

# Mineralogy and Geochemistry of Some Belt Rocks, Montana and Idaho

By J. E. HARRISON and D. J. GRIMES

CONTRIBUTIONS TO ECONOMIC GEOLOGY

---

GEOLOGICAL SURVEY BULLETIN 1312-O

*A comparison of rocks from two widely  
separated areas in Belt terrane*



**UNITED STATES DEPARTMENT OF THE INTERIOR**

**WALTER J. HICKEL, *Secretary***

**GEOLOGICAL SURVEY**

**William T. Pecora, *Director***

Library of Congress catalog-card No. 75-607766

## CONTENTS

---

	Page
Abstract .....	O1
Introduction .....	2
General geology .....	3
Methods of investigation .....	7
Sampling procedure .....	7
Analytical technique for mineralogy .....	11
Analytical technique and calculations for geochemistry.....	13
Mineralogy of rock types.....	29
Geochemistry .....	37
Discussion and interpretation .....	42
Implications about sedimentation .....	42
Metamorphic changes .....	46
Comparison of Belt rocks with younger rocks.....	46
Conclusions .....	47
References cited .....	48

---

## ILLUSTRATIONS

---

	Page
FIGURE 1. Geologic map of northern Idaho and northwestern Montana.....	O5
2. Correlation chart for part of the Belt Supergroup, northern Idaho and western Montana.....	6
3. Geologic sketch map of the Pend Oreille area, showing sample localities and numbers.....	9
4. Histograms showing precision of semiquantitative spectrographic analyses of some Belt rocks.....	27
5. Diagram showing average modes of rocks of the Belt Supergroup .....	35
6. Diagram showing ratio among quartz, potassium feldspar, and plagioclase in siltites .....	36
7. Diagram showing average mineralogy of clastic Belt rocks.....	37
8. Diagram showing geometric means of semiquantitative spectrographic analyses of different Belt rock types.....	40

TABLES

---

	Page
TABLE 1. Sample distribution by area, formation, rock type, and metamorphic grade .....	O10
2. Average modes of Belt rocks from the Mission Mountains Primitive Area .....	13
3. Semiquantitative spectrographic analyses of Belt rocks from the Pend Oreille area.....	14
4. Replicate semiquantitative spectrographic analyses of Belt rocks from the Pend Oreille area.....	24
5. Replicate analyses of standard sample G-1.....	28
6. Mean element content of low-grade Belt rocks from the Mission Mountains Primitive Area .....	31
7. Mean element content of Belt rocks from the Pend Oreille area .....	32
8. Numbers used to replace nonnumeric codes (N, L, and >) prior to geochemical calculations.....	34
9. Relative concentration of elements in the heavy mineral fraction of some Belt rocks from the Pend Oreille area.....	39
10. Average granite and average composition of the Canadian Shield compared with average Belt rock from the Pend Oreille area.....	43
11. Average minor element content of pelitic rocks of different ages and geologic environments.....	47

CONTRIBUTIONS TO ECONOMIC GEOLOGY

---

**MINERALOGY AND GEOCHEMISTRY  
OF SOME BELT ROCKS,  
MONTANA AND IDAHO**

---

By J. E. HARRISON and D. J. GRIMES

---

ABSTRACT

The mineralogy and geochemistry of about 20,000 feet of Belt rocks in the Mission Mountains Primitive Area, northwestern Montana, are compared with those of about 40,000 feet of Belt rocks in the Pend Oreille area, northern Idaho and northwestern Montana. Semiquantitative spectrographic analyses of 254 samples from the Mission Mountains and 230 samples from the Pend Oreille area form the basis for chemical comparison; quantitative X-ray mineralogic analyses of most samples provide the mineralogic data. Both analytical techniques are rapid and inexpensive.

All rocks were classified on the basis of grain size, texture, and carbonate content into one of four rock types: argillitic rocks (shale or mudstone equivalents), siltites (siltstone equivalents), quartzites (sandstone equivalents), and carbonate rocks. The semiquantitative spectrographic method has good precision for all rock types, but the accuracy is only fair for rocks of moderate to high carbonate content.

Comparison of clastic rocks from both areas shows the mineralogy to be very similar even to the ratio among quartz, potassium feldspar, and plagioclase in siltites. Most rocks are graywacke or like graywacke. Mineralogy is, not surprisingly, directly related to grain size; for example, we find that from argillitic rocks to siltites to quartzites the amount of quartz increases, the amount of feldspar remains about the same, and the illite-sericite-chlorite content decreases.

