation imply about the tectonic history during deposition of these sediments?

The diagenetic and low grade metamorphic features of the Mount Shields Formation are also examined in this study to understand better the alteration processes which have affected these rocks.

The Mount Shields Formation was chosen for this study because it is well exposed throughout the basin, it is only slightly metamorphosed, and the sand-sized grains lend themselves to examination under the petrographic microscope.

Methods of Study

Stratigraphic sections of the Mount Shields Formation, three measured by Winston (personal communication), one measured by McGill and Sommers (1967), two measured by Slover (1982), and three measured by myself, were representatively sampled every 20 to 50 feet; approximately 130 samples were collected. The nine measured sections are: Rock Creek (includes Flint Creek), Willow Creek, Morrell Mountain, Prickly Pear, Wood Creek, West Glacier, Kootenai Falls, and Clark Fork (Fig. 1).

Thin sections of the samples collected were stained with sodium cobaltinitrite for potassium feldspar indentification, and examined under a petrographic microscope to characterize rock compositions and textures. Sample grain sizes and percentages were visually estimated in thin section, and the histogram in Appendix III is based on grain size range frequencies. Diagenetic features, such as grain overgrowths, were also studied under the petrographic microscope.

X-ray diffraction methods were used to identify the general clay mineralogy, including illite polytypes. The proportion of 2M illite polytype to total illite was estimated using Velde and Hower's (1963) method. The relative intensities of the 3.74A and the 2.58A illite peaks were determined from randomly oriented samples using the method described by Schultz (1964).

Previous and Related Work

There are no previous petrographic studies on the Mount Shields Formation. Winston (personal communication) has examined thin sections of the Mount Shields sandstone but has not systematically analyzed them. Hernden (personal communication) is presently studying the petrology of the Revett Formation which is similar depositionally to the Mount Shields Formation but has undergone greater diagenetic and metamorphic alteration.

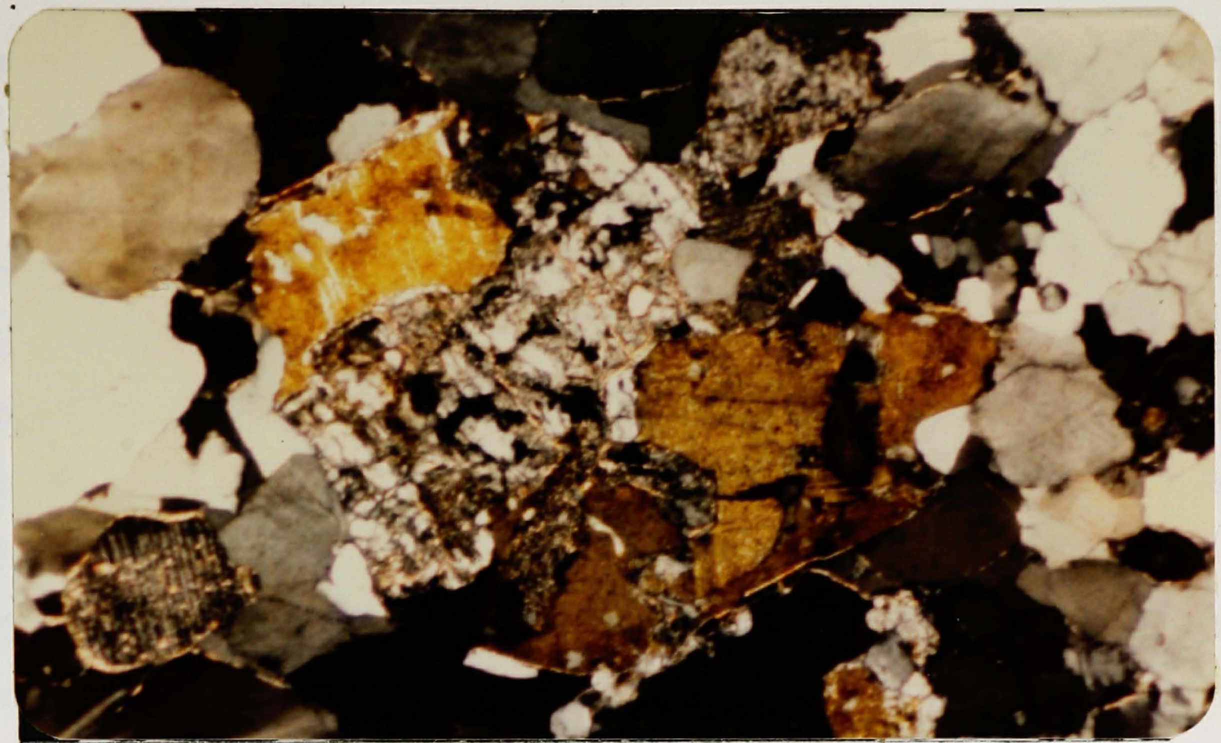
Burial metamorphism in the Belt Supergroup has been studied by Maxwell and Hower (1967) using illite polytypes. They collected samples ranging from the lower Belt to the upper Missoula Group from sections in the Little Belt Mountains and Glacier Park, Montana and at Clark Fork, Idaho. Eslinger and Savin (1973) also studied burial metamorphism of Belt rocks at Glacier Park and concluded from their oxygen isotope studies that metamorphic grade increases down section, and confirmed that illite polytypes can be used as a measure of geothermal grade in Belt rocks. Eslinger and Sellars (1981) examined evidence for conversion of illite from smectite during burial metamorphism of the Belt Supergroup at Clark Fork, Idaho. These studies provide important mineralogic and chemical data, and significant diagenetic interpretations which support the results and interpretations given in this paper for the diagenetic and low grade metamorphic processes in the Mount Shields Formation.

MINERALOGY OF DETRITAL GRAINS

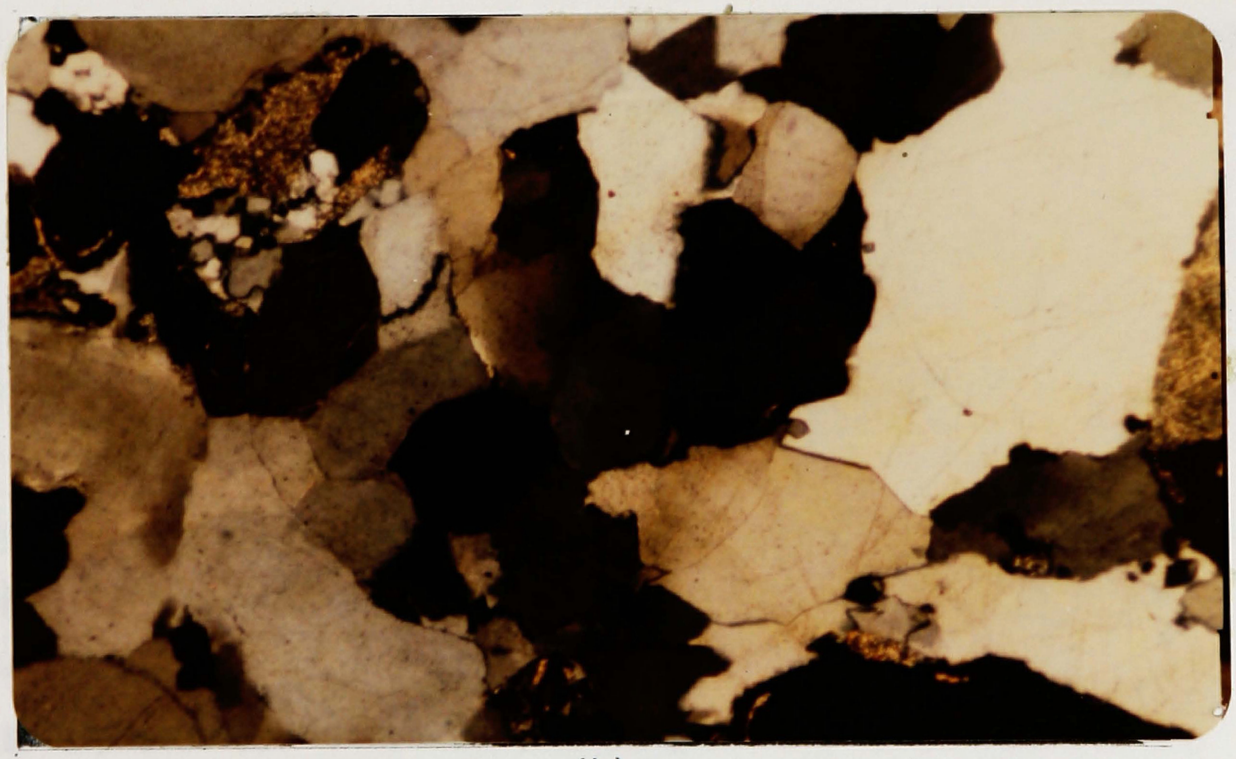
The following grain descriptions apply to the entire Mount Shields Formation except where specified. Grain percentages are tabulated in Appendix I, and Appendix II gives statistical support for some of the grain distribution discussed.

Granite Fragments

Description. Granite fragments in the Mount Shields Formation occur in poorly sorted beds of the coarse-grained population (greater than 250 microns; Appendix III) (Fig. 6a). These fragments range from 350 microns (medium sand) to 2000 microns (very coarse sand), and consist of grains 125 to 1000 microns in diameter (fine- to medium-grained granite). A few pebbles as large as 5000 and 9000 microns with 2000 to 4000 micron (medium granite) sized grains occur at Rock Creek. The maximum size and the angularity of the granite clasts at approximately the same stratigraphic level (top of the Mount Shields II) decrease in a general northward direction from Rock Creek (9000 microns; subrounded), Willow Creek (2000 microns; subrounded) and Prickly Pear (2000 microns; rounded) to Morreell Mountain (710 microns; round to well rounded) and Wood Creek (1410 microns; round to well rounded). Although the fine to medium granite fragments at West Glacier are also samller (710 microns) than those in the south they are equally angular (subrounded to rounded) as the southern granite fragments. Granite fragments are most abundant (more than one percent) at Prickly Pear, Wood Creek and Rock Creek, and less common (less than



(a)



(b)

Figure 6. Partly sericitized granite fragment from Rock Creek (35X) (K-feldspar stained yellow) (a). Quartz sandstone fragment from the upper Mount Shields II at Prickly Pear (42X) (b).

one percent) at all other sections except Kootenai Falls and Clark Fork where these grains are absent.

Clear quartz occurs in each granite fragment. These quartz grains have straight extinction. Approximately 75 percent of the granite clasts contain orthoclase. At the southern localities (Rock Creek, Willow Creek, Prickly Pear) granite grains containing sericitized orthoclase are commonly mixed with those which have fresh orthoclase; the orthoclase in granite fragments at other sections is mostly sericitized. Five percent or less of the granite clasts contain fresh microcline. About 10 percent of the granite grains in the Mount Shields Formation contain microperthite; they occur primarily at Rock Creek and Willow Creek. Fresh and sericitized antiperthite occur only at Willow Creek. Twinned plagioclase (albite-oligoclase) occurs in some granite clasts at Rock Creek (approximately one percent), and is sericitized. Biotite flakes in the granite casts are fresh and occur in about 3 to 5 percent of the granite fragments (only at Rock Creek and Prickly Pear). One granite grain at Willow Creek contains a clear, brown and green zoned tourmaline crystal. These zones parallel the c-axis of the crystal. Green tourmaline also occurs in other granite fragments at Willow Creek. Two granite clasts at Rock Creek have muscovite flakes and one grain has zircon.

Interpretation. Fine- and medium-grained granite supplied the granite fragments to the Mount Shields Formation. The decrease in size and angularity of the grains to the north from Rock Creek, Willow Creek and Prickly Pear suggests that they were transported from a source terrane in the south. Another granitic source in the northeast may be implied by the subrounded to rounded, coarse granite fragments at West Glacier.

Antiperthite is common at Willow Creek but absent at West Glacier, thereby implying that a granitic source nearby Willow Creek may have been more sodic than the northeastern granite which supplied detritus to the West Glacier area. Sericitic alteration probably resulted from burial metamorphism.

Sandstone Rock Fragments

Description. Fine- to very coarse grained (125 to 2000 microns) sandstone rock fragments in the Mount Shields Formation are subrounded to rounded, and contain moderately sorted round grains of very fine to fine-grained (62 to 250 microns) or fine to medium (177 to 350 microns) (only at Rock Creek) quartz sand cemented in clear quartz with straight extinction (Fig. 6b). One fragment contains a recycled quartz grain (doubly overgrown). Chert and polygonized quartz occur in approximately 20 percent of the sandstone clasts and one grain at Rock Creek contains orthoclase.

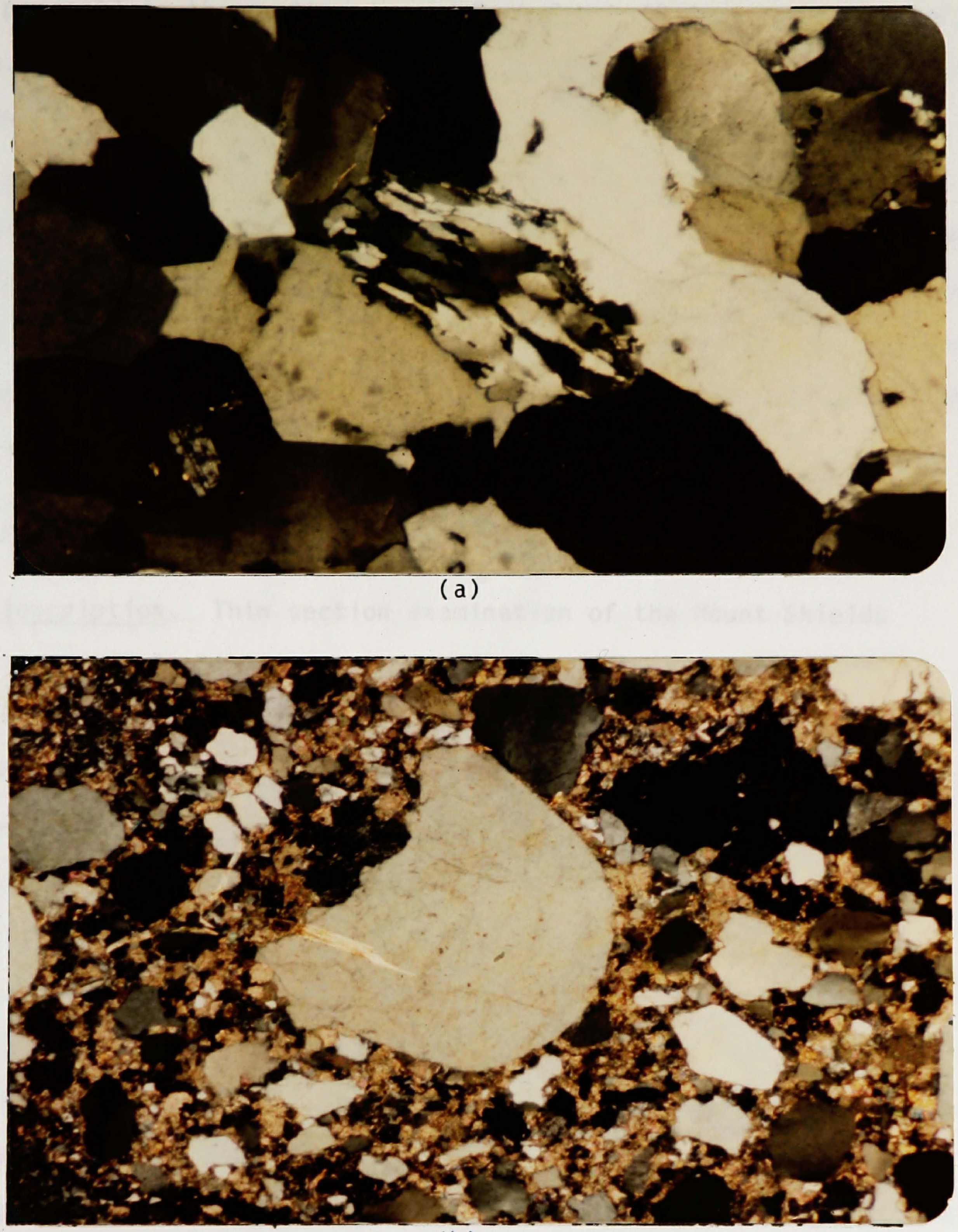
Sandstone fragments occur in moderately sorted beds of the fine-grained population (less than 250 microns; Appendix III) at Morrell Mountain and Kootenai Falls, and in coarse-grained beds at Prickly Pear, Morrell Mountain, West Glacier and Kootenai Falls. Sandstone clasts are absent at Clark Fork and Wood Creek. Sandstone clasts are most abundant in the coarse-grained population at Kootenai Falls and West Glacier (0.4 percent), and less common at Rock Creek

(0.2 percent), Willow Creek (less than 0.1 percent), and Prickly Pear and Morrell Mountain (0.1 percent) (Appendix I). Sandstone fragments make up 0.1 percent and less than 0.1 percent of the fine-grained population at Kootenai Falls and Morrell Mountain respectively.

Interpretation. The sandstone fragments in the Mount Shields Formation were derived from a very fine to fine-grained and fine- to medium-grained sandstone, probably a unit lower in the Belt Supergroup such as the lower part of the Shepard Formation. In addition to quartz, this sandstone contained small amounts of chert, polygonized quartz, and orthoclase. This sandstone may have been a more important source of sediment to the Kootenai Falls and West Glacier localities than to the other localities. Sediment from sandstone exposed in the northern end of the basin could have been transported southeast to West Glacier and southwest to Kootenai Falls. Sandstone in the southwest probably shed fragments and grains northeastward.

Quartzite Fragments

Description. Quartzite fragments are distinguished from sandstone fragments by the undulatory extinction and sutured grain boundaries of the quartz grains which comprise these fragments; these quartz grains are very fine to coarse sand (88 to 1410 microns) (Fig. 7a). Quartzite fragments in the Mount Shields Formation are subrounded to rounded, approximately 500 to 2000 microns in diameter, and are only present at Prickly Pear, Willow Creek and Rock Creek. Quartzite grains are most common at Willow Creek (0.8 percent) and less abundant at Prickly Pear



(a)

(b)

Figure 7. Quartzite fragment from Willow Creek (55X) (a). Broken round quartz grain from Flint Creek (35X) (b).

(0.6 percent) to the northeast, and Rock Creek (0.4 percent) in the south. Appendix II shows that the abundance of quartzite fragments is statistically higher at Willow Creek.

Interpretation. A metamorphic source terrane in the southewest provided the quartzite fragments to the sediments comprising the Mount Shields Formation. The greater abundance of these fragments at Willow Creek might imply that their source rock was closest to this location. Sediment from this source could have therefore been transported southward to Rock Creek and northeast to Prickly Pear.

Quartz

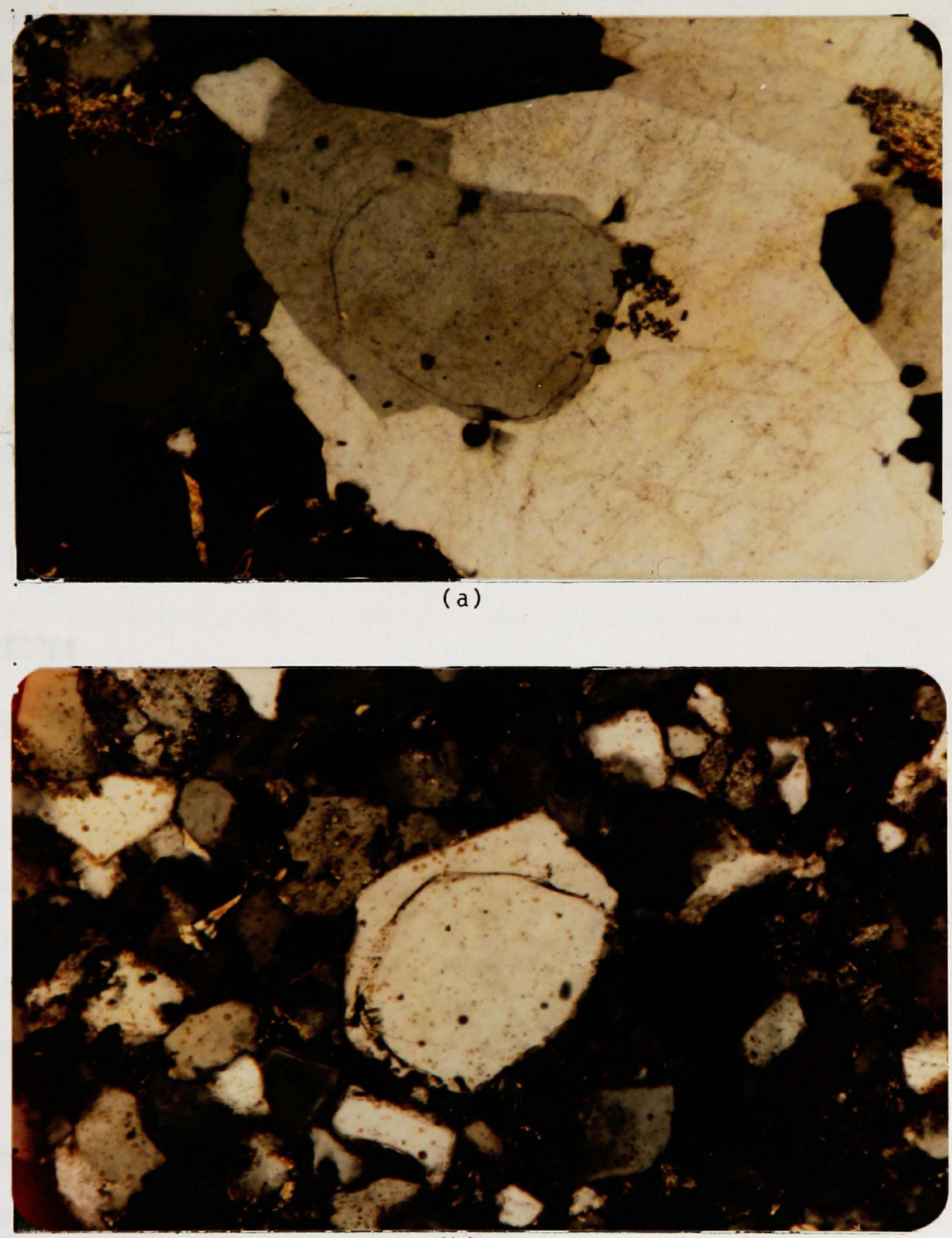
Description. Thin section examination of the Mount Shields Formation reveals two distinct populations of quartz, a moderately sorted fine-grained population (62 to 250 microns) and a poorly sorted coarse-grained population (250 to 2000 microns). The characteristics of the two modes are discussed below.