Several elements show distinct patterns of abundance related to the rock types. Elements directly related in abundance to amount of illite-sericite-chlorite in clastic rocks are B, Co, Cr, Ni, Sc, V, Fe, Mg, Ti, and possibly La and Y. Siltites and quartzites contain Cu in sulfide grains and flakes, and Cu is distinctly more abundant in those rocks or in fossil algal forms (usually calcareous or dolomitic siltite) in the Mission Mountains. Carbonate rocks or rocks containing moderately abundant carbonate minerals show increased amounts of Ca, Mg, Mn, Sr, and Pb. The higher B content of certain Pend Oreille area strata and the higher Co, Cu, and Ni contents of Mission Mountains strata seem most likely to reflect differences in source area of the original sediments. If so, the Cu abundance and distribution identified in this study may aid in the search for stratabound copper deposits in Belt rocks.

The excellent sorting of grain sizes in similar strata through tens of thousands of feet of rock in two widely separated areas, the remarkable uniformity of simple miner-

alogy, the apparently simple chemistry of depositional environments, and the bulk chemistry of the rocks suggest that the weathering and transportation processes of Belt time resulted in homogenization of clastic components drawn from large granitic source areas. This homogenization requires a chemical weathering of most mafic minerals, a low terrane and low stream gradient, a nearly uniform availability of many minor elements for absorption on or inclusion in clay minerals, and a slow isostatic adjustment between source areas and basins of deposition during the several hundred million years of Belt rock deposition. Sedimentation processes in Belt time were not complicated by living plants or animals on the land or by significant life in the sea. Organic compounds did not complicate chemical environments of deposition.

Regional metamorphism from the chlorite-sericite zone of the greenschist facies into the biotite zone in the Pend Oreille area appears to have resulted only in a loss of B among the elements studied. Contact metamorphism, also in the biotite zone, resulted in an increase in Ca and Sr, a decrease in Ni, and a possible decrease in Co and B.

## INTRODUCTION

Much attention has been given to Belt rocks during the past decade. Some of the interest has come from general recognition that the vast area of exposed Belt rocks represents one of the most poorly understood depositional basins in the United States; other interest is based on tectonic history yet to be deciphered; and more recent impetus for expanded study of Belt rocks comes from active exploration for stratabound copper deposits. So much new stratigraphic, structural, and chemical information has been gained recently that a compendium of data representing the state of knowledge only a few years ago (Ross, 1963) is rapidly becoming outdated.

This report discusses the mineralogy and minor element content of Belt rocks from two widely separated areas in the Idaho-Montana part of Belt terrane shown in figure 1. The data, accumulated from 1957 through 1968, represent samples collected for two purposes: a study of metamorphic effects in the Pend Oreille area and an evaluation of mineral potential in the Mission Mountains Primitive Area. The advent of reasonably precise and rapid semiquantitative spectrographic analyses, plus the availability of electronic computers to handle efficiently large masses of data, has permitted the geochemical study described here.

Several colleagues aided in collecting data included in this report. D. A. Jobin collected some samples from the Pend Oreille area and made some heavy mineral separations. M. W. Reynolds collected about half the samples from the Mission Mountains Primitive Area. Uteana Oda, now deceased, analyzed spectrographically the heavy and light mineral fractions. Paul W. Schmidt and George M. Fairer made X-ray spectrographic analyses of samples for the quantitative mineralogic studies. We are particularly grateful for the aid and counsel of Albert P. Marranzino on the spectrographic parts of the study. The manuscript benefited from reviews and discussions with M. R. Mudge and Jon Connor.