Quartz is evenly distributed throughout the fine-grained population. Approximately 53 percent of the detrital grains in the fine-grained population at Kootenai Falls, Prickly Pear, West Glacier, and Wood Creek is quartz; Clark Fork contains a little less quartz (48.6 percent) and Morrell Mountain slightly more (55.6 percent). All quartz grains in this population are subangular to angular, clear, and have straight extinction. Many grains have small overgrowths; some grains appear doubly overgrown. Polygonized quartz occurs at all sections and is included in the percentages given for quartz in Appendix I.

Quartz is not evenly distributed in the coarse-grained population. It is most abundant at Wood Creek (62.2 percent), Willow Creek (57.5 percent), and Rock Creek (58.7 percent). Quartz at other locations is less common and averages 51.4 percent. Appendix II shows that the greater abundance of quartz at Wood Creek, Willow Creek and Rock Creek is statistically significant. Quartz in the coarse-grained population is subrounded to well rounded, clear, and has straight or slightly undulatory extinction. Broken round grains, and large syntaxial overgrowths, some double or abraded, are also common (Figs. 7b, 8a, b). One quartz grain at Clark Fork has numerous bubble trains, and a fragment of composite, vein quartz occurs at Wood Creek.

Interpretation. Because the quartz in the granite fragments is clear and has straight extinction, the quartz in the fine-grained population which has the same characteristics was probably derived from erosion of the same granitic source rocks. The even distribution, and the uniform size and shape of these grains indicate that they were deposited evenly throughout the basin. The uniform abundance of fine-grained quartz also implies that the southern granite and the northeastern granite had similar quartz contents. The fine quartz grains with double overgrowths were clearly eroded from a sandstone, most likely the same sandstone that provided the sandstone fragments. Some polygonized grains may have also been eroded from this sandstone; others were polygonized after deposition, probably during compaction.

The high degree of rounding, and the occurrence of abraded and double overgrowths and broken round grains is convincing evidence that the coarse, common quartz grains were eroded from a sandstone coarser



(a)

(b)

Figure 8. Double quartz overgrowth from Prickly Pear (55X) (a).
Reworked quartz overgrowth from West Glacier (143X) (b).

than the sandstone which provided the fine-grained population. The relatively high percentages of coarse quartz at Wood Creek, and Willow Creek and Rock Creek suggests that the coarse-grained sandstone was exposed nearby these sections (i.e. in the east and the south). Coarse sandstone was probably a particularly important source of coarse quartz at Wood Creek. Less rounded coarse quartz resembles that in the coarse-grained granite fragments and was probably derived from the fine- to medium-grained granitic source rocks south and northeast of the Belt basin. The composite, vein quartz fragment and possibly the quartz grain with bubble trains were eroded from a hydrothermal vein (Krynine, 1946a) most likely in the northeastern granitic terrane.

Orthoclase

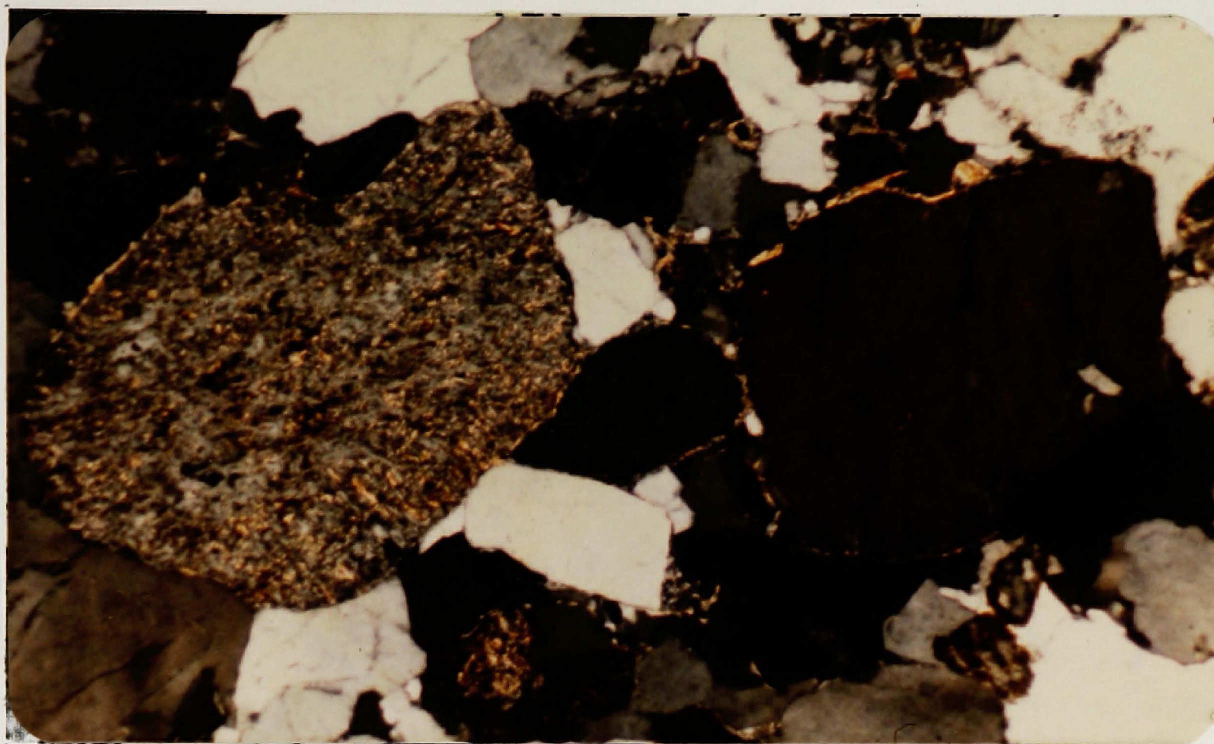
Description. There are two populations of orthoclase, a moderately sorted fine-grained population (62 to 250 microns) with a mode at 88 to 125 microns and a poorly sorted coarse-grained population (250 to 2000 microns) with a mode at 710 to 1000 microns (Appendix IV).

In the fine-grained population orthoclase is most abundant at Clark Fork (10.4 percent) and least common at Kootenai Falls (6.8 percent). The abundance of fine-grained orthoclase at the other sections is within one percent of the overall average of 8.6 percent. Specific percentages are given in Appendix I. Very fine and fine orthoclase is subangular to angular and is fresh or altered to sericite. Fresh syntaxial overgrowths surrounding fresh and altered detrital orthoclase occur in many samples. A few orthoclase grains at

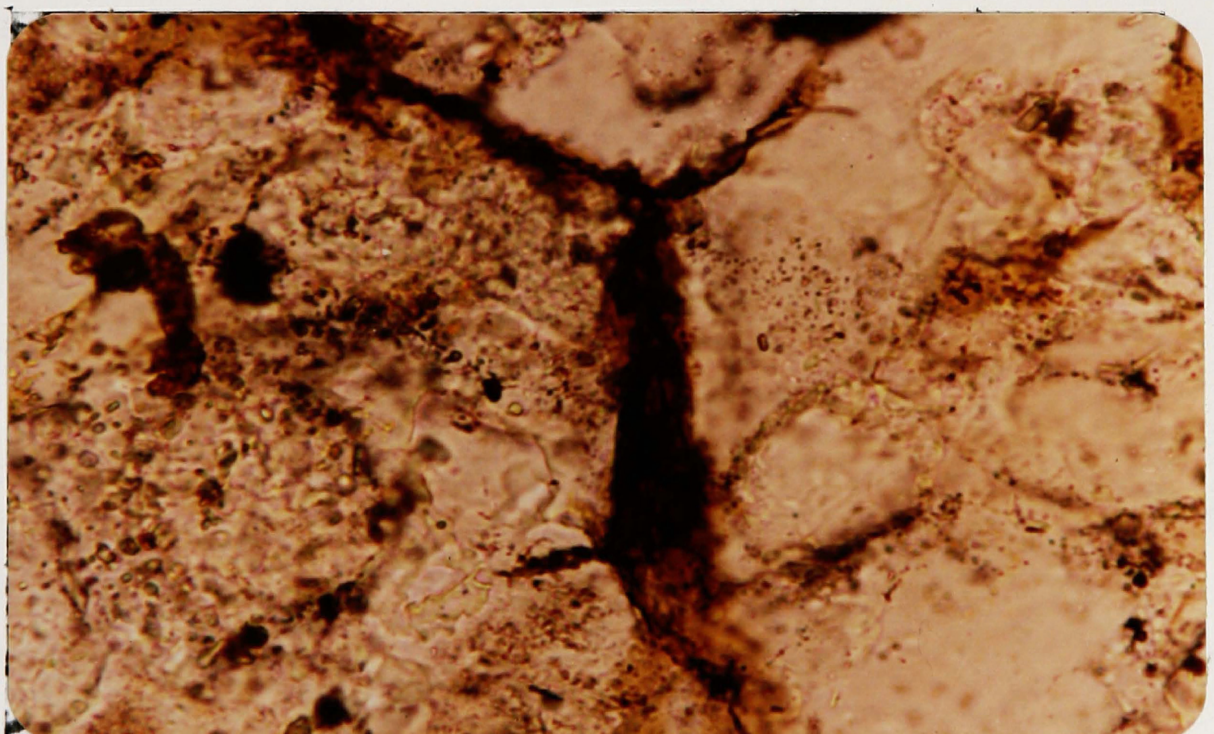
Kootenai Falls appear to have double overgrowths. Although the stratigraphic and aerial distribution of the very fine and fine-grained orthoclase is relatively uniform, the percentages of altered (sericitized) and fresh orthoclase vary inversely. Appendix II shows orthoclase is most altered (4.0 percent) at Kootenai Falls, Prickly Pear, and Morrell Mountain and freshest (8.8 percent) at Clark Fork, West Glacier and Wood Creek.

In the coarse-grained population orthoclase is subrounded to well rounded and averages 6.5 percent (Appendix II). The percentage of coarse orthoclase at Wood Creek (4.2 percent) varies farthest from this average. Orthoclase is coarsest at Rock Creek (2000+ microns), Willow Creek (2000 microns), Prickly Pear (2000 microns), Wood Creek (1410 microns), and West Glacier (1000 microns) and finer (710 microns) at Morrell Mountain, Kootenai Falls, and Clark Fork. Coarse orthoclase is fresh at Rock Creek, Wood Creek, West Glacier, and Clark Fork but is more altered at Willow Creek, Prickly Pear, Morrell Mountain and Kootenai Falls (Fig. 9a).

Interpretation. The percentage distribution and texture of the very fine and fine-grained orthoclase does not indicate source terrane locations, however, the granitic source rocks in the south and northeast are likely sources for most of this orthoclase. Doubly overgrown orthoclase at Kootenai Falls is evidence that some orthoclase was eroded from the sandstone source possibly in the north. The distribution of sericitized orthoclase probably is not a reflection of weathering or depositional processes but was probably produced by



(a)



(b)

Figure 9. Sericitized (left) and fresh, stained orthoclase (right) from Rock Creek (55X) (a). Fresh biotite flake sampled at Clark Fork (570X) (b).

differing diagenetic processes discussed in the chapter entitled <u>Weathering and Diagenesis</u>.

Orthoclase in the coarse-grained population bears evidence of source rocks in the south and northeast. The coarser orthoclase at Rock Creek, Willow Creek and Prickly Pear imply a southern source terrane. Orthoclase is less common in the coarse population than in the fine population because quartz from the coarse-grained sandstone source rock has "diluted" the population of orthoclase. Coarse orthoclase is least abundant at Wood Creek because this is where coarse quartz derived from the sandstone source is most common. Also, some orthoclase in the coarse population is in granite fragments and included in the percentages given for these fragments. The distribution of sericitized coarse orthoclase is similar to that of fine orthoclase. Coarse orthoclase has therefore undergone similar diagenetic alteration.

Microcline

<u>Description</u>. Microcline occurs in beds of all grain sizes (62 to 2000 microns). These grains are subangular to angular in the very fine and fine-grained rocks, and subrounded to rounded in the coarse and very coarse rocks. Appendix II shows that microcline is statistically more abundant (1.4 percent) at Prickly Pear and Rock Creek than at Clark Fork, Kootenai Falls, West Glacier, Wood Creek, Morrell Mountain and Willow Creek where only 0.6 percent of the detrital grains are microcline; specific percentages are tabulated in Appendix I.

Altered (sericitized) microcline occurs at all localities but is less common than altered orthoclase. Overgrowths are not common; they are small, not twinned and some at Prickly Pear are more altered than the grains.

Interpretation. A southeastern source of microcline would account for the relatively high abundance of this mineral at Rock Creek and Prickly Pear, and the smaller amount of microcline at Willow Creek. Granite fragments containing microcline are good evidence that the microcline grains in the Mount Shields Formation were eroded from southern (southeastern?), and probably northeastern granitic source rocks. Most sericitic alteration of the microcline probably resulted from burial metamorphism. Microcline is less altered than orthoclase because microcline is more stable under weathering and diagenetic conditions than orthoclase. Microcline overgrowths are more altered than detrital microcline probably because the overgrowths have monoclinic crystal symmetry and are therefore less stable (Baskin, 1956; Goldsmith, 1953).

Microperthite

Description. The abundance of microperthite is uniform within individual measured sections. These grains are very fine to very coarse sand (62 to 2000 microns), and subangular to rounded. The basin-wide distribution of microperthite is not uniform. Rock Creek, Willow Creek, Prickly Pear and Morrell Mountain contain an average amount of microperthite (1.2 percent) statistically greater than the average percentage of microperthite (0.8 percent) at Wood Creek, West Glacier, Kootenai Falls and Clark Fork (Appendices I and II). The sodic phases of feldspar occur as "blebs" in orthoclase and less commonly in microcline. Three samples at Willow Creek contain approximately one percent antiperthite. A few grains with symplektitic texture also occur in these rocks. Overgrowths are absent and most grains are sericitized, especially the albite intergrowths.

Interpretation. Microperthite and antiperthite in granite fragments at Rock Creek and Willow Creek, and the greater abundance of these minerals at the southern-most sections suggest that the southern granite may have been more sodic than the other granitic sources. Microperthite and antiperthite were probably replaced by sericite during high grade diagenesis or low grade metamorphism.

Plagioclase

Description. The table in Appendix I shows that plagioclase (albite-oligoclase) is most common at Rock Creek (1.0 percent), comprises less than one percent of the grains at Willow Creek, Prickly Pear, Morrell Mountain, Wood Creek and West Glacier, and less than one tenth of one percent at Clark Fork, and is absent at Kootenai Falls. Harrison and Campbell (1963), however, report 10 percent or more albite-oligoclase in the Striped Peak Formation at Clark Fork, Idaho. The reason for this discrepancy is not certain. Plagioclase grains are equally abundant in the fine-grained and the coarse-grained beds, range from very fine to coarse-grained (approximately 62 to 1000 microns), and are subangular to subrounded. All grains are twinned, not overgrown, and most are slightly to highly sericitized.

Interpretation. Plagioclase-bearing granite fragments at Rock Creek certainly indicate that the southern granitic source provided plagioclase to the Belt basin. Plagioclase at West Glacier and perhaps Wood Creek was eroded from the northeastern granite. The paucity of plagioclase grains at Clark Fork and their absence at Kootenai Falls is the result of prolonged transport and removal of these grains by weathering. Sericitic alteration of plagioclase is the result of burial metamorphism.

Muscovite

Description. Muscovite is ubiquitous throughout the Mount Shields Formation. The average length of these muscovite flakes ranges from approximately 125 microns in the very fine and fine-grained beds to 1000 microns in the coarse and very coarse beds. Notice from Appendix I that the distribution of this mineral is relatively uniform from section to section. Muscovite comprises 0.9 percent of the detrital grains in these rocks. The muscovite grains are not visibly altered.

Interpretation. The even distribution of muscovite does not reflect source terrane directions, however, the occurrence of muscovite in granite fragments at Rock Creek indicates that at least some of the muscovite grains were eroded from the southern granite. The northeastern granite most likely contained muscovite and is another probable source for these grains. The lack of alteration of the muscovite is not surprising considering its chemical stability under weathering and diagenetic conditions.

Biotite

Description. Less than 0.5 percent of the detrital grains in the Mount Shields Formation are biotite. These grains are commonly aligned subparallel to bedding and are approximately 250 to 500 microns long. Many biotite grains are crushed between other detrital grains. Biotite is equally abundant in beds of all grain sizes. Appendix I shows that all sections except Willow Creek contain this mineral. Most biotite flakes are oxidized to hematite but the Rock Creek, Kootenai Falls and Clark Fork sections contain some fresh biotite (Fig. 9b).

Interpretation. Biotite flakes oriented subparallel to bedding, and crushed between other grains are definitive evidence that the biotite in the samples collected is detrital. Considering that granite fragments at Rock Creek and Prickly Pear contain biotite, the southern granite is a likely source for the biotite in the southern part of the basin. The northeastern granite probably supplied biotite to the Wood Creek and perhaps the Kootenai Falls and Clark Fork sections. Absence of biotite at Willow Creek may imply that the grains at this section were derived from a source separate from that which shed grains into the Rock Creek area. Biotite oxidation is discussed in the chapter entitled Weathering and Diagenesis.

Chlorite

Description. Detrital chlorite in the Mount Shields Formation is commonly associated with biotite and has a similar distribution (Appendix I). Chlorite comprises less than 0.5 percent of the detrital grains in these rocks and is absent at Willow Creek. Chlorite flakes are approximately the same length as the biotite flakes (250 to 500 microns). They are clean and have light to medium green pleochroism.

Interpretation. The association of detrital chlorite with biotite, and their similar distribution and grain size may imply that they came from the same source terranes. Chlorite is a common alteration product of ferromagnesium minerals such as biotite, therefore, some of the biotite in the granitic source rocks may have been altered to chlorite before erosion and transport. Low grade metamorphic rocks are other possible sources of chlorite.

Chert

Description. Chert is most common at Willow Creek (1.1 percent) and less abundant (0.5 percent) at the other sections (Appendices I and II). These grains are commonly subangular to subrounded and range from approximately 62 to 1000 microns in diameter. A few chert grains at Willow Creek contain chalcedony.

Interpretation. Recall that several sandstone fragments in these rocks contain chert. The sandstone which provided these rock fragments probably also supplied most or all of the chert grains. The apparent concentration of chert at Willow Creek suggests that sandstone was a more important source rock near Willow Creek and/or this sandstone contained more chert than the eastern and northern sandstones.

Magnetite and Leucoxene

Description. Magnetite and leucoxene (an alteration product of ilmenite) grains in the Mount Shields Formation are very fine to fine-grained (62 to 250 microns), subangular to angular, and occur in heavy mineral bands with zircon and tourmaline. Appendices I and II show that magnetite and leucoxene are most abundant (1.5 percent) at Clark Fork and Kootenai Falls and less common (0.3 to 1.0 percent) at the other sections. Magnetite is commonly oxidized to hematite. At Rock Creek, and Kootenai Falls and Clark Fork where the beds are mostly drab white or green, magnetite is not as oxidized as at the other sections where red beds predominate.

Interpretation. Magnetite and ilmenite are common accessory minerals in granite and were most likely eroded from the southern and northeastern granites. The abundance of magnetite and leucoxene at Clark Fork and Kootenai Falls probably reflects a favorable diagenetic environment for the preservation of these minerals. The section entitled Weathering and Diagenesis discusses the conditions under which the magnetite was oxidized and the association of fresh magnetite with drab and green beds, and oxidized magnetite with red beds.

Zircon

Description. Zircon is evenly distributed and comprises approximately 0.4 percent of the detrital grains in the Mount Shields

Formation. These grains are very fine to fine-grained (62 to 250 microns), clear and occur in heavy mineral bands. There are two populations of zircon, a subhedral and euhedral population, and a rounded population which also includes broken round grains. Grains from both populations occur at all sections.

Interpretation. Zircon in a granite fragment at Rock Creek is conclusive evidence that euhedral and subhedral zircon was eroded from the southern granitic source. The northeastern granite is a likely source of zircon. Zircon is a highly durable mineral, therefore, the round and broken round grains could not have attained their degree of rounding in a single sedimentary cycle. These grains were eroded from another sedimentary rock, probably sandstone in the south, east or north.

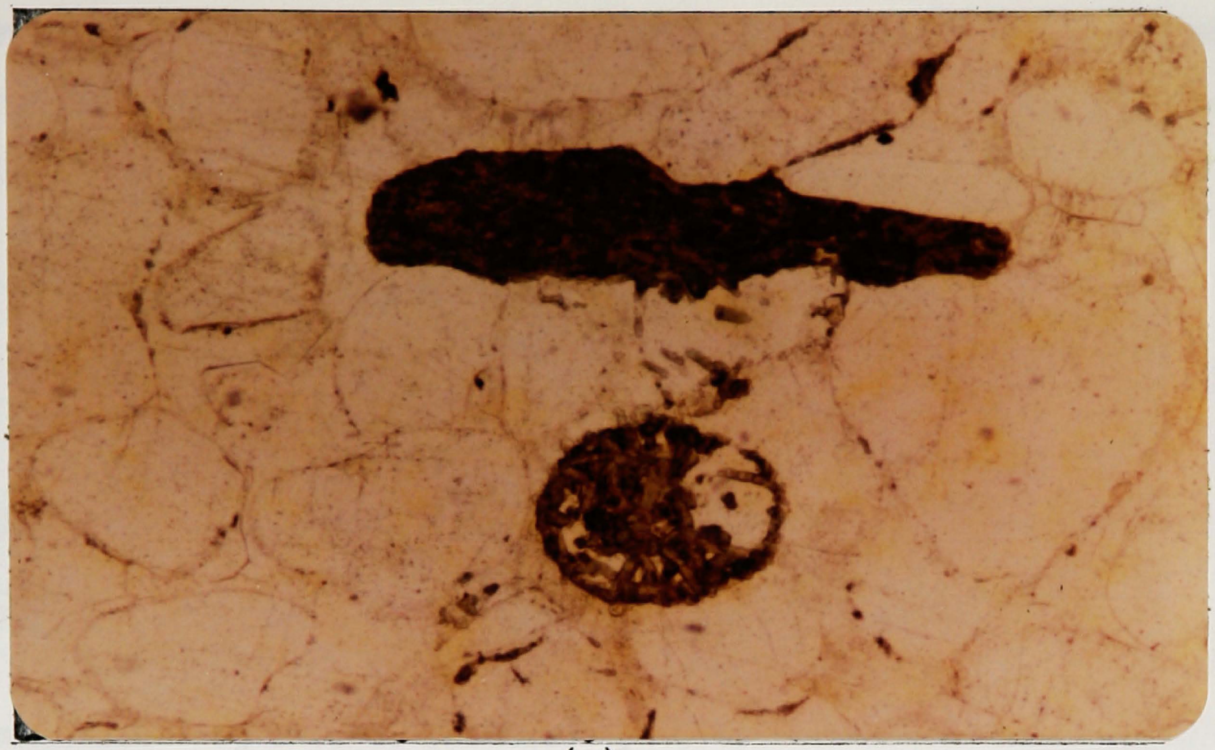
Tourmaline and Tourmaline Rock Fragments

Description. The table in Appendix I shows that tourmaline is evenly distributed and comprises about 0.5 percent of the detrital grains in the Mount Shields Formation. These grains are very fine to fine sand (62 to 250 microns), subangular or subrounded to rounded, and range from mostly green, blue, brown or pink to pale yellow or black; some grains are colorless, others are zoned brown and green parallel to the c-axis. Bubbles and black inclusions are common in all varieties. Tourmaline overgrowths are ubiquitous; some are tens of microns long.

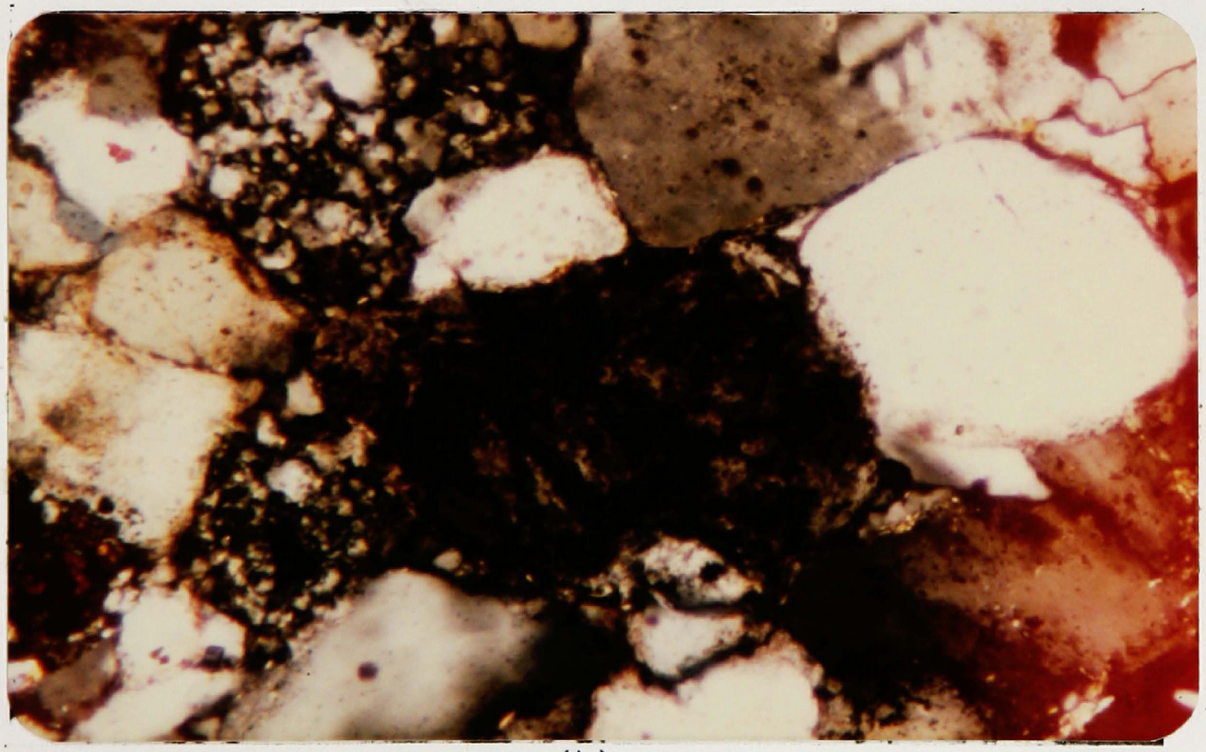
Brown and green zoned tourmaline predominantly occur as crystal groupings and aggregates or small euhedra in two kinds of rock fragments. In addition to the granite fragment at Willow Creek, this distinctive variety of tourmaline is commonly contained in very fine grained chert or amorphous-looking material, and mudchips (Fig. 10a). These rock fragments contain as much as 50 percent tourmaline and are medium- to coarse-grained; fine-grained fragments occur at Clark Fork. In Appendix I, tourmaline rock fragments are tabulated separately from tourmaline. They are found only in the middle to upper part of the Mount Shields II and are most abundant at Clark Fork (0.2 percent fine grains; 0.7 percent coarse grains) and less common at West Glacier (0.2 percent), Willow Creek (0.4 percent) and Rock Creek (less than 0.1 percent); these grains are absent at other sections.

Interpretation. Green, brown and pink, and blue tourmaline are typical granite and pegmatite varieties. The other types of tourmaline are diagnostic of pegmatite injected terranes (Krynine, 1946b). The subangular fragments were probably eroded directly from granite and pegmatites. Tourmaline-bearing granite fragments at Willow Creek support this interpretation. The occurrence of zoned tourmaline in a granite fragment at Willow Creek and in rock fragments certainly suggests that they were derived from a granite and its country rock. The southern and northeastern granitic terranes are likely sources. Schofield (1915) reports very fine grained chert bearing tourmaline crystals near Cranbrook, British Columbia (Sullivan mining district). Perhaps some of the tourmaline-bearing chert in the Mount Shields Formation was eroded from a Sullivan type terrane, although this is highly speculative.

Because of its high durability the subround and round tourmaline probably could not have attained its degree of rounding in a single



(a)



(b)

Figure 10. Tourmaline rock fragments from Willow Creek (plane light) (55X) (a). Volcanic rock fragment from West Glacier (225X) (b).

sedimentary cycle, therefore, these grains were eroded from a sedimentary rock. The southern, eastern and northern sandstones are likely sources.

Volcanic Rock Fragments

Description. Subangular volcanic rock fragments, one at Kootenai Falls (177 microns) and another at West Glacier (710 microns), occur in the upper Mount Shields II. These grains are glass containing gray or white feldspar laths (Fig. 10b).

Interpretation. Basalt, probably the Purcell lava, provided the volcanic rock fragments to the Mount Shields Formation. The Purcell lava extends from the central part of Glacier Park and northwest into British Columbia, therefore, the basalt fragments at West Glacier and Kootenai Falls were transported from the north.

EXPANDED ANALYSIS AND INTERPRETATION

This chapter analyzes the detrital mineralogy of the fine-grained population and the coarse-grained population, and fully develops and relates the interpretations discussed here to previous studies.

Fine-Grained Population

Grains in the fine-grained population range from 62 to 250 microns in diameter (Appendix III), are subangular to subrounded, and moderately sorted. Listed below are the grain types in the fine-grained population.

quartz	(52.9 percent)	chlorite	(0.2 percent)
orthoclase	(8.6 percent)	chert	(0.5 percent)
microcline	(0.8 percent)	magnetite/leucoxene	(0.9 percent)
microperthite	(1.0 percent)	zircon	(0.4 percent)
plagioclase	(0.4 percent)	tourmaline	(0.5 percent)
muscovite	(0.9 percent)	tourmaline rock fragments	(0.2 percent)
biotite	(0.3 percent)	volcanic rock fragments	(trace)
sandstone rock fragments	(trace)		

The size and shape of the grains in the fine-grained population is uniform throughout the Mount Shields Formation, however, the detrital mineralogy is not. The uneven distribution of fresh and sericitized orthoclase is the most striking mineralogic inhomogeneity of the fine-grained population. The abundance of microcline, microperthite, plagioclase, biotite, chlorite, chert, and magnetite and leucoxene, as well as tourmaline rock fragments, sandstone rock fragments and volcanic rock fragments, also vary within this population. The fine-grained population occurs alone or mixed with the coarse-grained population.

Coarse-Grained Population

The coarse-grained population contains grains which range from 250 to 2000 microns in diameter (Appendix III). A few grains at Rock Creek are as large as 5000 and 9000 microns. Grains in this population are subrounded to well rounded and poorly sorted. Grain types in the coarse-grained population include:

quartz	(54.3 percent)	chlorite	(0.2 percent)
orthoclase	(6.5 percent)	chert	(0.5 percent)
microcline	(0.8 percent)	granite fragments	(0.7 percent)
microperthite	(1.0 percent)	tourmaline rock fragments	(0.2 percent)
plagioclase	(0.4 percent)	quartzite fragments	(0.2 percent)
muscovite	(0.9 percent)	volcanic rock fragments	(trace)
biotite	(0.3 percent)		
sandstone rock fragments	(0.1 percent)		

The texture, as well as the detrital mineralogy, of the coarse-grained population varies. The grains in this population are largest (up to 9000 microns) and most angular (subrounded) in the south and southwest, but smaller (up to 2000 microns) and more rounded (rounded to well rounded) in the other parts of the basin. Quartz in the coarse-grained population is most abundant at Rock Creek, Willow Creek and Wood Creek, whereas the percentage of orthoclase is not only low at these sections but is less common in the coarse-grained population than in the fine population.

Provenance

The mineralogy, texture and distribution of grains in the fine-grained population and the coarse-grained population reflect the composition and locations of four source terranes for the Mount Shields Formation. These terranes are located in Figure 11 and discussed below.

Southern Source Terrane. A southern source terrane is indicated by both textural and mineralogical evidence in the Mount Shields I and II. The maximum grain size of these rocks decreases north and northwestward from Rock Creek (9000 microns), Willow Creek (2000 microns), and Prickly Pear (2000 microns) to Morrell Mountain (710 microns), Kootenai Falls (710 microns) and Clark Fork (710 microns) certainly suggesting source rocks at the southern end of the basin (Fig. 11). The concentration of granite fragments and microcline at Rock Creek and Prickly Pear, and microperthite at Rock Creek, Willow Creek, Prickly Pear and Morrell Mountain is evidence of granitic source rocks in the south and perhaps southeast. Very fine to medium-grained quartz sandstone and coarse-grained sandstone also shed grains and rock fragments from the south.

A southern source terrane for the Belt Supergroup and therefore the Mount Shields Formation has been proposed by McMannis (1963) who demonstrates that the sediments of the LaHood Formation (lower Belt) were eroded from an uplifted crystalline terrane (Dillon Block) south of the Willow Creek fault (along the Perry line). Ruppel et al. (1981) suggests a southwestern source for the Mount Shields Formation and other Missoula Group Formations. Stratigraphic and sedimentologic evidence in the Bonner Formation cited by Quattlebaum (1980) and his paleocurrent analysis of planar cross-beds in these rocks show that the sediments comprising the Bonner Formation were derived from the south or southwest.

Southwestern Source Terrane. Unlike the southern source rocks, coarse, chert-bearing quartz sandstone and quartzite provided the abundant quartz, chert and quartzite fragments at Willow Creek. The relatively low amount of granite fragments and the absence of biotite and chlorite (possibly a weathering product of biotite) in these rocks suggest that granite was a subordinate source of sediment. Detritus from the southwestern terrane was most likely transported north and northeastward and deposited with sediment derived from the south (Fig. 11).

Northeastern Source Terrane. Coarse-grained granite fragments and orthoclase at West Glacier and Wood Creek and abundant coarse round quartz at Wood Creek are evidence of granitic and coarse sandstone source rocks east of these sections (Fig. 11). Eastward thinning and coarsening of the Mount Shields Formation (Harrison, 1972) also implies a source terrane east of the basin. The Canadian Shield is a likely source of granite fragments at West Glacier and possibly Wood Creek. Harrison and Grimes (1970) found that the average composition of Belt rocks closely approximates the average composition of the Canadian Shield (granite-granodiorite) (Shaw et al. 1967). An eastern sandstone source rock is contrary to Harrison's (1972) assertion that sedimentary source rocks for the Belt Supergroup were limited to the southwestern part of the basin. At West Glacier, sediment from the northeastern terrane was deposited with grains eroded from the northern source area.

Northern Source Terrane. Thinning of the Snowslip Formation and the Purcell lava northwest from the Whitefish Range into southeastern British Columbia (Smith, 1963) shows that a low-relief "positive" area lay at the northern end of the basin. Price (1962) found that the Purcell basalt and the Snowslip Formation had been eroded prior to deposition of the upper part of the Shepard Formation. Pebbles of Purcell basalt in the lower part of the Gateway Formation (Shepard equivalent) near Cranbrook, British Columbia (Schofield, 1915) confirm Price's findings. The very fine to fine-grained sandstone rock fragments at West Glacier and Kootenai Falls could have been eroded from the upper most Snowslip or other fine-grained sandstone and probably a little coarse sandstone in the Shepard Formation exposed in the "positive" area at the north end of the Belt basin (Fig. 11). Basalt fragments in these sections may have been reworked from the Shepard and eroded directly from the Purcell lava.

Tectonics

The overall mineralogy of the Mount Shields Formation at a single stratigraphic section is relatively uniform and therefore does not provide evidence of tectonism or changes in source terranes during deposition of these sediments. Slover (1982), however, attributes the abrupt increase in grain size from the Mount Shields I to the Mount Shields II to a major episode of basin subsidence relative to the surrounding source terranes. The uniform texture within the Mount Shields I and within the Mount Shields II reflect gradual and constant subsidence of

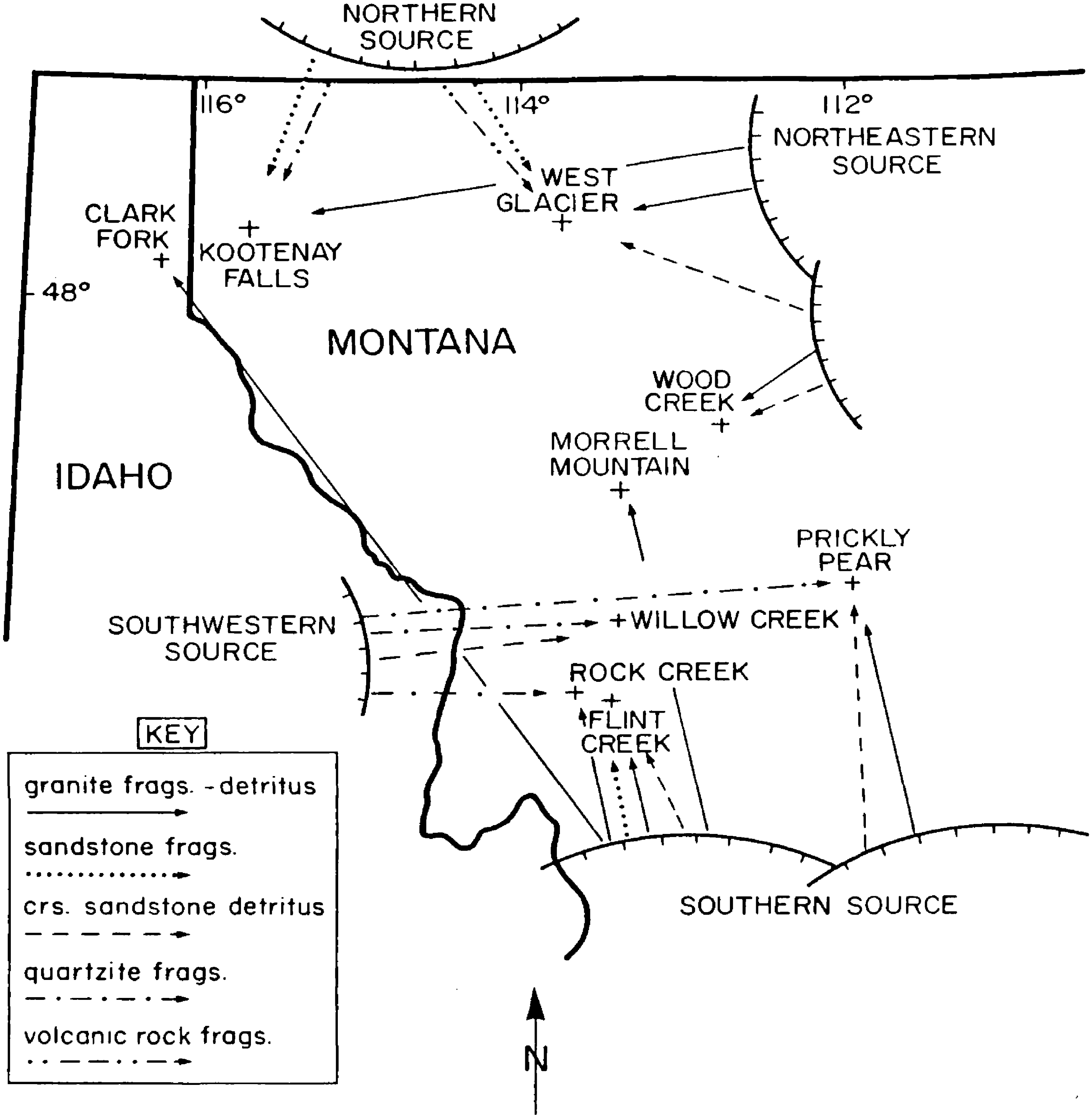


Figure 11. Schematic diagram of approximate source terrane locations showing transport directions of selected grain types.

the basin and/or uplift of the source areas. Textural variations within these units were produced by climatic changes (Slover, 1982).

WEATHERING AND DIAGENESIS

Given a granitic source and long transport, one would deduce that the sediment of the Mount Shields Formation was weathered during transport. Although most weathering products have been diagenetically altered, the climatic conditions during deposition of these sediments (Slover, 1982) and diagenetic characteristics in these rocks imply the pre-diagenetic mineralogy that includes smectite, magnetite and ilmenite, and biotite.

Weathering Products

Smectite. Although smectite was not detected in the samples collected, Eslinger and Sellars (1981) propose that smectite was originally present in the Belt Supergroup. Smectite is usually the primary weathering product of feldspars in arid environments (James et al. 1981), and salt casts in the Mount Shields III certainly suggest high evaporative conditions during deposition of these sediments. Wilson et al. (1971) report that the formation of smectite is favored by an alkaline environment with minimal leaching. The sediments of the Mount Shields Formation may have been deposited in such an environment.

Hematite. Hematite produced from the oxidation of iron in magnetite, ilmenite and biotite commonly coats detrital grains and grain overgrowths and comprises 20 percent or more of the red pigmented beds but is less common in green and white strata. Evidence that the hematite in the Mount Shields Formation was formed prior to deposition (Van Houten, 1973) is inconclusive. Although some of the hematite in these rocks may be pre-diagenetic, evidence indicates that most hematite formed by diagenetic oxidation of iron-bearing minerals. Diagenetic hematite is discussed in a subsequent section.

Chlorite. The amount of chlorite weathered from detrital biotite and the process of this transformation are uncertain. Some chlorite probably formed by aluminum, iron, or magnesium hydroxyls replacing the interlayer potassium ions in the biotite. Vermiculite or montmorillonite may have been intermediate phases (Birkeland, 1974).

Diagenetic Products

Carbonates. Calcite and dolomite commonly occur together in the Mount Shields Formation; siderite is not common. Calcite crystals are anhedral and range from 62 to 88 microns in the fine-grained rocks and up to 500 microns in the coarse beds. Dolomite crystals are rhombic, 62 to 88 microns in diameter in fine-grained rocks and 125 to 177 microns in coarse rocks. Calcite and dolomite occur primarily as interstitial cement, and commonly have replaced detrital grains, particularly feldspar. These carbonates show no conclusive evidence of having replaced each other.

Dolomite and calcite occur low in the Mount Shields I, at the top of the Mount Shields II and in the Mount Shields III. The gradational decrease in the amount of carbonate cement from the base of the Mount Shields Formation up into the lower Mount Shields I reflects the transition from the subaqueous depositional environment of the Shepard Formation to the fluvial environment of the Mount Shields I and II. Dolomite and calcite at the top of the Mount Shields II and in the

Mount Shields III also indicate a subaqueous depositional environment. Although there is no evidence that calcite precipitation preceeded dolomite, the high evaporative conditions during deposition of these sediments was probably favorable for calcite followed by precipitation of dolomite.