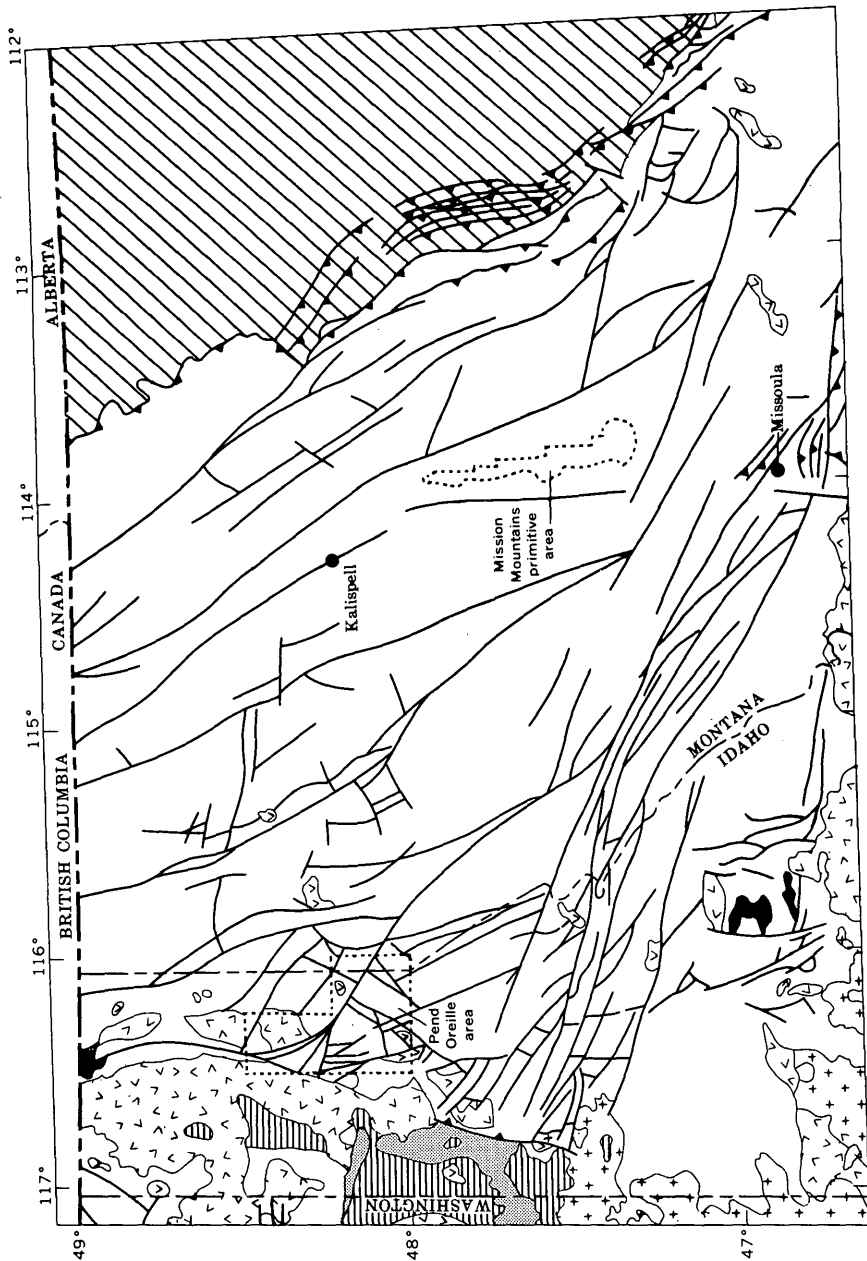
## GENERAL GEOLOGY

Rocks of the Belt Supergroup crop out over much of western Montana and northern Idaho (fig. 1) and northward into Canada. Equivalent Belt rocks extend southward from Missoula, Mont., for at least 150 miles, and scattered outcrops are known in northeastern Washington near the Idaho-Washington State line. The limits of the basin, or basins, of deposition of Belt rocks are poorly known, although evidence indicates that the thrust zone on the eastern edge of Belt terrane (fig. 1) may mark the depositional edge of Belt rocks (Mudge, 1970). The western edge of the Belt terrane is so complicated by extensive intrusion and faulting that it has not yet been satisfactorily determined whether some high-grade metamorphic rocks in this area are Belt or pre-Belt. Between the thrust belt on the east and a Cretaceous batholith in the Idaho Panhandle (fig. 1), Belt rocks either are nearly unmetamorphosed or are not above the greenschist facies. The grade of regional metamorphism progressively increases from east to west and with depth in the stratigraphic section, as demonstrated by illite transformations to the 2M polymorph (Maxwell and Hower, 1967).

Belt rocks are generally monotonous in appearance because of fine grain size and drab color. The bulk of the supergroup has a grain size of silt or clay, and medium sand is the coarsest grain size observed in thousands of feet of rock over large areas. Quartzites and relatively pure to impure dolomites and minor amounts of limestones are scattered through the supergroup, although the carbonate rocks are uncommon in the lower part. Some carbonate rocks contain fossil algal forms, which are the only megascopic evidence of Precambrian life in the rocks. All rocks are dense and hard, reflecting the widespread low-grade metamorphism of most of the supergroup. Because of the metamorphism in most rocks of the Pend Oreille area and in some rocks of the Mission Mountains area, we use terms such as argillite, siltite, and quartzite rather than claystone, shale, siltstone, and sandstone to describe the rocks. Mudstone equivalents in the Belt Supergroup include argillite, silty argillite, and laminated argillite and siltite. Descriptions of rock types and formations for the Pend Oreille area are given by Harrison and Jobin (1963) and for the Mission Mountains Primitive Area by Harrison, Reynolds, Kleinkopf, and Pattee (1969). Most rocks contain shallow-water structures, although the abundance of such structures decreases noticeably in the lower parts of the section. Disconformities in the supergroup are difficult to identify, and angular unconformities are rare.