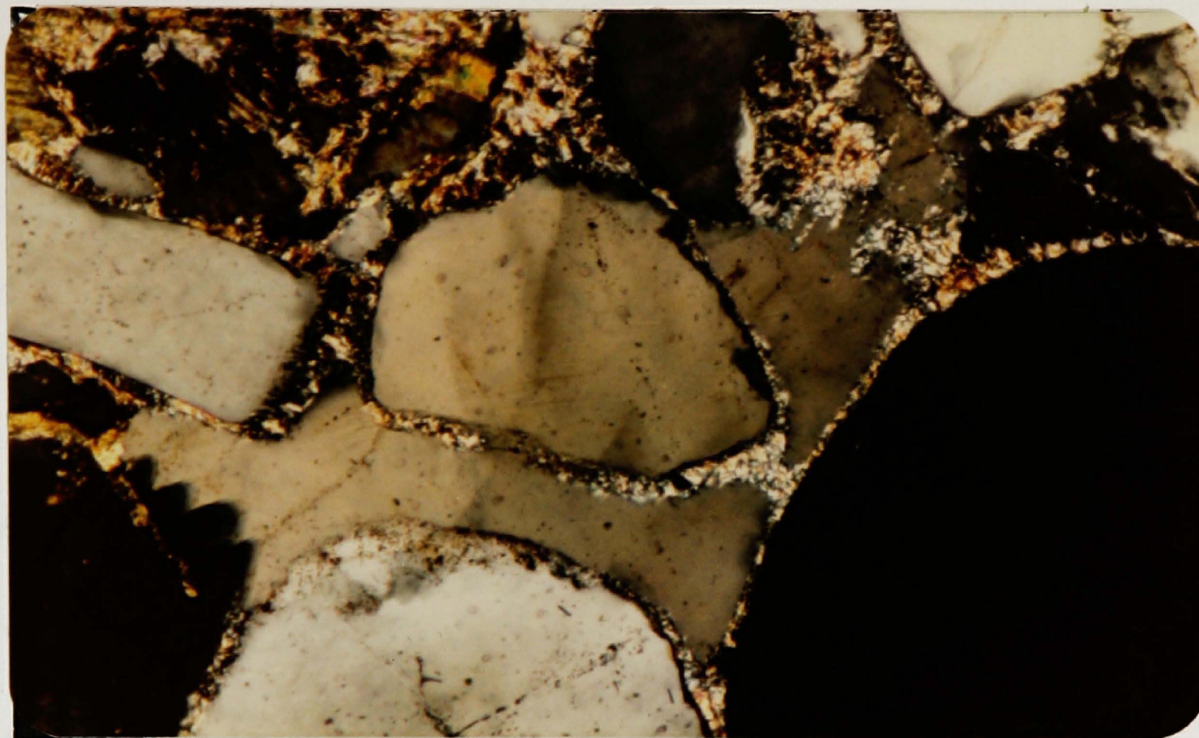
Hematite. Hematite is most abundant in the red beds of the Mount Shields Formation and less common in the green and white beds (Rock Creek, Kootenai Falls, and Clark Fork). This mineral coats detrital grains and overgrowths and rarely forms dust rims around quartz grains. These coatings are thin or absent at grain contacts. Hematite coatings are particularly thick around biotite, magnetite, and leucoxene grains as if iron were "bleeding" from these minerals. Walker (1967; 1974) and Walker et al. (1978) also found hematite-lined interstices and coated iron-bearing minerals in desert alluvium and red beds in tropical climates. These workers propose a diagenetic origin for the hematite. Conditions during deposition of the sediments in the Mount Shields Formation were probably ideal for the production of hematite. The cyclic alternation of rainy and dry periods proposed by Slover (1982) would have repeatedly raised and lowered the water table allowing oxidation of the iron-bearing minerals. Conditions at Clark Fork, Kootenai Falls and Rock Creek were apparently unfavorable for the precipitation of ferric oxide. Here there is no evidence of hematite oxidation followed by reduction (McBride, 1974). Instead, most magnetite and biotite grains at these localities are fresh and do not appear etched or eaten away. The sediments comprising the rocks at Clark Fork and Kootenai Falls were deposited on the distal reaches of alluvial aprons. The water table at these locations may have therefore remained high prohibiting oxygenation of the sediments. The rocks at Rock Creek were probably originally quite permeable and formed relatively high on the depositional slope. Hematite that might have been deposited in these sediments may have been flushed out and deposited farther down the depositional slope.

Illite and Chlorite. Illite and chlorite occur at all localities. The green beds owe their color directly to illite and chlorite (Keller, 1953) and indirectly to the absence of other coloring agents such as hematite (McBride, 1974). In addition to illite (sericite) and chlorite replacing feldspars, illite and chlorite occur intergrown and form "furry" coatings on detrital grains, grain overgrowths and less commonly between quartz overgrowths and their detrital nuclei (Fig. 12a). Smectite formed from weathered feldspars was the probable precursor of the illite (Eslinger and Sellars, 1981). Through progressive burial, temperature and pressure increased and brought about the conversion of smectite to mixed layered illite/smectite (50°C to 200°C) and finally to 1Md and 2M illite (200°C to 350°C). Eslinger and Savin (1973) determined from their oxygen isotope studies that the Belt rocks at Glacier Park reached temperatures between 225°C and 310°C. These mineralogic changes were accomplished by substitution of Al^{3+} for Si^{4+} in the tetrahedral sites (Hower et al. 1976) and fixation of K^{+} in the interlayer sites of smectite (Hower et al. 1976; Hoffman and Hower, 1979). These workers propose that the aluminum and potassium were derived from potassium feldspar. Silicon released from decomposed potassium feldspar, and iron and magnesium expelled from the octahedral layer of smectite contributed to the formation of quartz and chlorite respectively. These mineralogic transformations are represented in the equation below.

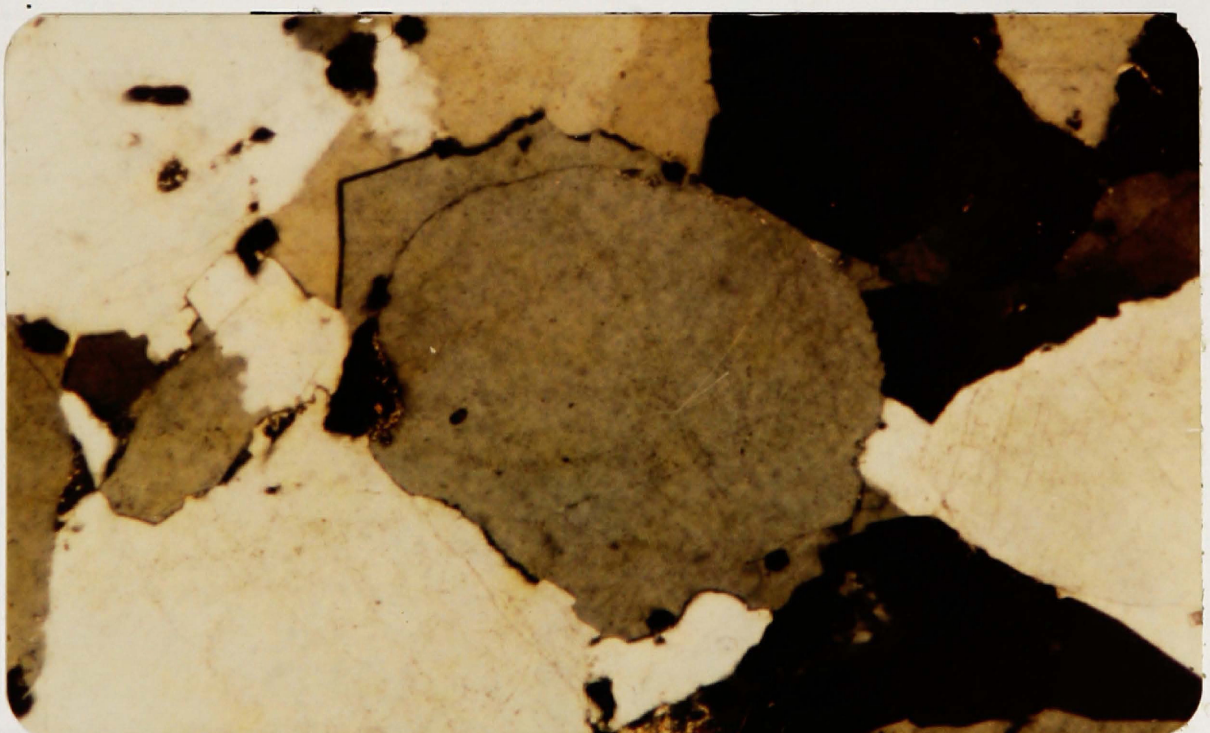
smectite + K-feldspar = illite + chlorite + quartz

The penecontemporaneous relationship of illite, chlorite and quartz represented in the equation above agrees with the textural relationships of these minerals in thin section. High proportions of 2M illite do not necessarily accompany large amounts of sericitized feldspar therefore, the higher percentages of altered orthoclase at Willow Creek, Prickly Pear, Morrell Mountain and Kootenai Falls probably did not result from the same diagenetic processes which produced 2M illite. Apparently, local unexplained geochemical conditions controlled feldspar sericitization. Further quantitative clay mineral and geochemical analyses is needed to solve this problem.

Maxwell and Hower (1967) studied burial diagenesis in the Belt Supergroup and documented an increase in the porportion of 2M illite from the east side of the basin at the Little Belt Mountains westward to Glacier Park and Clark Fork, Idaho. They attribute this increase to westward thickening of the supergroup and therefore progressively higher grades of burial diagenesis from the east side of the basin to the west side of the basin. Proportions of 2M illite in the Mount Shields Formation follow a similar trend. Where the Missoula Group is thinnest the percent 2M illite in the Mount Shields Formation is



(a)



(b)

Figure 12. Sericite coatings on quartz grains and overgrowths from Flint Creek (143X)(a). Euhedral quartz overgrowth sampled at Prickly Pear (55X) (b).

lowest; 2M illite in these rocks is most common at sections where the Missoula Group is thickest. Listed below are the localities sampled with their corresponding proportions of 2M illite and approximate thicknesses of the lower Missoula Group at these locations. The proportions of 2M illite at each section are also listed in Appendix I.

SECTION	MISSOULA GROUP THICKNESS	PERCENT 2M ILLITE 2M/2M + 1Md x 100
WOOD CREEK	1500 FEET (MCGILL AND SOMERS, 1967)	18 PERCENT
MORRELL MOUNTAIN	UNKNOWN	19 PERCENT
PRICKLY PEAR	4800+ FEET (KNOPF, 1963)	22 PERCENT
WEST GLACIER	5400+ FEET (ROSS, 1959)	24 PERCENT
ROCK CREEK	5000+ FEET (CALKINS AND EMMONS, 1915)	27 PERCENT
WILLOW CREEK	5000+ FEET (CALKINS AND EMMONS, 1915)	27 PERCENT
KOOTENAI FALLS	7000+ FEET (WINSTON, PERS. COMM.)	32 PERCENT
CLARK FORK	7000+ FEET (WINSTON, PERS. COMM.)	34 PERCENT

Table 1. Table showing correlation of highest proportions of 2M illite in the Mount Shields Formation with the thickest Missoula Group sections.

Maxwell and Hower (1967), as well as this thesis, do not consider additional burial of the Belt Supergroup by stacked thrust sheets. A future study examining the affects of Cretaceous-Tertiary thrusting on the low grade metamorphism of the Belt Supergroup may provide insight to this problem.

Quartz. Quartz overgrowths occur in most of the samples collected. These overgrowths range from tens of microns thick on fine grains to hundreds of microns thick on coarse grains (Fig. 12b). Some coarse-grained samples contain grains which are loosely packed and cemented in quartz. Large volumes of pore water circulating through the sediments are required for precipitation of silica cement (Blatt, 1979). The abundance of quartz cement in the coarse-grained beds is therefore not surprising considering the original permeability of these beds was probably much higher than that of the finer grained beds. Quartz cementation may have occurred over a wide range of temperatures. Detrital grains loosely packed in quartz cement certainly suggest early cementation before deep burial and therefore at near surface temperatures (Blatt, 1979). Quartz overgrowths on illite and chlorite coated grains implies that silica may have also precipitated at temperatures as high as 200°C to 350°C. Silicon released by the conversion of smectite to illite is one likely source of silica for the later quartz cement in the Mount Shields Formation. Evidence of pressure solution was not observed in these rocks and can therefore be discounted as a source of silica.

K-Feldspar. Thin (a few tens of microns) potassium feldspar overgrowths occur on detrital orthoclase and less commonly on detrital microcline. The source of potassium, aluminum and silicon ions needed for the growth of diagenetic feldspar in the Mount Shields Formation is not certain. Ali and Turner(1982), Stablein and Dapples (1977) and other workers consider interstitially degraded detrital potassium feldspars important sources of potassium, aluminum and silicon ions. Degraded biotite may have also contributed these constituents. Baskin (1956) proposes that diagenetic feldspar forms at low temperatures (less than 100°C). Oxygen isotope studies by Savin and Epstein (1970) confirm a low crystallization temperature for diagenetic feldspar. Unlike some quartz overgrowths in the Mount Shields Formation, illite and chlorite occur only on the outside surfaces of feldspar overgrowths not between overgrowths and their detrital nuclei. Diagenetic potassium feldspar in these rocks therefore, probably precipitated prior to illite and chlorite growth at temperatures less than 200°C.

CONCLUSIONS

The detrital mineralogy of the Mount Shields Formation is characterized by a fine-grained population and a coarse-grained population. Grains in the fine-grained population are subangular to subrounded, moderately sorted and range from 62 to 250 microns in diameter. Grains in the coarse-grained population are characteristically subrounded to well rounded, poorly sorted, and range from 250 to 2000 microns in diameter. A few pebbles (5000 to 9000 microns) occur at Rock Creek. Four source terranes supplied the detritus in the Mount Shields Formation. These terranes were located south, southwest, northeast and north of the Belt basin. Granite fragments, abundant subrounded quartz and feldspar and muscovite reflect granitic source rocks in the south, southwest and northeast. Tourmaline rock fragments and tourmaline were eroded from igneous injected rocks within these granitic terranes. Coarse, rounded and well rounded quartz grains, some of which are broken, doubly overgrown or have abraded overgrowths, are common at Rock Creek, Willow Creek and Wood Creek, and were eroded from coarse, chert-bearing sandstone exposed nearby these sections. Very fine to medium sandstone also outcropped in the south. Very fine to fine-grained sandstone, perhaps the upper Snowslip and lower Shepard, shed grains and rock fragments south from the northern source terrane. Volcanic rock fragments were reworked from the lower Shepard and/or eroded directly from the Purcell basalt exposed north of the basin.

The detrital mineralogy of the Mount Shields I and II at a single locality is relatively uniform, thus reflecting constant source terrane compositions. The abrupt increase in sandstone content from the Mount Shields I to the Mount Shields II was produced by an episode of rapid basin subsidence. Textural variations within these units were climatically controlled (Slover, 1982).

Some feldspar in the Mount Shields Formation was probably originally weathered to smectite, although this mineral was converted to illite and therefore not detected in any samples. Some hematite in these rocks may have formed from oxidized magnetite, ilmenite and biotite before deposition of these minerals. Some detrital biotite might have altered to chlorite prior to deposition.

Abundant diagenetic hematite is responsible for the red coloration of these rocks. Repeated raising and lowering of the water table brought about by cyclic alternation of rainy and arid periods (Slover, 1982) oxygenated the sediments and allowed formation of iron oxide from biotite, magnetite and ilmenite. Hematite is absent from the distal green beds because a high water table produced reducing conditions. Hematite was flushed through the permeable white coarse beds at Rock Creek. Quartz overgrowths formed at low, near surface temperatures and penecontemporaneously with illite and chlorite at temperatures perhaps as high as 200°C to 350°C. The conversion of smectite to illite is one likely source of silica (quartz). Potassium feldspar overgrowths formed early at relatively low temperatures. Potassium, aluminum and silicon in these overgrowths were probably derived from degraded potassium feldspar and possibly biotite.

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APPENDIX I

TABLE OF DETRITAL MINERALOGY

GRAIN TYPES	GRAIN POPULATION	CLARK FORK	KOOTENAI FALLS	PRICKLY PEAR	MORRELL MOUNTAIN	WEST GLACIER	WOOD CREEK	WILLOW CREEK	ROCK CREEK
quartz	fine	48.6	53.6	52.5	55.6	53.6	53.4	-	-
	coarse	54.6	50.0	49.5	48.7	53.5	62.2	57.5	58.7
orthoclase (fresh)	fine	9.6	3.5	3.6	4.3	8.0	8.8	-	-
	coarse	6.5	2.5	3.2	2.0	5.8	3.7	2.6	5.4
orthoclase (altered)	fine	0.8	3.3	4.3	4.5	0.4	0.8	-	-
	coarse	1.3	3.0	3.8	3.0	2.7	0.5	3.6	2.1
microcline	general	0.5	0.6	1.4	0.8	0.5	0.7	0.3	1.3
microperthite	general	0.9	0.8	1.3	1.3	0.9	0.5	1.1	1.3
plagioclase	general	trace	-	0.2	0.7	0.3	0.6	0.4	1.0
muscovite	general	1.2	1.0	0.9	1.0	1.1	0.9	0.6	0.9
biotite	general	0.1	trace	0.5	0.6	0.1	0.6	-	0.3
chlorite	general	0.2	trace	0.2	0.4	0.5	0.6	-	0.1
chert	general	0.4	0.2	0.8	0.4	0.1	0.6	1.1	0.6
magnetite and leucoxene	general	1.5	1.5	0.8	0.9	1.0	0.3	0.3	0.8

GRAIN TYPES	GRAIN POPULATION	CLARK FORK	KOOTENAI FALLS	PRICKLY PEAR	MORRELL MOUNTAIN	WEST GLACIER	WOOD CREEK	WILLOW CREEK	ROCK CREEK
zircon	general	0.5	0.5	0.4	0.4	0.4	0.2	0.4	0.4
tourmaline	general	0.5	0.5	0.5	0.5	0.5	0.4	0.6	0.4
sandstone rock frags.	fine	-	0.1	-	trace	-	-	-	-
	coarse	-	0.4	0.1	0.1	0.4	-	trace	0.2
granite rock frags.	coarse	-	-	1.8	0.4	0.2	1.3	0.3	1.5
tourmaline rock frags.	fine	0.2	-	-	-	-	-	-	-
	coarse	0.7	-	-	-	0.2	-	0.4	trace
volcanic rock frags.	fine	-	trace	-	-	-	-	-	-
	coarse	-	-	-	-	trace	-	-	-
quartzite rock frags.	coarse	-	-	0.6	-	-	-	0.8	0.4
illite $\frac{2M}{2M+1Md} \times 100$	general	34	32	22	19	24	18	27	27

values given are percent detrital grains
trace--less than 0.1 percent

APPENDIX II

STATISTICAL COMPARISONS (t TEST)

OF DETRITAL GRAIN MEANS

FINE POPULATION

Orthoclase (Fresh)

Clark Fork, West Glacier, Wood Creek vs. Kootenai Falls, Prickly Pear, Morrell Mountain

mean	mean
8.8 percent	3.8 percent

degrees of freedom
72

t value
8.35

probability of random occurrence

1×10^{-15}

Orthoclase (Altered)

Clark Fork, West Glacier, Wood Creek vs. Kootenai Falls, Prickly Pear, Morrell Mountain

mean	mean
0.7 percent	4.0 percent

degrees of freedom
69

t value
7.00

probability of random occurrence

1×10^{-12}

COARSE POPULATION

Quartz

COARSE POPULATION (cont.)

Quartz (cont.)

Rock Creek, Willow Creek, Wood Creek vs Clark Fork, West Glacier Kootenai Falls, Prickly Pear, Morrell Mountain

mean	mean
58.3 percent	51.4 percent

degrees of freedom
46

t value
3.39

probability of random occurrence

1×10^{-3}

Quartzite

Willow Creek vs. Rock Creek, Prickly Pear

mean	mean
0.8 percent	0.5 percent

degrees of freedom
29

t value
1.85

probability of random occurrence

1×10^{-2}

GENERAL POPULATION

Orthoclase

Fine Population vs. Coarse Population

GENERAL POPULATION (cont.)

Orthoclase (cont.)

mean	mean
8.6 percent	6.5 percent

degrees of freedom
124

t value
5.20

probability of random occurrence

1×10^{-7}

Microcline

Prickly Pear, Rock Creek, vs. Clark Fork, Kootenai Falls, West Glacier, Wood Creek, Morrell Mountain, Willow Creek

mean	mean
1.4 percent	0.6 percent

degrees of freedom
127

t value
6.22

probability of random occurrence

1×10^{-9}

Microperthite

Rock Creek, Willow Creek, Prickly Pear, Morrell Mountain vs. Wood Creek, West Glacier Kootenai Falls, Clark Fork

GENERAL POPULATION (cont.)

mean 1.2 percent

mean 0.8 percent

degrees of freedom
127

t value
3.70

probability of random occurrence

1×10^{-4}

Plagioclase

Clark Fork, Kootenai Falls vs. Rock Creek, Willow Creek, Morrell Mountain, Prickly Pear, Wood Creek, West Glacier

mean 0.03 percent

mean 0.5 percent

degrees of freedom
128

t value
6.03

probability of random occurrence

1×10^{-9}

Chert

Willow Creek vs. Rock Creek, Morrell Mountain, Prickly Pear, Wood Creek, West Glacier, Kootenai Falls, Clark Fork

GENERAL POPULATION (cont.)

Chert (cont.)

mean	mean
1.1 percent	0.5 percent

degrees of freedom
127

t value
3.53

probability of random occurrence

1×10^{-4}

Magnetite and Leucoxene

Clark Fork, Kootenai Falls vs. Rock Creek, Willow Creek, Morrell Mountain, Prickly Pear, Wood Creek, West Glacier

mean	mean
1.5 percent	0.7 percent

degrees of freedom
128

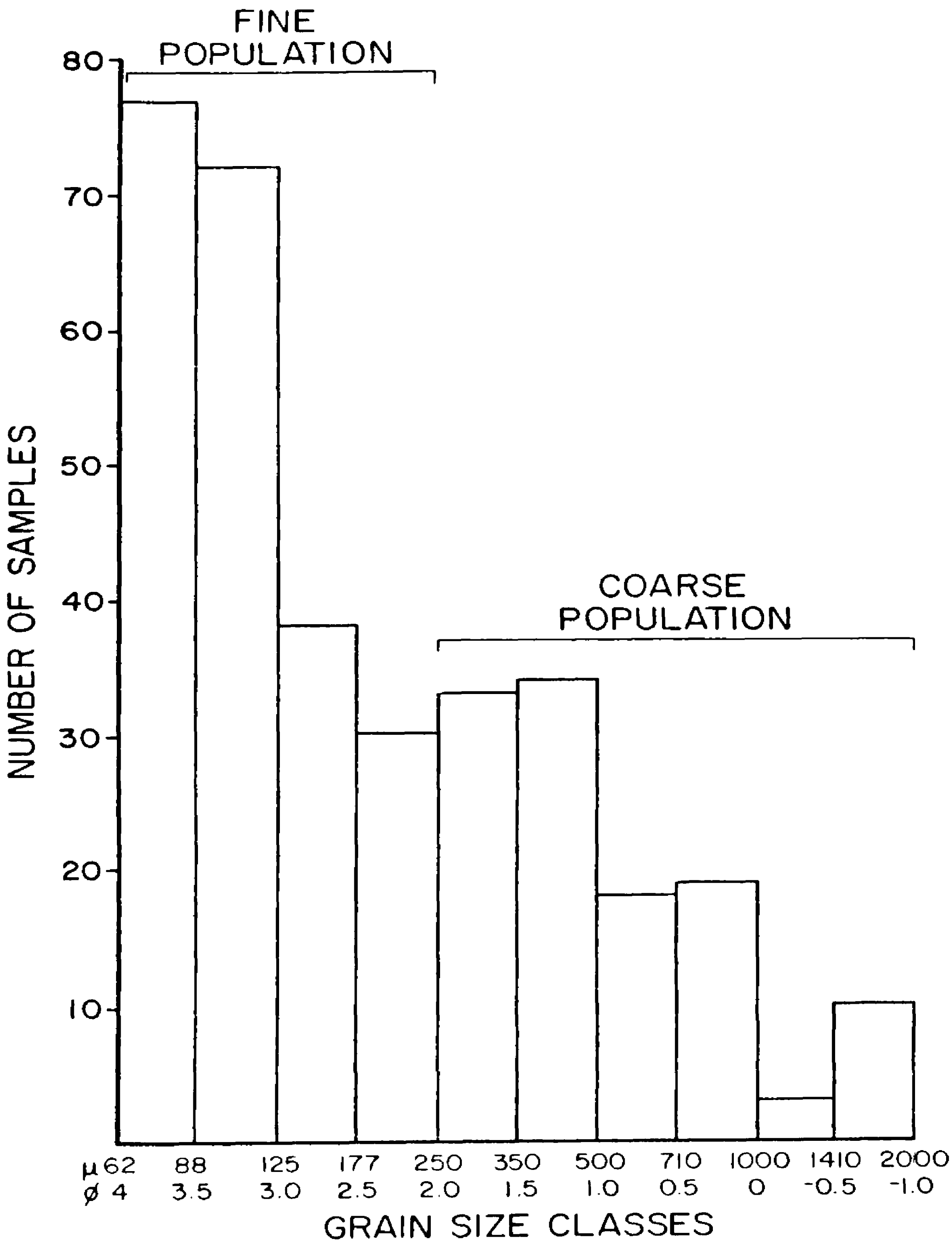
t value
5.00

probability of random occurrence

1×10^{-6}

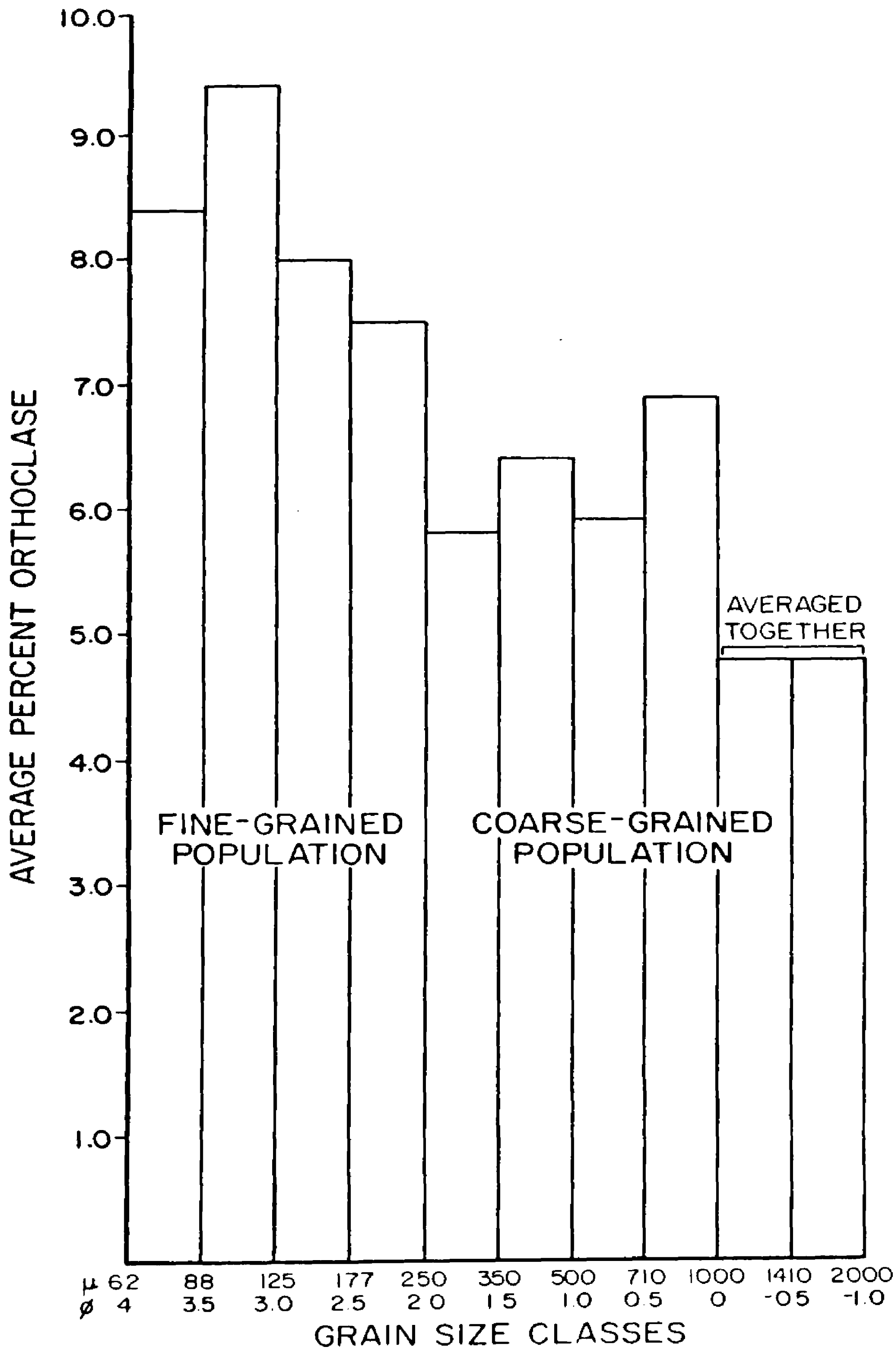
APPENDIX III

HISTOGRAM OF APPROXIMATE GRAIN SIZE DISTRIBUTION


FINE
POPULATION
COARSE
POPULATION
NUMBER OF SAMPLES
80
70
60
50
40
30
20
10
μ 62 88 125 177 250 350 500 710 1000 1410 2000
ø 4 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5 -1.0
GRAIN SIZE CLASSES

APPENDIX IV

HISTOGRAM OF APPROXIMATE GRAIN SIZE DISTRIBUTION OF ORTHOCLASE



AVERAGE PERCENT ORTHOCLASE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVERAGED TOGETHER
FINE-GRAINED POPULATION
COARSE-GRAINED POPULATION
μ 62 88 125 177 250 350 500 710 1000 1410 2000
ø 4 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5 -1.0
GRAIN SIZE CLASSES

APPENDIX V

THIN SECTION DESCRIPTIONS

CF 0 CLARK FORK

Grains: 50%

size ≤ 62-83μ (silt to very fine sand)

shape subangular to subrounded

sorting moderate

composition qtz -- 30%

maybe higher (some replaced by calcite) → K-feld - ≥10% (mostly clean, some slightly dirty)

perthite -- trace

tour trace (one green grain)

musc -- 4%

leucoxene -- <1%

chlorite -- 2%

Matrix: 50%

calcite (probably replaces original matrix + some grains), a little dolomite.

CF 45 take photo of double overgrowths

Grains: 75%

size: 62-250μ (very fine - fine sand) w/ ≤1% 350-500μ (med. sand)

shape: subrounded to subangular (larger grains more rounded)

sorting: moderate to poor (some grading)

composition: qtz -- 62% (some w/ double overgrowths) (one large grn. w/ lots of bubble trains)

maybe 1-2% replaced by calcite K-feld -- 7% (pretty clean)

microcline -- 1% clean

perthite -- 1% clean

musc trace - 1%

tour -- trace

Matrix: 25% magnetite - 1% (scattered); zircon trace subrounded (seen)

CF 49

Grains: ~50%? in coarse layer; 70% in fine-grained portion
size: 62-710μ (very fine to coarse); 62-125μ (very fine sand)
shape: rounded to well rounded; subangular to subrounded
sorting: poor ; moderate
composition: qtz -- 39% (overgrowth) ; 55% qtz
K-feld ≤ 8% (some very dirty); K-feld -- 12%
musc - 1%
micro -- trace (clean)
perthite -- 1% (clean)

zircon -- trace (subrounded)
tour - trace
leucoxene - trace (scattered)

Matrix: 50% ; 30%

CF 100

Grains: 75%+
size. 62-125μ (very fine to fine sand)
shape. subangular
sorting: moderate
composition. qtz -- 55%+
K-feld -- 10%
perthite - 2%
microcline -- trace
musc 1% biotite -- trace
tour - trace
mudchips - 6%
zircon -- trace
mag/leuc 1% (scattered)

CF 200

Grains: 65%
size: 88 177μ (very fine to fine sand)
Shape: subangular to angular
Sorting: moderate
composition: qtz -- 48% (a few overgrowth)
may some replace by K-feld -- 12% (most spotty clean)(some ser. cal.
micro -- 1% (clean)
perthite -- 1% (clean)
tour -- trace
musc -- ≤1% biotite? (trace)
mud chips -- 3%
opaques mag. leuc (1%) (scattered)(one euhedral grn)
chert -- trace zircon -- trace (euhedral, subangular)
plag trace (dirty)

CF 231 Too fine-grained (a few grns. are very fine sand)

Calcareous feldspathic siltstone.
~~tour~~ ~~tou~~
General composition -- calcite
some leuc (heavy mineral layers)
qtz
Tour K-feld
1. brown-green basal musc
2. yellow-brown (X); med. green-brown (Z), hiddes zircon
green biotite, ...
3 yel. tint (X), med. green (Z); bubbles

Most of the rock is calcite (cement) and muscovite w/ maybe 30% grains

CF 300

Grains: 75%

size: 88-125μ (very fine sand)
shape: subangular to subrounded
sorting: moderate to well
composition. qtz -- 51%
K-feld -- 10% (2% dirty)
microcline - trace
perthite -- ~~trace~~ ≤1%
musc -- 1% biotite -- trace
tour -- trace
(mudchips) -- 7%
zircon -- trace
tour rock frags? trace (quite small)
mag -- 3% (scattered)

CF 355

Grains: 75%

size: 62-125μ (very fine sand)
shape: subangular to subrounded
sorting: moderate 55%
composition. qtz -- [illegible] (overgrowth)
K-feld -- 12% (slightly dirty,) some overgrowth
microcline - trace (clean)
perthite 1%
musc ≤1%
zircon trace
might approach → tour - trace 1% tour rock frag (small ?) (mudchips?) -- ≤1%
chert ≤1%
mag/leuc/oxides - 2% (scattered)
mudchips -- 2%

CF 405 — Photo of double overgrowths, tour. rock frags. try to find

Grains: 75%

size: 250-350μ (med. sand)

shape: subrounded to rounded, a few well rounded

sorting: moderate

composition: qtz — 65% (double overgrowths)

maybe 2% replaced by calcite? — K-feld — 3% (slightly dirty,

perthite — trace

microcline — trace

chert — ≤1%

igneous? tour. rock frags (siltstone w/tour) — 3%+

tour — trace, zircon — trace (large & rounded-well rounded)

Matrix: 25%

chlorite — 2%, qtz — 18%, calcite — 5%

CF 500 — 2. 4.5, 2.5, 3.5 — Photo of 25% med-grained rounded grains, chlorite

Grains: 70%+

size: 88-125μ (very fine sand); w/ some layers & lenses 88 - 350μ (very fine to med)

Shape: subangular to subrounded (smaller grains more angular)

sorting: moderate; (coarser layers less well sorted)

composition: qtz - 48% ← stained ≈ 57%, in coarser layers

K-feld - 15%+ (coarse layers w/5% & more ?) ≈ 2%+

perthite - ≤1% (clean)

micro - trace (clean)

chert — 1-2%

zircon trace (euhedral, euhedral, subangular)

musc - <1%

opaques — 2% (may include some in layers)

tour — trace

CF 545 Hayne photo of ooids?

Grains: ≈60%± <1% ooids, qtz <≈1% grns.

size: 62-88μ (v. fine sand); w/pebble-sized mud chips, 350-500μ (med. s.)

shape: subangular ; subrounded to rounded qtz + qtzite

sorting: poor

composition: qtz 39%

clot of calcite, prob = K-feld - 5-7% (only fine grained) (replaced alot by calcite). higher?

perthite -- trace

musc -- ±1%

zircon -- (rounded) -- trace (in heavies layers)

mud chips: 10% tour -- trace (approaches 1%) -- brown + green euhedra (same as in rock frags)

magnetite ≈2% in layers, esp. coarser area

ooids -- 1% -- many are larger and broken

Matrix 40% (ave)

FC 1 FLINT CREEK

Grains: 70%

size: 88-1410μ (very fine to very coarse sand)

shape: rounded

sorting: poor

composition: qtz -- 55%

K-feld 10% (dirty, 7% stained) - some sericitized

micro -- 1% (slightly dirty)

perthite -- 1% (clean)

granite frags - 1% (med. grained)

qtzite frags - 2% (fine to med. grained)

tour... trace

musc - trace

zircon - trace euhedral magnetite - trace

FC 5

Grains: 70%

size: 88 - 250 μ (very fine to fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz - 56%

K-feld - 10% (slightly dirty, some sericitized, all stained)

perthite - 2%

microcline ≤ 1%

plag.? - trace

zircon - trace (anhedral + subrounded) (some brown)

tour. - ~~trace~~ 1% (subrounded)

mag + leucoxene - trace

musc. - trace siltite - trace

FC6 qtzite frag., granite frags., reworked grns

Grains: 65%

size: 177 - 1410 μ (fine to very coarse sand)

shape: subrounded to rounded

sorting: poor

composition: qtz - 54% (some overgrowth)

K-feld - 10% (dirty, replaced by dolomite)

micro ≤ 1%

perthite - trace

qtzite - trace (mostly v. fine grained, some highly sutured, some coarse grained)

granite - trace, coarse grained

musc - trace

Matrix: 35%

dolomite and calcite? - 35% qtz - trace
(replaces alot of feld.)

FC 9 — photo of tour in rock frags.

Grains: 70%
size: 88 - 350µ (very fine to medium)
shape: subangular to subrounded
sorting: moderate
composition: qtz - 52%
K-feld - 12% (some is pretty dirty, sericitized)
perthite - ~2% clean
plag. - trace (dirty)
micro - 1% (clean)
musc. - trace
☆ mudchips + siltstone w/ tour xls - ~~trace~~ 1% (~~a few grains~~)
mag. & leucoxene - 1% (scattered)
tour. - 1% siltite - trace
zircon - trace (brown)

FC 14

Grains: 75%
size: 62-83µ (very fine sand)
shape: subangular to subrounded
sorting: moderate to well sorted
composition: qtz - 66%
K-feld - 7% (dirty along cleavage)
microcl. - trace (clean)
perthite - trace
musc. - ≤ 1%
plag - trace (~~dusty~~ (dirty)
chert - trace
tour. - trace
opaques (oxidized grns, mag, leuc.) - 1% (some oxide layers)
zircon - trace

FC 15 ~~pt~~ photo of qtzite, etc.

Grains: 60%
size: 62 - 1410μ (very fine to very coarse sand)
shape: subrounded and rounded
sorting: very poor
composition: qtz -- 44%
K-feld -- 4% (3% stained | clean
micro - trace
perthite - 1%
chert -- trace (1 grn)
qtzite - 1% (fine & coarse grns) (some w/ feldsp granite?)
mud chips -- 10%
tour. -- trace in 2 grns. colorless & light green (clear)
musc - trace

KF 70 KOOTENAY FALLS

Grains: 60%
size: 62 - 88μ (very fine sand), a few (3 or 4) fine grains
shape: subangular
sorting: moderate 50%
composition: qtz -- (some little overgrowths)
+4% seric. & K-feld -- 4%+ (original maybe higher, alot of sericite)
perthite - ≤1%
musc - 1%
tour trace
magnetite/leuc % (some in layers)
mud chips -- % ignored in total
Matrix: ~~35~~ 40%
sericite 30%
chlorite 10%

KF 120   Photo of s.s. frag

Grains: 65% ←10% med → coarse qtz
size: 62-125 μ (very fine sand) and 350-710 μ (med. → coarse sand)
shape: subangular-subrounded; rounded
sorting: poor
composition: qtz 59%
+2% replaced by seri-calcite ⇒ K-feld - 3%; ; (some of these overgrown once in terrace)
microcline - trace
perthite - trace
zircon - trace
magnetite - 3% (scattered in layers)
177-250 fine sand ⇒ sandstone frag. (~~[illegible]~~) - note grain w/ double overgrowth!
musc - ≤trace

KF 205

Grains: 65%
size: 62-125 μ (very fine sand)
shape: subangular
sorting: moderate
composition: qtz 48%
+7% sericitized ⇒ K-feld - 4% (albite sericitized?)
microcline - trace
perthite - trace
musc - 3%
magnetite - 2% (some in layers)
zircon - (subrounded) trace
tourm - ≤1%

Matrix 35%
sericite 30%   chlorite - 5%

KF 265

Grains: 60%⁻
sizes 62-350μ (~500) (very fine to med. sand)
shape: subangular to subrounded
sorting: moderate to poor
composition: qtz - 53% some overgrowth / many are reworked (double) overgrowths
≃+5% replaced by sericite/calcite   K-feld - 2% (sericitized)
perthite -- ≤10%
microcline -- ≤1% (
muscovite - trace
tour - trace   zircon - trace (subrounded)
leuc - trace

mudchips -- not included in %
Matrix: 40%

KF 300   Great clay sample

Grains: 50%⁻
60%   40%
size: ≤62μ (silt to very fine sand); 177-350μ (fine to med. sand) (some 100% reworked)
shape: subangular to subrounded; some of these are rounded
sorting - moderate to poor
composition: qtz - 39% ← some overgrowth
slightly lower in finer grained part, maybe from more sericitization   K-feld - 2%⁻ (sericite),
perthite - ≤1% ← maybe a bit higher (5%?) because of sericite
microcline - trace
sandstone frags (very fine - fine) - ≤1%
muscovite - 2%
some detrital chl? tour - trace
zircon - trace (subrounded to rounded)
mag/leuc - 1% (scattered; mostly w/ med. grns)
Matrix: 50%⁺

KF 350

Grains: 65%

size: 62 250μ (very fine to fine sand)

shape: subangular to subrounded (maybe a few rounded)

sorting: moderate to poor

composition: qtz 55% (some overgrown)

+5% sericitized → K-feld -- 3% (dirty, some sericite)

perthite -- 1% (slightly dirty)

microcline -- trace (slightly dirty w/ some sericite)

muscovite -- ≤1%

tour -- trace

zircon -- trace (subrounded & rounded)

magnetite/leuc -- trace → 1%

Matrix: 35%

sericite -- 20% chlorite -- 15%

KF 400 (Take photo of fuzzy sericite) (good clay sample)

Grains: 55%

size: 88-350μ (very fine to medium sand)

shape: subangular to angular

sorting: moderate to poor

composition: qtz 45% (a few overgrown)

2-3% sericitized → K-feld -- 5% (dirty) some kaolinized

perthite -- 1% (dirty)

chert trace

siltite -- 1% (mudchips)

zircon trace (subrounded)

tour trace (euhedral) (brown)

musc. -- ≤1%

Matrix: 45%

KF 465 (Take photo of (good clay sample) sericite+ ... replaced grains)

Grains: 50% (original may have been higher)
size: 62-88μ (very fine sand)
Shape: subangular + angular
sorting: moderate 42%
composition: qtz (some replaced)
biotite - trace
mus - 1%
opaques (2%) mag. + tour - trace (euhedral - green)
leucoxene zircon - trace (anhedral)
X → no apparent K-feld - looks as though all replaced by sericite ≈ 5% sericite

Matrix: 50%
composition: sericite 48% (replaces grains) qtz - trace siderite - 2%

KF500 Maybe a photo of s.s. frag

Grains: 70%
size: 88-177μ (very fine to fine) & 250-350μ (med. sand) <1%
shapes: subangular to subrounded; ≥ subrounded & rounded
sorting: moderate to poor
composition: qtz 63% overgrowth & some overgrowth sericitized
+3% replaced ⇒ K-feld - 3% (slightly dirty), (rounded, fine-med)
perthite - 1%+ (clean)
microcline - 1% (clean)
muscovite - trace
tour - trace ~~apparently~~
zircon - trace (subrounded)
☆ sandstone frag 2 fragment (~~coarse sand~~ very fine to fine) well-cemented

Note: overgrown grains probably reworked

magnetite 1% (scattered)

KF 550 (good clay sample)

Grains: 60%
- size: 88 - 250μ (very fine to fine sand)
- shape: subangular to subrounded
- sorting: moderate
- composition: qtz - 49% (some small overgrowths)

±2% sericitized — K-feld - 7%
- micro. - trace

opaque (1%) - mag. & leucoxene — siltite - 1%+
- tour. - trace (green) (subrounded)
- zircon - trace (subrounded)
- musc. - trace

Matrix: 40% sericite - 25% calcite - 15%

KF 600

Grains: 70%
- size: 88 - 350μ (very fine to med. sand)
- shape: subangular to subrounded w/ a few rounded (med. sand)
- sorting: moderate to poor
- composition: qtz - 54% recrystallized? (some overgrowths, some polygonized)

±2% sericitized — K-feld - 6% (some sericitized,
- microcline - 2% (pretty clean)
- perthite - 2% (pretty clean)
- muscovite - trace
- tour. - trace
- zircon - trace (subrounded)
- magnetite - 2% (some in circle layers)
- chert - trace
- 1 - ≤1% (mud chips)

KF 650 (good clay sample) (photo of remarked grns?)

Grains: 60%
size: 88-177μ (very fine to fine sand) some 250-350μ (med. sand)
shape -- subrounded to subangular
sorting: moderate remarked grns.
composition: qtz -- 50%
≈1% sericitized K-feld - 5% (clean)
mica trace (clean)
opaque (3%) mag. tour -- trace (green) (subangular)
(patchy concentrations) zircon -- trace (subrounded) (some euhedral?)
perthite - trace (clean)
siltite -- ≤ 1% (chert?)
musc trace
Matrix: 40%
composition: sericite -- 37% calcite -- 3%

KF 700 (good clay sample) (some remarked grns. (sutured grains)

Grains: 65%
size: 62 - 250μ (very fine to fine sand) w/a few medium grns.
shape: subrounded to subangular
sorting. moderate
composition: qtz -- 56% (some small overgrowths)
1-2% sericitized K-feld. ≤ 5% (slightly dirty)
mica - trace (clean)
opaques (trace) mag perthite - 1% (slightly dirty)
leucoxene tour -- trace (green) (subrounded)
zircon trace (subrounded)
mudchips -- 1%
chert - 1% musc. - trace
Matrix: 35% replaces grns
composition: sericite -- 34% qtz trace calcite -- 1%

KF 745

Grains: 65%

size 62 - 250μ (very fine to fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz ... 55%

+5% sericite K-feld - 3% (clean or sericitized)

opaques (1%), mag, perthite 1% (clean)

leuc. (mag altering to micro - trace (clean)

leucoxene) musc - 1%

zircon - trace subrounded, euhedral

tour. - trace (green) subrounded

chert - trace

Matrix: 35% replaces grn edges

composition: sericite - 32% calcite - 3% (patchy, replaces sericite)

KF 800

Grains: 70%

size: 62-125μ (very fine sand); a few 177-250μ (fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz - - 55% (some overgrowths)

4% sericite K-feld - - 10% (clean)

perthite - trace (clean; green

opaques (3%) mag, tour - - trace (dark brown) subangular

leucoxene, some zircon - - trace (subangular)

in layers musc - 1%

micro - trace (clean)

Matrix 30%

composition. sericite - 27%

alteration material(?) - 3%

KF 850 — Take photo of vol. fragment (if you can find it).

Grains: 70%
size: 88–250μ (very fine to fine sand)
shape: subangular to subrounded; some rounded
sorting: moderate
composition: qtz — 60% (polygonized grns., some overgrown)
≈1% sericitized — K-feld — 5% (some sericitized, others clean)
microcline — ≤1% (clean)
perthite — ≤1% (clean)
magnetite — 2% — muscovite — ≤1% — biotite — trace (detrital)
(some in coarse layers) — tour — trace
zircon — trace (subrounded to rounded)
chert — ≤1%
sandstone frags 2 or 3 (fine sand qtz + unstained feld)
⇒ ☆ Volcanic rock frag — glass w/ feld laths 1 grn.

KF 900 — Maybe take photo of dentritic overgrowth.

Grains: 75%
size: 88–350μ (very fine to fine) — few just about (250–350μ) med. ss.
shape: subangular to subrounded; some larger grains are rounded
sorting: moderate to poor
composition: qtz — 62% (some polygonized, overgrown some)
+4% sericite some rewashed — K-feld — 5% (sericitized or clean)
microcline — trace (clean)
perthite — trace (clean)
muscovite — 1%
chert — 1%
tour — trace — zircon — trace (subrounded)
magnetite — ≤1% (scattered)
chlorite — trace (detrital)
sandstone frags (qtz grns. cemented together) — ≤1%

KF 95C (original mineralogy obscured by calcite replacement)

Grains: 60%⁻
size: 62-125 (very fine sand)
shape: angular to subangular
sorting: moderate to good
composition: qtz - 52%
≈2% replaced by cal, sericite — k-feld — 3%± (sericitized or clean)
perthite — trace (clean)
microcline — trace (clean)
musc — ≤1%
tour — trace
zircon — trace (subrounded)
leuc/magnetite — 2%⁻ (well layered w/ other heavies)
Matrix: 40%⁺
calcite 25% sericite 15% ← probably some chlorite too

MM 259a MORRELL MOUNTAIN

Grains, 75%
size: ≤ 62.5µm (very fine sand to silt)
shape: subangular
sorting: moderate
composition: qtz - 62%
K-feld — 5%⁻ (some looks dirty,)
perthite — trace (clean)
microcline — trace (clean)
plagioclase — trace (clean)
biotite — ≤1% (red stained)
musc — ≤1%
red mud chips 5% magnetite — trace-1% (scattered)
chlorite — trace
zircon — trace (subrounded); tour — trace

MM 300 reworked grns.

Grains: 70%
size: 62-125μ (very fine sand)
shape: subangular
sorting: ~~sort~~ moderate
composition: qtz - 56%
original amt. prob. higher. K-feld - 5% (highly altered grns. ≈5-7%) (others are clear)
perthite 2% (slightly dirty)
plag. - 1% (slightly dirty) micro trace (slightly dirty)
biotite trace (green) (brown)
siltite frag. trace (mudchips)
zircon trace (subrounded)
musc - 1%
tour. - trace
mag + leucoxene 1% (scattered)

MM 390

Grains: 70%
size: 62-177μ (very fine to fine sand)
shape: subangular to subrounded
sorting: moderate
composition: qtz - 57% (overgrown some)
original % ⇒ K-feld - 5% 5%+ (sericitized chert ← so not stained
previously higher perthite - 1% (slightly dirty)
plag - 1%
opaque - mag, 1% leuc. (~~trace~~) ore under layer
siltite - trace — maybe some chert
tour. - trace
zircon - trace (subangular)
musc - 1%
biotite - trace
microcline - trace (dirty)

HM 445

Grains 65%

size: 83-250µ (very fine to fine sand)

shape: subangular, some rounded

sorting: moderate

composition: qtz - 48% (overgrown)

original higher?→ K-feld - 8% (overgrown) } +5% ser.

plag - 1%+ (clean, some dirty)

perthite - 1% microcline - ≤ 1% (dirty)

opaques-mag. (trace) zircon trace (subrounded)

tour. trace

siltite trace ⟷ mudchips 1%

chert trace

biotite trace (brown) chl. trace

musc - 1%

HM 489

Grains - 70%

size - 62-125 (very fine sand)

shape - subangular to angular

sorting - moderate

composition - qtz - 54% (some overgrown)

→ K-feld - 10%+ (pretty clean)

perthite - 2% (clean)

plag - ≤1% (clean, slightly dirty)

microcline - trace (clean, some dirty)

chert - trace

tour - trace biotite trace (brown)

musc ≤ 1%

opaques mag, leuc., oxides (2%) in layers

zircon subrounded (trace)

MM 533

Grains: 75%

size: 62-125μ (very fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz -- 59%

+6% sericitized → K-feld -- 5%

perthite -- 2%

microcline -- 1%

plagioclase -- 2% (some sericite, some clean)

muscovite -- 1%

chlorite -- trace (detrital) biotite -- 1% (red stained, weathered?)

chert -- trace tour -- trace

zircon -- trace subangular

magnetite: <1% (scattered)

MM 585

Grains: 70%

size: 88-177μ (very fine to fine sand)

shape: subangular

sorting: moderate

composition: qtz 55% ← (polygonal)

K-feld - 10% (sericite < 3%)

perthite 2% (clean)

microcline 1% (clean)

plagioclase -- ≤1% (dirty)

tour -- trace

siltite -- trace

opaques - 1% (mag., leuc.) scattered)

zircon - trace (subangular)

biotite -- trace (green)

HM 637

Grains: 70%
size. 88-177μ (very fine to fine sand); about 4-6 grns. of qtz (250-350μ) med. sand
shape: subangular to subrounded
sorting. moderate
composition: qtz 56%
2% replaced by carb or seri. K-feld 7%
microcline -- trace (clean)
perthite - ≤2% (clean)
plag -- ≤1% (dirty)
musc. -- 1%
chert -- trace mud chips - 1%
tour. - trace
biotite trace → 1% (brown, some green)
opaques - mag, leuc. (≤1%) -- some in dark layers

HM 640

Grains. 75%
size: 88-177μ (very fine to fine sand)
shape: subangular to subrounded
sorting. moderate
composition: qtz = 59% (wavy extinction)
6% replaced by CO_3 + sericite K-feld -- 7% (sericitized dust) (wavy extinction)
perthite - 2% (clean)
microcline - 1% (clean)
musc ≤ 1%
biotite - trace (red stained, weathered?)
mud chips 3% tour - trace
plagioclase - trace (sericitized)
chlorite - trace
magnetite - 2% (layered)

MM 740

Grains: 70%

size: 62--177 μ (very fine to fine sand)

shape: subangular

sorting: moderate

composition: qtz-- 55% (overgrown)

K-feld-- 7% (3% altered to sericite)

microcline-- trace (clean, overgrown)

plag-- trace (dirty, clean)

perthite-- 1% (slightly dirty)

tourm-- trace mag, leuc.-- trace (scattered)

musc. -- 2%

biotite trace (brown)

chert --trace

mudchips- 3%

MM 790

Grains: 70%

size. 62-125 μ (very fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz-- 57%

K-feld-- 10% (2% sericitized)

microcline ≤1% (clean)

perthite ≤1% (slightly dirty)

plag trace (dirty, sericite)

musc ≤1%

tourm--trace biotite--trace

chert -- trace

zircon -- trace (angular-subangular)

opaques - mag, leuc. (trace) scattered

MM 840

Grains: 70%
size: 88-177μ (very fine to fine sand)
shape: subrounded to subangular
sorting: moderate
composition: qtz -- 55% ≤ (some overgrowth)
K-feld -- 10% (1-2% sericitized grns).
microcline -- 1% (clean)
plagioclase -- ≤1% (clean)
perthite - 1% (clean)
musc. -- ≤1%
tour - trace zircon -- trace (subangular)
opaques mag, leuc., oxides 1% (scattered)
biotite (trace)

MM 890 slide not stained - feld all eaten up

Grains: 70%+
size: 88 - 350μ (very fine to med.) (mostly very fine - fine)
shape: subangular → angular (larger grains more rounded)
sorting: moderate
composition: qtz 60% (some overgrowth)
K-feld? 10%+ (looks all sericitized - not stained)
zircon trace (subangular, subrounded)
biotite - trace
tour - trace
chlorite - trace
difficult to see → granitic frag ?? (very fine grained, feld highly sericitized) (mixed grn.) (myrmekitic?)
musc. - trace

Matrix: 30% -
sericite -- 30% ; 3 trace

MM 940

Grains: 70%

size: 88-177μ (v. fine to fine sand) w/a few 250-350 (med. sand) ≤≤1% qtz & feld.

shape: subangular

sorting moderate, poorer in layer w/ coarser grains

composition: qtz -- 56% ≤ (some overgrowths)

+2% sensitized K-feld - 7% (sensitized)

microcline - 1-2% (clean)

perthite - 1% (dirty)

musc - 2%

biotite - trace

chert -- ≤1% mag, leuc. 1% (in dk layers)

plag -- trace (dirty)

mudchips -- 1%

tour -- trace zircon -- trace (subangular)

MM 990 some recrystallized grns.

Grains: 75%+

size: 125-250μ (fine sand) w/ a few med grains

shape: subangular to subrounded

sorting moderate

composition. qtz -- 55%

This slide not stained so K-feld % approx. K-feld ≈ 7% (very approx.) (sensitized plat) ≈ 4% sensitized

microcline - ≤1% (slightly dirty)

perthite - 1%

musc 2%

chlorite trace (altered) biotite -- 2% (red stained)

tour -- trace

plagioclase ≤1% (dirty)

mudchips 3%

magnetite/leuc. -- ≤1% (some layers)

MM 1035

Grains: 70% +
size: 125 - 250μ (med. sand)
shape: subrounded
sorting: moderate
composition: qtz ..... 57% ← (some overgrown) (some polygonized)
4% ± sericitized K-feld -- 7% (slightly dirty or sericitized)
micro -- 1% (clean)
perthite - 2% (clean)
may, lux (trace) plag -- trace (dirty) + (clean)
tour -- trace
mus. -- 1% zircon -- trace (euhedral)
zircon -- trace (subangular)
biotite -- trace
mudchips -- 1% ± chert - trace

MM 1091

Grains: 70%
size: 62 - 125μ (very fine sand)
shape: subangular to subrounded
sorting: moderate
composition: qtz 56%
3% sericitized K-feld 8% (clean or sericitized)
micro -- 1% (clean)
perthite -- 1% (clean, slightly dirty)
mus. -- ≤ 1%
tour trace chert -- ≤ 1%
zircon -- trace (subangular)
biotite -- trace
mag, leuc -- ≤ 1% (ande layers)
plag -- trace (dirty)

MM 1140 — maybe s.s. and/or granite frags; rounded grns.

Grains: 65%
mostly qtz w/ orth

size: 88-177μ (very fine to fine sand); 1-2% (177-350μ) (fine to med. sand)
shape: subangular to subrounded
sorting: moderate to poor
composition: qtz — 51%
K-feld — 6% stained → (5% sericitized) not stained
perthite — 2% (clean)
microcline 1% (clean)
musc — 1%   biotite — trace
tour — trace
plag — trace (clean)
chert — 1%
zircon — trace (subangular)
opaques (mag, leuc., oxides) ≤ 1% (scattered)

MM 1190 — Take photo tour attached to qtz grn(s).

Grains: 65%
size: 62-125μ (very fine sand) w/ some 125-177μ (fine sand)
shape: subangular to angular
sorting — moderate
composition: qtz — 52%
note low % → K-feld — 2% stained (6% sericitized)
perthite — trace
musc — 1%
tour — trace
opaques — 1% (mag, leuc., oxidized grns) (in some layers)
∴ silty. v. fine (very fine s.) — biotite ≤ 1% (green, brown)
zircon — trace (subangular)
mudchips — 1%
chert — ≤ 1%

also chert grn. counted as ssf!
MM 1200 photo of coarse grns, broken round grn., sericite

Grains: 65% ; 50%
size: 88-125μ (very fine sand); 250-710μ (med. to coarse sand)
shape: subangular-subrounded; subrounded to rounded - some well-round
sorting. poor
composition: qf - 57% (maybe some poly.) ; qq - 37% (overgrown) sericite
K-feld - 4% + 3% highly weathered; K-feld 1%
mica trace perthite - 1% ; mudchips - 10%
plagioclase - trace (pretty clean)
biotite - trace
chert (in s.s.f.) - 1grn. musc. trace def. s.s. frags!
ooids - 2 or 3 ooids
magnetite/leuc ≤ 1% granite frag(s) (all qtz) (rnd grns).
tour trace
zircon - trace (subrounded?)

MM 1210 Maybe good clay sample

Grains: 65%.
Size: 88-177μ (very fine to fine sand); 350-710μ (med. - coarse sand)
shape. subangular; rounded - well rounded
sorting. poor
composition. qf - 56% ; qq 43%
3% replaced by K-feld - 5%, alot seriated ; K-feld 1% stained,
cl./sericite perthite - 1% (clean) ; granite frags - 1%
microcline 1% (clean) mudchips + - 20%
muscovite 1%
plagioclase - trace (slightly dirty);
biotite - trace
Worite trace
zircon - trace
tour - trace

PPO Poor Slide PRICKLY PEAR

Grains. 60%

size -- 62-88μ (very fine sand)

sorting - moderate

shape -- subangular

composition -- qtz - 46%

K-feld - 10% (some sericitized)

musc. - 2%

mica - 2%

☆ lithics (mudchips) - 1%

perthite - 1%

chlorite - 1% (detrital)

plag. - trace

tour. - trace

Matrix: 40% (over)

PP 5C Slide not stained

Grains: 75%

size -- 62-88μ (very fine sand)

sorting -- moderate

shape - subangular to subrounded

composition -- qtz - 59% (overgrowth)

replaced by sil/cal/dol -- K-feld - 7% (dirty w/ clean overgrowths)

biotite - ≤1% (altered to hematite) (long flakes) perthite - 1% (fresh)

plag. - 1% (fresh)

hematite grns. (2%) musc. - 1% long flakes zircon trace (rounded)

(some could be weathered micro. - 1% (fresh) tour - trace

magnetite chert - 1% (some seem dirty)

~~Tour~~ trace (mud chips 3%) (some are

~~Matrix~~ smashed into pseudomatrix.

Matrix 25% (over)

PP145

Grains: 65%

size: 88-125μ (very fine sand)

shape: subangular to subrounded

sorting: moderate

composition: qtz -- 51% (some double overgrowths)

5% sericitized o/r replaced by carbonate ⇒ K-feld -- 5% (clean; or sericitized)

perthite -- 1% (clean)

microcline -- ≤1% (clean)

tour -- trace

musc -- 2%

zircon -- trace (subrounded)

chert -- 1%

Matrix: 35%

qtz -- trace   mud (alt pseudomatrix) - 20%   dolomite - 13%   calcite - 2%

PP210

Grains: 70%

size -- 62-125μ (very fine sand)

shape - subangular to angular

sorting -- moderate

composition   qtz - 58% (maybe some double overgrowths)

5% sericitized o/r replaced by carbonate   K-Feld -- 5% (clean)

perthite -- 1% (clean)

microcline -- trace (clean)

musc - 1%

tour - trace

chert - trace   magnetite - ≤1% (oxidized) (scattered)

zircon - trace (broken round grain)

Matrix: 30%

qtz 1%   hematite (coatings) 15%   calcite 13% (also in vein)

PP 254 Too much replacement to tell correct original composition

Grains: 50%

size -- 62-125μ (very fine sand)

sorting -- moderate to poor

shape -- subangular

composition -- qtz - 43% (some overgrowths)

musc - 2%

plag. - trace

zircon - trace subrounded

chlorite - 1%

chert - 1%

some leucoxene

biotite 2%+ (altered to vermiculite)

K-feld - 1%

tourm. -- trace

sericitization replaced by carbonate

Matrix: 50%

composition -- calcite - 45%

dolomite - 5%

quartz trace also some sericite trace

The percentage of grains is probably quite different from the original!

PP 280

This rock is ≈90% carbonate (calcite)

Minerals identified include: (grains are silt to very fine sand)

qtz

biotite

tourm. blue & green varieties

musc

plag

microcline (looks clean)

Not practical or worthwhile to estimate grain %!

PP 350 ~~tt~~ broken round grns. Q, Maybe photo of sericite

Grains: 65%

size: 88-500μ (very fine to med. sand) ← about 3% of coarser grns, bimodal

shape -: subangular to rounded & some well rounded

sorting - moderate to poor

composition -: qtz - 49% (some poly; few overgrowths)

≈3% sericitized K-feld - 10% (clear; or sericitized)

microcline - 3% (clean)

perthite - 3% (mostly clean)

plag - trace

granite frags - trace tour - ≤1%

(fine grained) mag/leuc - 2% (oxidized; in crude layers)

(all qtz) zircon - trace (subrounded)

qtzite - trace (stretched)

chert - trace

PP 415 This slide has too much carbonate replacement.

(40-50% grains, remainder in carbonate (mostly calcite w/ dolo)

grain composition includes:

qtz + orth. % not distinguished (slide not stained) - - 30%

perthite (clean) - ≤1%, microcline - trace (clean)

3% ⇒ musc } seminal %

4% ⇒ biotite } also some chlorite - 2%

tour - green - - trace

glauconite ? ← could ~~be~~ be chlorite

chert ? - - trace

PP450 broken round grains? (?

Grains: 65%
size: 62-88μ (very fine sand); 1% 250-350μ (medium sand)
shape: subangular to angular
sorting: moderate-poor
composition qtz--52% (polyg, some overgrowth)
4% sericitized or replaced K-feld--6% (a little dirty) = ; (med + vf grains)
microcline--1% (clean)
perthite--1% (clean)
plag--?
granite frags trace musc--1%
(v. fine) (w/ qtz) biotite--trace
mag (oxidized)--1% (scattered)
tourm--trace
chert--1%+

PP495 May be good clay sample (poor slide)

Grains: 65%
size--62-88μ (very fine sand)
sorting--moderate
shape--subangular to angular
composition--qtz 54% (overgrowth)
+ 7% sericitized, altered K-feld-3% (overgrowth) (dirty centers)
Biotite--trace musc 1%
Chert--trace perthite + microc. trace (clean)
Zircon--trace (rounded) plag--trace
tourm.--trace

Matrix: 35%
composition--phyllosilicates (musc, ser) 10%
quartz--20%
feld--5% [illegible]

PP550

Grains: 70%
size: 125-177μ (fine sand)
shape: subrounded to subangular
sorting: moderate
composition: qtz -59% (some poly. overgrowth)
4% sericitized, K-feld - 7% (slightly dirty; overgrowth)
microcline 2% (clean)
perthite 3% (clean)
musc - trace
zircon - trace (subangular)
tour - trace
mag - trace
biotite - trace

PP610 Good clay sample

Grains: 65%
size - 62-125μ (very fine sand)
sorting - moderate
shape - subangular to subrounded
composition - qtz - 53% (overgrowth) some polygonized
5% sericitized K feld - 5% dirty (some overgrowths);
micro - 2%
musc. - 1%; biotite - trace
perthite 1% plag - trace (dirty) (small grns)

tour. - trace mag. (oxidized) 1%
zircon - trace (subrounded)
chert trace

Matrix 35%

PP650 May be good day sample

Grains: 65%
size - 62-125μ (very fine sand) also some fine sand
sorting - moderate
shape - subangular to subrounded
composition -- qtz - 50% (overgrown)(some poly.)
7% sericitized, K-feld - 4%+
musc 1% biotite - 1%+ (altered to hematite)
tour. trace chert 1%+
1% oxidized grns.(mag.?) perthite 1% (slightly dirty)
zircon - trace (subround) microcline - 1% (some overgrown)(slightly dirty)
plag - trace
Matrix: 35%
composition - sericite - 33% feld - trace
quartz - 2%- hematite - trace

PP 700 Take photo of overgrown micro. (Good day sample)
Grains: 65%
size -- 88 to 177μ (very fine to fine sand)
sorting - moderate
shape - subangular to subrounded
composition -- qtz - 50% (overgrown)(some poly.)
5% sericitized K-feld - 10% (dirty)(some overgrown)
biotite trace musc trace
zircon - trace (subang) perthite - 2%
tour. trace chert -- trace
microcline - 1% (some overgrown)(some w/ sericite (?) thin grain)
Matrix 35%
composition - sericite 35% (some "limy")
quartz trace
feld - trace (over)

PP 795 Take photo of overgrown microcline.
(Good sample for clay)

Grains: 65%

size -- 88-177 μ (very fine to fine sand)

sorting -- moderate

shape -- subrounded to subangular

composition -- qtz 52% (poly, overgrown some)

4% sericitized a lot K-feld - 7% (overgrown)

chert -- trace microcline - 2% (overgrown (clean) - more altered than grain)

zircon - trace (round) musc - 1%

tour. trace (anhedral & euhedral in heavy layer) plag - trace biotite -- trace

perthite - 1% (clean) mag -- (in heavies layer) trace

Matrix: 35%

composition -- sericite - 35%

quartz - trace

feld - trace

PP810 Slide too thin, not stained

Grains: 65%

size -- 88 - 350 μ (very fine to med.)

shape -- subangular to subrounded

sorting -- moderate to poor

composition -- qtz -- 57% (poly. some stretched)

orth -- 5%+ dirty grains

microcline -- 2% (clean)

perthite -- 1% (clean)

musc -- trace

chert -- trace

tour -- trace

Matrix: 35%

sericite & clays

PP 900

Grains: 60%
size: - 62 - 125 μ (very fine sand); a few grns. 250 350 μ (med. sand)
sorting -- moderate
shape: subangular, some subrounded
composition -- qtz - 47% (poly)
3% sericitized K-feld - 6% (dirty)
☆ microcline - 2% (clean), perthite = 1% (clean)
3% Un I.D. heavys (oxidized) tour - trace
in layers musc. - 1% (smashed into pseudomatrix)
biotite -- trace zircon - trace (subround)
- chert - trace

Matrix: 40% ← sericite
composition --

PP 950 Slide not stained

Grains: 70%
size -- 88 - 177 μ (very fine to fine sand) a few med. grains
sorting -- moderate to poor
shape - subangular
composition - qtz - 56% some overgrowths, poly
micro - 2% (overgrown) (clean)
orth - 6% ± (highly sericitized)
2% heavys (may oxidized)
in layers (poor) ☆
chert - 2% perthite - 1% (clean)
musc -- ≤1% ? plag. - trace biotite -- trace (altered to hematite)
tour - trace zircon trace (small) (rounded, subrounded)

Matrix 30%
composition - sericite - 30% feldspar - trace
quartz trace hematite - trace

PP 1000 65%

Grains:
size -- mostly 88-125μ (very fine), a handfull of 250-350μ (medium sand)
sorting: poor
shape -- subangular to subrounded
composition: qtz - 52% (very few overgrowths)
3% sericitized K-feld - 10% (clean)
musc - trace
detrital heavys microcline - 2% (clean); perthite -- 1%+ (clean)
(trace)
biotite -- trace tour - trace (approaches 1%)
zircon - trace (rounded)
chert - trace

Matrix 35 %
composition -- sericite 35 (seen)

PP 1150 (Slide Not Stained)
Grains: 60% F/Q = .15
size -- 62-250μm (very fine to fine sand) and 350-1410μm (med. to v. coarse) in separate layer (sharp contact)
sorting -- poor
shape -- large grains (rounded to well-rounded), small grains (subangular)
composition -- qtz - 48% (poly - some stretched
orthite - 5%+ (dirty, sericitized grains)
2% heavys (mostly mixed w/ large grains) oxidized, mag. granite - 2% (med coarse grain) (all qtz)
perthite - 1% (clean)
musc - trace chert trace (med sized grain)

micro - 2% (clean)
tour - trace, zircon - trace (subrounded)
Matrix 40% sericite - 37%, calcite - ≤1%, hematite - 2%

PP 1200 — Maybe good clay sample, take photo of large grain w/ qtz + feld (granite)

Grains: 65%

size -- 88 - 1000μ (very fine to coarse sand) (bimodal)

sorting - poor

shape -- large grains are rounded, small grains are subangular - subrounded

composition - qtz - 48% (a few overgrowths/ poly.)

3% sericitized — K-feld 10% (clean or sericitized)

some hemp. — micro - 2% (clean) — qtzite - 1% (high grade) (stretched)

some mag, mostly — perthite - 2% (clean) — granite frag - 1% (f → c) ↑ qtz + altered K-feld.

oxidized. -- 1% — zircon - trace (subeuhedral)

tour. - trace — chert - ≤1%

Matrix: 35%

composition -- sericite 32%, hematite - 3% (coats grains), qtz - trace

Sericite has replaced alot of the feldspars.

Few overgrowths are present.

PP 1250 — Maybe take picture of granite frag + also sandstone frag.

Grains: 70% — F/Q = .12 — Double growth on poly qtz !!

size -- 88 - 350μ (very fine to med. sand), 500 - 2000μ (coarse to very coarse)

sorting - poor

shape - large grains (rounded to well rounded), small grains (subangular)

composition — qtz - 53% (a few overgrowths) + double growths, some poly.)

3%+ sericitized — K-feld - 6% (highly sericitized - some;

musc - trace — microcline - 2% (slightly cruddy)

≤1% hemp, oxidized, mag? — qtzite - 2% + fine sand sized grains (some really stretched)

most have mica — granite frag - 3% (med-c, has biot, orth, ns orth, micro)

chert - 2% (some look metamorphosed)

perthite - 1% (slightly cruddy-cruddy)

tour - trace, zircon - trace (rounded) (anhedral)

Matrix 30% — (qtz + feld cement trace)

composition - sericite 27% — hematite - 3% (some looks interlayered w/ sericite)

PP 1345

Grains: 70%

size - 62-88μ (very fine sand) w/some fine sand
sorting -- moderate
shape -- subangular to angular
composition -- qtz - 60%
2% = sericitized K-feld - 4%
perthite - 1% (clean)
1% opaques (mag, leucoxene, oxides) evenly scattered musc. - 2%
microcline - 1% (clean)
zircon - trace (subround) tour. - trace biotite -- ≤1% (altered to hematite)

Matrix: 30%

composition -- sericite - 15% (some is "furry")
hematite - 15% (patchy) (some interlayered w/ sericite)

PP II 71 (1416') Take photo of "granite" clast; Photo of chert

Grains: 70%

size -- 177-710μ (fine to coarse sand), 710μ-2000μ (coarse to very coarse)
sorting - poor
shape -- subangular (small grains), rounded to well rounded (large grains)
composition -- qtz - 55% (a few small overgrowths) (poly) ⇒ (some a little stretched)
4% sericitized ⟶ K-feld - 6% (sericitized)
tour - trace microcline 1% (slightly dirty)
opaques (1%) - oxidized grns., mag.?, leucoxene scattered perthite 2% (slightly dirty)
granite frag 3% (micro; orth, qtz, biot)
chert 1%+
musc. - trace ~ approaches 1%
zircon - trace (subround) large grains, also inherited (over)

Matrix 30%

PP II 82 (1427') Photo of s.s. frag, some small double overgrowths

Grains: 65%
size -- 88 500μ (very fine to med. sand), 710 - 2000μ (coarse to very coarse)
sorting -- poor
shape -- small (subrounded), large grains (rounded to well rounded)
composition -- qtz - 57% (a lot of overgrowths)(few double growths)
5% highly sericitized → K-feld - 3% (dusty + sericitized)
no opaques chert -- ≤1%
s.s. frag (v.f. - has chert) - trace biotite - trace
perthite - 2% (dirty)
micro - 1% (some are overgrown)(dirty)
(m-c; with qtz) → granite frags - 2%+ zircon - trace, tour. - trace
Matrix: 35%
composition - quartz - 35% feld. - trace
trace → sericite -

PP II 84 (1429')

Grains: 65%
size -- 88 - 250 (very fine to fine sand), 500 - 2000μ (coarse to very coarse) — only 4-5 grains
sorting -- moderate
shape - small (subangular to subrounded), large (rounded)
composition - qtz. - 53% (some overgrowths)(some poly
3% sericitized → K-feld - 6% (altered, sericitized)
perthite - 2% (clean)
no opaques
microcline - ≤1% (clean)
tour. - trace musc - trace
chert - 3%+ zircon - trace
granite clast - trace (mostly K-feld)(med)
Matrix: 35%
composition -- sericite - 35% qtz - trace

PPII 15C (1495')   broken round grains (?)

Grains: 50% (original was higher)
size-- 88-177μ (very fine to fine), 350-2000μ (med. to very coarse sand)
sorting -- poor
shape -- small (subangular), large (rounded to subrounded)
composition -- qtz - 39% (some overgrowths) poly (some stretched)
perthite - 2% (clean)
microcline - 1% (clean)
opaques (1%) mag, oxidiz w/coarse grns.   chert 1%+   musc - trace
K-feld - 4%   , 4% sericitized and/or calcitized
granite - 1%+ (fine grained; w/ qtz and orth)
tour. - trace, zircon - trace

Matrix: 50% (original prob. lower)
composition -- calcite 50 (mud size)
sericite - trace   quartz - trace   (...)

RC 0   ROCK CREEK

Grains: 75%+
size: 88-250μ (very fine to fine sand)
shape: subangular to subrounded + some rounded
sorting: moderate
composition: qtz - 61% (some overgrowths) (some polygonized)
+ 24% sericitized   K-feld -- 7% (dirty, sericitization)
microcline -- 3% (clean, slightly dirty)
tour. rock frag - trace   perthite 2% (slightly dirty or clean)
plagioclase - ≤1%   clear or sericitized
muscovite ≤1%   biotite - trace
chlorite trace
granite frag - trace (fine)   tour -- trace   mag - 1% (mostly oxidized)
chert - trace
zircon -- trace (subangular, angular)

RC 26 — Maybe try to find s.s. frag. for photo.

Grains: 70%

size: 177–1000 μm (fine to coarse sand) w/ ~2 grns. of v. coarse

shape: subrounded to rounded

sorting: poor

composition: qtz – 62% (polygonized grns., overgrowths)

±2% sericitized K-feld – 5% (some clean, some sericitized)

perthite – ≤1% (slightly dirty)

microcline ≤1% (dirty or clean)

plagioclase – trace (dirty)

no tour. granite frags – 1% ((feld. highly sericitized, fine-med. grained size)

muscovite – trace

zircon – trace

(difficult to define grn. bound.) chert – trace

⇒ s.s. frag – 1 grn. (fine – med sand)(has poly. qtz.)

RC 53 — double overgrowths, reworked grns.

Grains: 75%+

size: 62–125 μm (very fine sand) 95%; 250–1000 μm (med. to coarse sand)(5% of rock)

shape: subangular – subrounded; subrounded to rounded

sorting: poor

composition: qtz – 60% (some polygonized) (double overgrowths + maybe a triple one!) (one w/ a lot of greasy inclusions)

+2% sericitized K-feld – 10% (clean or dirty) (some overgrowth)

microcline – ≤1% (clean → slightly dirty)

perthite – ≤1% (clean → slightly dirty)

plagioclase – ≤1% (sericitized or clean)

mag./ilm. trace (in layer) musc 1%

tour – trace

chert – trace zircon – trace (euhedral)

Illite – trace biotite – trace (looks altered may be to laumontite?)

granite frags trace – 1% (med.) w/ qtz, ...

RC 268

Grains: 75%+ — Slide is too thin
size: 62-125μ (very fine sand) and a few grs. (250-350μ) med.
shape: subangular to subrounded; subrounded
sorting: moderate
composition: qtz--62% (some poly., some overgrowth)
+3% sericitized — K-feld--3% (clean or sericitized),
micro--≤1% (clean → slightly dirty)
perthite--≤1% (clean → slightly dirty)
plagioclase--trace (clean & dirty)
tourm--trace
musc--1% — biotite?--trace (highly altered to hematite)
zircon trace (rounded)
chert ? trace-1%
mag/oxidized--trace

RC 316

Grains: 65%
size 88-350μ (very fine to med.) and 500-5000μ (coarse to pebbles)
shape: subangular to subrounded
sorting: very poor 49%
composition: qtz-- (overgrowths (mod. abundant), (some w/ a lot of bubble trains)
≈3% sericitized → K-feld--10% (highly sericitized or clean),
perthite--2% (slightly sericitized)
microcline--≤1% (sericitized)--alike
plagioclase ≤1% (mostly in granite frags)(sericitized)
large grns — tour--trace
granite frags--2 or 3 — zircon trace (subround)
(med to coarse grained) — musc--trace
(w/ perth, plag, quartz) — biotite trace (altered red)
mag/hem 2% (wide layers)

RC 348 broken round grns (?)

Grains: 75%
size: 88-710μ (very fine to coarse sand)
shape: subrounded to rounded and well rounded
sorting: moderate to poor
composition: qtz - 58% (maybe some poly, overgrowths
≈1% sericitized K-feld - 10% (slightly dirty);
perthite ≤2% (clean)
microcline - 1% (clean)
plagioclase - ≤1% (dirty & some sericite)
zircon trace (euhedral or rounded)
biotite 1 tiny flake tour - trace
glauconite! - 1 grn. musc - 2% mag - 1% (mostly oxidized)
chert - ≤1%
granite frags - 1% (fine-med grnd) (has unst. orth)

RC 375 maybe some reworked broken grns (?)
large grns mostly qtz - 1 perth, orth, chert
Grains: 75%+ 50-50
size: 62-250μ (very fine to fine) and 350-710μ (med-coarse)
shape: subangular-subrounded; rounded to subrounded
sorting: poor
composition: qtz 55% (some poly, a few small overgrowths)
+≤2% sericitized → K-feld - 10% (clean or slightly dirty)
perthite - 1% (clean)
microcline - 2% (pretty clean)
(?) one broken on rounded plagioclase ≤1% (a little sericitized)
zircon - trace (subang) (round) musc - 2%
tour - trace biotite - trace (altered to hematite)
mag - 2% (scattered) qtzite - ≤1% (really stretched)
granite frags - 1% (med. grn, has qtz, orth, microcline)
chert - 1%

RC 402

Grains: 75%

size: ≈125-1000 (fc) w/ a few 1000-1410 (very coarse) stained with.

shape: subangular to subrounded, larger grains are rounded.

sorting: moderate to poor

composition: qtz--63% (polys, overgrowths)

≈2% sericitized K-feld-7%

microcline-1%+ (pretty clean)

perthite-1%+ (pretty clean)

plagioclase-trace (sericitized)

granite frags-2% (fine grained, qtz, plag, qtz ← clean biot)

may trace (scattered) chert-trace (not vf to grain size-fine and coarse)

musc-≤1%

tourm-trace

qtzite-trace (stretched)

RC 423 photo of granite, sandstone, qtzite

Grains: 70%+

size 350-9000μ (med sand to pebbles)

shape: subrounded and rounded

sorting: very poor

composition: qtz-- ≈52% (overgrown alot) ; a few small overgrowths

K-feld--6%

micro--2% (clean)

perthite <1% (dirty, seri.)

plag. 1% (sericitized and dirty)

chert ≤1% biotite-trace

musc trace

qtzite-2%: (88-1410μ ind. grains) (highly sutured)

granite frags--5% (500-9000μ, and 1400 ind. coarse grains)

(cont) sandstone frags 1-2% (<2 88μ grains)

RC 450 <u>slides too thin</u>

Grains: 80%+
size. 250–7000μ (med sand to pebbles)
shape. subrounded and rounded
sorting: poor
composition: qtz--67% (some overgrowth
≤1% sericitized K-feld--8% (clean or very sericitized;
perthite 1% (clean or slightly ser.)
microcline--1% (clean)
plagioclase--1% (sericitized)
tour--trace (one tiny grain) granite frags: 3%+ (fine & coarse grained, perth, micro, musc, plag, zircon, qtz, biotite) sericitized!!
chert--trace
qtzite: trace (stretched)

Matrix: 20% (looks like most was plucked out) sericite & qtz cement

RC 490

Grains 75%
size. 250–710μ (med-coarse) w/ 2000–4000μ (very coarse to pebbles) 2%
shape: rounded to subrounded
sorting: poor
composition: qtz 62% (one large authedral grn., overgrowth alot)
3% sericitized K-feld--7% (most is highly sericitized)
perthite-≤1% (clean)
microcline--1% (clean)
plagioclase--1% (sericitized)
granite frags--2% (ser, qtz, perthite, musc, micro
biot.--trace chert--trace
mag--trace tour--trace zircon--trace (authedral & euhedral)
qtzite--trace (stretched)
musc--trace

WO WILLOW CREEK

Grains: 60%

size: 88–2000µ (very fine to very coarse sand)

shape: subangular (small grains); subrounded → rounded (large grns)

sorting: very poor

composition: qtz 50%

K-feld - 3% one large euhedral grn. (smaller grns)

microcline - trace (clean) small grn.

plag. - trace (pretty clean) small grn.

perthite - trace (clean) small grn.

qtzite - 2% (mostly 500–710µ grns. some w/ 88µ grns)

mudchips 5% (red w/ v fine sand grns.)

tour - trace (green basal sect. clear)

chert - trace

granite frag. - trace (coarse-grn.)

W13 # (take photo of tour. aggregates"); double overgrowths!

Grains: 70%

size: 177–710µ (fine to coarse sand)

shape: subrounded to rounded

sorting: poor to moderate

composition: qtz 62% (overgrowns) double overgrowths

maybe +1% ser. → K-feld 3% (overgrown) (1% is sericitized, others are very clean)

plag. - trace (clean/or sericitized)

perthite - trace (clean)

qtzite - 1% (coarse grn; siltite) (some stretched)

rock frag w/ euhedral tour. (see back) 2%+

tour. - 1 discrete grain (large & rounded), abundant (1%) tiny euhedral grains

granite frags (some w/ tour) trace muscovite - trace

Matrix: 30%

W 50 (Take photo of coarse grns. qtzite, broken round grns.)

Grains: 65%
size: 62-88μ (very fine sand) to 710^+ - 1000μ (coarse sand) [large grns: qtz + qtzite]
shape: subangular to angular | rounded & well rounded
sorting: very poor 54%
composition: qtz - - (some overgrowns)
5% dirty → K-feld - - 5% (mostly dirty & a large % is altered)
micro. - trace
perthite - 3% opaques (trace) - magnetite
siltite - - trace
qtzite - - 1% (some welly stretched); granite - trace
tour - trace (green) subangular, brownish green.
plag - trace (dirty)
zircon - trace (subrounded) almost euhedral

Note: feld, & diff. grn sizes not evenly distributed; just "dumped" in places

W 51 (Take photo of qtz, broken round grns.)

Grains: 65%
size: 62-88μ (very fine sand) to 710 - 1000μ (coarse sand)
shape: subangular | rounded
sorting: very poor
composition: qtz - 57% (some overgrowns)
most is not stained because too altered. → K-feld - 7% (very dirty).
micro. - trace ← found in coarse round layers (not K-enriched pop)
qtzite - 1%
chert trace (one grain has chalcedony)
zircon trace
tour - trace (green, subangular)

plag. trace

W 100 Photo of double overgrowths, unstained perthite, tour. R.F.

Grains: 80%

size: 125-710µ (fine to coarse sand)

shape: subrounded (smaller grns.); rounded - well rounded (larger grains)

sorting: poor

composition: qtz -- 70% (abt overgrowths, many recrystallized (polygonized grns.

K-feld -- 2%+ (dirty, ≤1% not stained = larger grns. (round)) dirty &

most do not stain?! ⇒ perthite - 1% (round altered grn. w/ zoned tour.) ☆

plagioclase -- ≤1% (dirty slightly or clean)

muscovite -- trace

☆ tour. rock frags -- ≤1% (some are granite?) ← ☆ some kind of tour. ↖ has albite-rich perthite

mag. trace zircon -- trace

tour -- ≤1% microcline - trace (altered)

chert - 2% (some looks sericitized)

granite frags -- ≤1%.

W 153 photo of qtzite, chalcedony

Grains: 65%

size. 62 - 500µ (some mixed, some in separate layers of small grns, + large grns)

shape: subrounded

sorting: poor in some layers, moderate in others

composition qtz 58% (some overgrowths, some double)

2% altered so ⇒ K-feld 2% not stained

plag trace (quite dirty) (also a clean grn.)

perthite - trace (dirty & stained)

qtzite frags 1% (v.f. & fine sand grns) (some highly sutured)

tour, trace (round grn.)

magnetite (1%) scattered

musc. - 1%

zircon trace

chert - trace (maybe cement)

W 200

Grains: 75%

size: 62-1000μ (very fine to coarse sand)

shape: subangular to subrounded (small grns.); rounded & well rounded (large grns)

sorting: poor

composition: qtz -- 65% (overgrown (some double)

K-feld -- ≤1% stained, ≈5% ± altered (overgrown)

perthite - 3% (dirty; what doesn't stain?)

plagioclase - trace (slightly dirty)

zircon - trace (well rounded, brown)

muscovite - trace

TRF (looks like tour in w/qtz grains - i.e. granite) trace

tour - trace mag - trace

chert -- ≤1%

granite frags trace (fine-med. grained)

sandstone frags?

W 250 (Take photo of grain w/tour!!, overgrown grns, qtzite)

Grains: 60%

size: 125 to 500μ (fine to medium sand)

shape: subrounded to rounded

sorting: moderate to poor (well cemented)

composition: qtz -- 53% (alot of overgrowths) (some double)

K-feld 3% (dirty) + 3% dirty + not stained

plag - trace (slightly dirty)

perthite 1% (slightly dirty)

chert - 1%

qtzite trace

microcline trace (clean)

lithics 0.5% (grains w/alot of green tour) TRF's

tour - trace (green)

W302 — photo of qtzite, rounded [illegible] grns.

Grains. 65%
size: 62 – 1000μ (v. fine to coarse sand)
shape. subrounded & rounded
sorting: poor
composition: qtz -- 49%
K-feld -- 7% (clean)
micro trace
perthite 1% – that doesn't stain & is clean
tour. trace — chert -- 1%
zircon (brown) trace subrounded — qtzite 2% (v. f. to coarse grns) (feldspathic)
musc. -- 3%
mudchips (micaceous, some w/ tour) -- 2%

Matrix: 35%
hematite -- 5% — fine-grained stuff (musc) -- 25%

W 365

Grains. 70%
size: 62–88μ & 350–500μ (very fine to medium sand)
shape. subrounded & rounded
sorting: moderate
composition: qtz -- 58% (overgrown) (some double)
K feld 10% (about one dirty, sericitized) 5% of these is too dirty to stain
perthite -- 1% (dirty)
opaque (1%) mag. in [illegible] layers — mud chips -- 1%
tour. trace (brown, green) subrounded)
micro trace (clean)
biot.? altered to hematite (trace) — plag. trace (dirty)
qtzite – trace } [illegible]
chert trace
musc. trace — zircon – trace
TRF?? very small (trace)

W 330 photo of qtzite, granite

Grains 65%

size: 62-1000μ (very fine to coarse sand) — separate beds (more feld in fine rep.
shape: rounded to well rounded
sorting: poor
composition: qtz--54% ← (overgrown) (double overgrowths)
K-feld-3% ← (not stained & dirty, other are large clean grns)
mica--trace dirty
perthite-1% dirty
chert--2% (some seems to have chalcedony too) (length slow)
qtzite frags--1% (stretched)
granite frags--1%
musc.--trace
zircon--trace (angular)
tour. trace (rounded mica chips--trace

W 404 broken round grains

Grains: 65%

size: 62-1000μ (v. fine to coarse sand)
shape: rounded
sorting: poor
composition: qtz--53% (some overgrown some double
K-feld--3% stained (4% not stained smaller grns — altered ;)
mica--trace (clean)
perthite--trace (clean)
granite frags.-1% (med. grained)
qtzite frags--1% (fine-med grained)
Zircon--rounded (trace)
plag.--trace (dirty) (clean)
tour.--trace musc. trace
chert 3%

W 500

Grains: 70%

size: 62-500μ (v fine to med. sand - mostly in one layer)

shape: subrounded to subangular

sorting: moderate to poor

composition: qtz - 57%

K-feld 5% stained + (5% altered)

micro 1% (clean)

perthite trace (dirty)

granite - trace

chert - 2%

qtzite - trace

musc - 1%

tour - trace

zircon - trace

W 515

Grains: 75%

size: 177 - 710μ (fine to coarse sand)

shape: rounded to well rounded

sorting: poor

composition: qtz - 67% (≈ 1 or 2% sutured & polygonized; most are overgrown; (reworked grains) of qtz with chert or tourmaline)

K-feld - 4% stained; < 2% altered or unstained (overgrown)

perthite - 2% (clean) (some slightly dirty)

microcline - 1% (clean)

granite - 1%

muscovite - trace

plag - trace (slightly dirty)

tour - trace

qtzite (stretched) & poly qtz - trace

zircon - trace (subrounded - rounded)

chert - 1% some with chalcedony

magnetite trace

biotite - trace (altered to hematite)

WC 270 WOOD CREEK

Grains · 65%
size -- 62-125μ (very fine sand)
sorting -- moderate
shape -- subangular to angular
composition -- qtz - 45%
K-feld ~~&~~ 10%⁺ - pretty fresh (some slightly dirty)
plag. - 1% - " " " " "
some very rounded → micro - trace
musc - 1% biotite - trace and chlorite
opaque (trace) mag, oxides mud chips - 1% tourm. trace
chert (and/or siltite grains) - 1%
perthite - trace

(Maybe good clay sample)
WC 295 (take photo(s) of reworked (broken) grains)!

Grains: 65%⁺
size · 62-88μ (very fine sand), w/ 177-500μ layers of grains (fine-med)
sorting -- moderate ↑ poor ↑
shape -- subrounded → subangular, subangular → subrounded, a few round.
composition -- qtz. 56%
K-feld - 9%⁺ pretty clean (hard to tell from qtz)
micro. - 5% overgrown (reworked?) (some large, round)
tourm. - trace perthite -- 1% a little dirty
plag. - trace mostly very fine grained
siltite - trace ; biotite - trace and chlorite

Matrix: 35%
composition: illite - (alligned) -- 35%⁻

WC 310 (take photos showing K-feld stain under normal light)

Grains: 70% (fine sand)
size – 62-125μ (very fine sand), about 1 or so grains 125-177μ
sorting -- moderate to well
shape – subangular to angular (some K-feld slightly euhedral)
composition – qtz – 49% – larger grains less angular
K-feld: 15% (sericite) feldspars all dirty, esp. K-feld.
perthite – 1%
microcline – 1%
tour – trace plag. – 1% chlorite – trace
musc. – trace
zircon – trace (very small, round)
mud chips (coarse-grained) – 5%
(over)

WC 330

Grains: 65%
size -- 62-125μ (very fine sand)
sorting -- moderate
shape -- subangular to angular, some larger grains subrounded
composition -- qtz -- 54%
K-feld -- 10% (sericitized)
microcline -- 1% (one grain)
trace of scattered, oxidized opaques plag -- 1%
perthite -- trace
glauconite? musc -- trace zircon – trace
→ chlorite (trace)
Matrix: 35% tour -- trace (light gr/med. gr w/ bubbles) rounded also light gry/gry green)
(over)

WC 350

Grains: 60%
size.. ≤ 62-88μ (silt + very fine sand)
sorting.. moderate
shape.. subangular
composition.. qtz.. 48%
K-feld - 10%+ (quite altered, sericitized)
plag. -- trace
tour. .. trace
musc. -- 2%
micro. -- trace biot. (chl) - trace
chert ? -- trace (very fine-grained)

Matrix: 40%
composition.. red mud 40%

WC 360

Grains: 65%
size: ≤ 62-88μ (silt to very fine sand)
shape: subangular to angular
sorting: moderate
composition: qtz.. 49%
maybe 3% replaced by calc, K-feld.. 10%+ (3/4 is clean, 1/4 fairly dirty) microgram
plag.. - trace (dirty)
opaque.. 1%, in layers (mag, oxides)
musc. - ≤1%
biotite -- ≤1% and chlorite
zircon - trace
tour. - trace (one large grain w/ brown & green together)

Matrix 35%

(over)

WC 370 (take photo of coarse grains)

Grains: 70%	70%
size: ≤ 62-88μ (silt & v.f. sand), &	350-1000μ (m.→c.) w/62-125μ v.f.s.
shape: subangular to angular	rounded, subrounded; subangular
sorting: moderate	very poor
composition: qtz -- 58% (overgrowns)	qtz -- 66% (some presolved) overgrowns
musc. - 1%	K-feld -- 2% (slightly dirty)
trace opaque oxides, mag. chlorite -- 1%	mudchips - 1%
zircon - trace tour. -- trace	plag. -- 1% (fairly fresh)
~~iron trace~~ plag. - trace (very dirty)	musc. - trace
(Glauconite?) K-feld 10%⁺ (dirty) (overgrown)	granite frag
Matrix: 30%	Matrix: 30%
composition: qtz -- 3%, 27% mud	composition: qtz -- 12% siderite & calcite - 3% mud - 15%

WC 390

Grains: 70%

size: 62-125μ (very fine sand)

shape: subangular, subrounded

sorting: moderate

composition: qtz -- 57% (overgrown)

K-feld - 10% (overgrown)

plag. -- ≤ 1%

micro -- 1%

musc -- 1% no tour. found

perthite -- 1%

mudchips -- 1%

chert -- trace

biotite -- trace

☆

WC 410

Grains: 70%
size: 62-88μ (very fine sand) also see other side
shape: subangular, subrounded
sorting: moderate (layer along edge is very poor--see comments)
composition: qtz--55% (overgrowth)
+2% sericitized K-feld--10% .. dirty
micro--1% (overgrowth) fairly clean
opaque--1%, magnetite, in crude layers perthite--2% (overgrowth) dirty
chert--1%
zircon--trace biotite--trace chlorite
siltite?--1% tour.--trace
plag--trace dirtier

Matrix: 30% calcite 2%, hematite--20%, feld--3%, qtz--5%

WC 425

Grains: 65%
size ≤ 62 88μ (silt > very fine sand)
shape: subangular to angular
sorting: moderate
composition: qtz--52% (overgrowth)
K-feld--8% (seems quite dirty) (overgrowth)
plag--trace (dirty)
mudchips--1-2%
chert?--1% tour.--trace
perthite--<1%
biotite--1% ; chl. 1%
musc--1% tour.--trace, zircon--trace
(overg) (green)

WC 480

Grains: 60-65%
size: ≤ 62-88μ (silt → very fine sand)
shape: subangular to angular
sorting: moderate
composition: qtz -- 40% (some small aung grains)
K-feld -10%± (slightly dirty)
plag -- trace
musc -- 2%
⇒ biotite -- 1%+
chert -- 1%
chl -- 2%+ ‖ bedding
glauconite? trace mudchips 2%
mudchips -- 2%
tour. -- trace

WC 491

Grains: 70%
size: ≤ 62-88μ (silt to very fine sand)
shape: subrounded (some) w/ mostly subangular & angular
sorting: moderate
composition. qtz -- 60% (aung grains)
maybe + 1%+ replaced by calcite K-feld -- 7%
biotite -- trace (very small grains)
opaque - trace musc -- trace
mag, oxides chert -- 2%
(scattered) plag. - trace (sericite)
musc - trace (highly altered)
tour trace ? (green)

(cont)

WC 515

Grains: 75%

size. ≤ 62-88μ (silt to very fine sand)

shape: subangular & subrounded

sorting: moderate

composition: qtz -- 67% (one grain)

⇒ K-feld -- 4% (pretty clean)

micro -- trace - 1%

≤1% opaque (oxides, leucoxene)

biotite -- 1% and chlorite

tour. -- trace

perthite -- trace (clean)

plag -- trace (clean)

chert - trace - 1%

(over)

WC 520

Grains: 70%

size: ≤ 62-88μ (silt to very fine sand) & 350-500μ (med. s. mudchips)

shape: ~~st~~ subangular to angular

sorting: moderate

composition: qtz - 57% (one grain)

K-feld -- 7% (one grain) (dirty along cleavage planes)

micro. - trace (pretty clean)

trace opaque -- mag.

musc -- 1%

biotite -- 1%, chlorite tour. trace

tour. -- trace (light -- gray green) & (green)

plag. -- trace

chert - 1% ; mudchips -- 3%

(over)

WC 530 (maybe take photo of tour. x-section near right center of slide)

Grains: 70%
size: ≤ 62-88μ (silt to very fine sand)
shape: subangular, subrounded (maybe some rounded)
sorting: moderate
composition: qtz -- 58%
K-feld - 10%+? (pretty clean) (also some altered)
plag -- trace (dirty)
musc. -- trace
tour. -- trace (green to tan brown -- euhedral x-section)
glauconite - trace biotite -- 1% and chlorite
chert -- 1%
perthite -- trace zircon - trace
(one, 1)

WC 540 (take photo of granite)

Grains: 75%
size: 88-125μ (very fine sand) + 1000-1410μ (very coarse sand)
sorting: very poor
shape: subrounded to subangular
composition: qtz -- 68% some polygonized
K-feld -- 2%
granite fragments -- 3% (med. grained) (qtz)
No Tour. Found musc 1% } in ?, smeared aggregates (mud chips?)
biotite 1% }
zircon - trace (rounded) & subangular
Matrix: 25% chlorite -- trace
composition qtz 20%, K-feld 5%
difficult to tell % because so well compacted + cemented

WG 0

WEST GLACIER

Grains: 65%

size: 62-125μ (very fine sand)

shape: subangular to angular, some are subrounded

sorting: moderate ~~to poor~~

composition: qtz -- 53% (a lot of overgrowths)

≈2% sericitized K-feld -- 7% (~~a lot~~ some thick overgrowths, [illegible])

micro -- 1% (not too dirty)

opaques (3%) - mag, oxides, plag. - trace (pretty dirty)

leucoxene (some in perthite -- 1% (dirty)

oxide layers) zircon -- trace (subangular), rounded

tour -- trace (brown to green [illegible]), bluish green

biotite -- trace, chlorite

musc - trace

WG 19

Grains: 75%

size: 88 - 250μ (fine to med. sand)

shape: subangular to subrounded (some angular)

sorting: moderate to poor

composition: qtz -- 66% (overgrowth)

3% hematite coated K-feld -- 6% dirty (overgrowth)

micro -- 1% + dirty (overgrowth)

opaque (trace) mag perthite -- 1% dirty (overgrowth)

oxides, leucoxene plag -- trace dirty

musc -- trace

tour. 1 tiny grain

mud chips -- trace

zircon -- trace (rounded, subrounded)

WG 41 (take photo of broken round grn. (?))

Grains: 70%
size: 88 - 710μ (very fine to coarse s.s.)
shape: rounded & subrounded
sorting: poor
composition: qtz - - 60% (overgrown)
K-feld - 9% (maybe overgrowths X mostly clean, or (replaced" by calcite))
opaque (trace) oxides scattered — micro - - 1% (clean)
plag. - trace (dirty)
perthite - - 1% (dirty)
Volc. frag (one grain) — tour. - - trace (rounded grn. & subangular grn.) blue-green & brown, 1 small overgrowth
chert - - 1%

zircon - trace (subrounded)

WG 60 (take photo of broken round grn. (?))

Grains: 75%
size - - 88 - 177μ (v.f. → f.s.) layers & 250 → 500μ (med. s.s.) layers
shape - - subrounded & rounded (finer grains a little more angular)
sorting - - moderate to poor
composition - - qtz - - 64% (overgrown)
+5% altered — K-feld - - 5% (overgrown) (some dirty, clean)
micro - 1% (pretty clean)
opaques (<1%) mag. scattered — perthite - - 1% (a little dirty)
musc. - - trace
tour. - trace (green brown) subrounded (some euhedral like in TRF's)
zircon - trace subrounded & subangular (one euhedral)
Matrix: 25%

(cont.)

WG 82 (Maybe good clay sample) (take photo of broken round grain (?) granite frag -- fine s. ind. grns

Grains: 55%
size -- 62 to 710μ (v. f. to coarse ss - mixed layers in mud
shape - subrounded & rounded, smaller grns. more angular
sorting -- Very poor
composition: qtz -- 43% ← more qtz in large grain size fraction
1% hematite stained K-feld -- 8% ( ) (pretty clean, hematite coats)
plag -- 1% (dirty)
← micro -- trace -- clean
opaques (1%) magnetite perthite -- 1% -- (a little dirty)
in crude layers tour. -- trace (green) (subangular)
chert -- trace
musc. -- trace chlorite - (trace) - green
zircon -- trace -- (subrounded)
1% granite (qtz grains) (fine)

WG 102

Grains: 70%
size -- ≤ 62-88μ (silt to very fine sand), a few 177-250μ grains (f. sand)
shape -- subangular
sorting -- moderate
composition -- qtz -- 55%
K-feld -- 10% (clean)
plag -- 1% (slightly dirty)
opaque (trace) magnetite, perthite - trace (clean
leucoxene tour -- trace (dark green) (subangular, subrounded ?)
Zircon - trace (subrounded)
musc. -- 1%
siltite -- 1% chlorite -- 1%

Note: No microcline found

WG 120

(Take photo of broken round grains (?))
(Take photo of TRF's, granite.)

Grains: 70% (v.f. - v.f.s.)

size - ≤62-83μ w/ 1% 177-350μ (c-m.s.) — layer of 62-1000μ (very fine to coarse sand) subangular (small); larger grns. subangular rounded

shape -- subangular

sorting -- moderate — poor — mostly mainly qtz

composition - qtz - 51% (some overgrowths)

calcite may replace 10 to 2%? — K-feld -- 10% (some overgrowths)

plag. -- trace

perthite -- trace

* ⇒ tour. -- ≤1% (euhedral, subeuhedral) (TRF)

opaques (trace) — musc. -- trace

leucoxene, cal. — mudchips - 5% (calcareous) — chlorite -- trace

granite -- 2 grains seen (coarse)

zircon -- rounded -- trace

WG 127

(Take photo of granite, broken round grain)
* Photo of poly qtz + qtz cemented together (S.S. frag.)

Grains: 50%

size, 62-710μ (very fine to coarse s.s.)

shape. subangular → subrounded (some rounded)

sorting - poor

composition: qtz - 37% (some overgrowths), some poly

maybe several % replaced by cal. — K-feld -- 5% (some overgrowths)

perthite -- 1% dirty, some clean

microcline -- trace dirty

S.S. frag -- trace (1) — zircon - trace — musc. trace (some edges slightly aligned)

mudchips -- 1% (qtz, pm)

granite 2%? chlorite (trace)

(TRF) trace — chert - trace

tour. trace (green) subrounded, subangular, euhedral

WG 143

Grains: 65%
size - 62-88μ (very fine sand), 3 or 4 177-250μ (fine sand) qtz grns.
shape - subangular, angular
sorting -- moderate
composition - qtz -- 50%
K-feld - 10% (pretty fresh)
perthite - trace clean
opaque (1%) magnetite in wide layers
micro -- trace pretty clean
red mud chips -- 3%
musc -- 1%
chlorite - trace
zircon - trace subangular
tour. - trace subangular

WG 160

Grains: 60%
size ≤ 62-88μ (very fine sand)
shape - subangular & angular
sorting - moderate
composition - qtz - 48% (overgrowns)
K-feld - 5%? (pretty clean)
perthite - 1% (clean)
opaque (1%) magnetite, scattered
tour. - trace (green) subangular, some brown ~~[illegible]~~ bluish green
musc. - 1%
red mud chips - 5%
zircon - trace (subrounded) euhedral
biotite trace & chlorite
microcline - trace (clean) (overgrown)

WG 180

Grains: 70%
size: ≤62-88μ (silt to very fine sand)
shape: subangular to angular
sorting: moderate
composition: qtz -- 55% (some small overgrowths)
K-feld -- 10%+ (pretty clean)
perthite -- trace
opaque (2%+) magnetite scattered & in crude layers. zircon -- trace (subrounded)
musc. -- 2%
biot. -- trace and chlorite
tour -- ≤1% (green, bluish green, grey-green) subangular, euhedral

WG 200

Grains: 75%
size: 62-88μ (very fine sand) w/ 350-500μ (med. sand) mudchips
shape: subangular to angular
sorting: moderate
composition: qtz 55% (overgrowths)
→ K-feld 15% (overgrowths, pretty clean)
there seems to be compositional layering of K-feld (can be very high % there) perthite 2% (vacuolized)
microcline -- trace (clean) (some overgrowths)
zircon -- trace (subrounded)
tour. -- trace (green, subangular) (euhedral)
mudchips 1%
opaque (1%) mag, leucoxene, scattered red mud chips ~3%
musc. -- 1% chlorite trace

WG 220

Grains: ~~65~~ 70%
size: ≤62-88μ (silt to very fine sand)
shape: subangular to angular
sorting: moderate
composition: qtz - 58% (overgrown)
K-feld - 5%? (dirty, overgrown) } slide not stained; approx %
perthite - 1% (pretty clean, some dirty)
opaques (trace) microcline - trace (clean or slightly dirty)
magnetite, scattered plag. - trace (pretty clean)
tour. trace (green to gray green) subangular, euhedral
zircon - trace (subrounded)
musc - 1%
chlorite - trace
red mud chips - 5%