The stratigraphy of both areas is reasonably well known, and map units are traceable for many miles from each area. Correlation between the areas is still somewhat unreliable for a few members or formations (see queries in fig. 2), although for most it is adequate (fig. 2).

Obradovich and Peterman (1968) stated that the Belt rocks are from about 900 m. y. (million years) to more than 1,300 m.y. old. The bulk of the





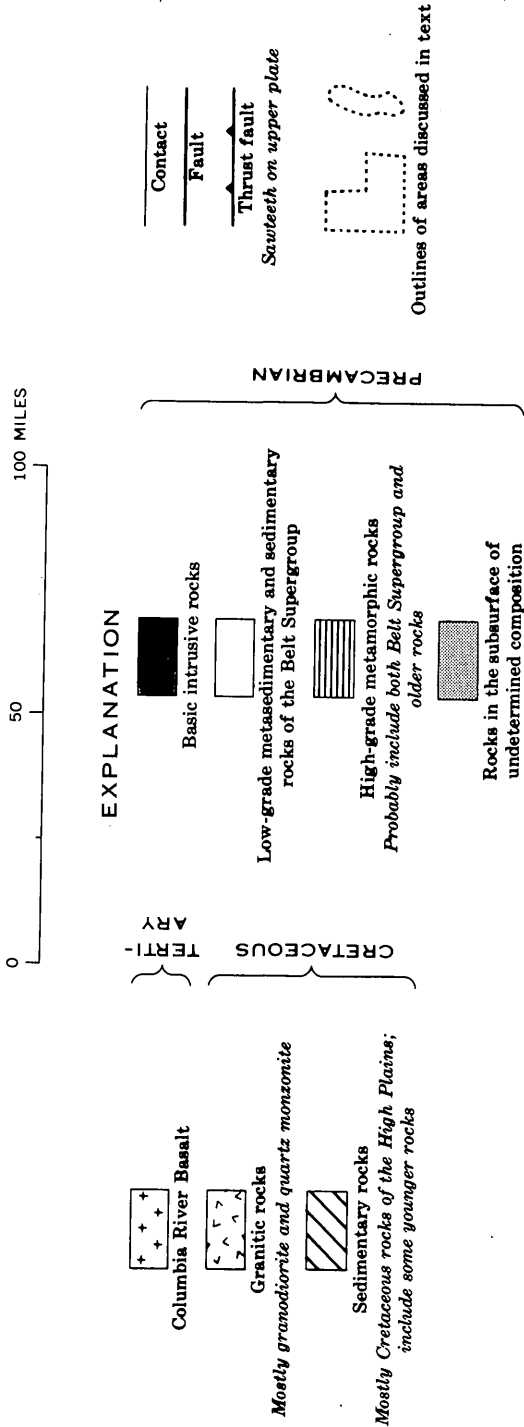


FIGURE 1.—Geologic map of northern Idaho and northwestern Montana. After Bayley and Muehlberger (1968).

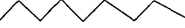




PEND OREILLE AREA (Harrison and Campbell, 1963)		MISSION MOUNTAINS PRIMITIVE AREA (Harrison and others, 1969)	CAMP CREEK, SOUTHERN LEWIS AND CLARK RANGE (McGILL and Sommers, 1967)
Top eroded 			Top eroded 
Libby Fm 1,900+ ft			Garnet Range Fm 985+ ft
(McNamara Fm equivalent missing)			McNamara Fm 3,070 ft
Striped Peak Formation	Member 4 700 ft		Bonner Qtz 1,265 ft
	—?—		
	—?—	Top eroded 	Shields Fm 2,730 ft
	Members 3 and 2 700 ft	Shields Fm 1,400+ ft	Shepard Fm 1,980 ft
Member 1 600 ft	Shepard Fm 2,500 ft	Shepard Fm 1,980 ft	
	Snowslip Fm 3,800 ft	Snowslip Fm 2,235 ft	
Wallace Fm 10,200 ft	Helena Fm 9,800 ft	Siyeh Fm 1,480+ ft 	
St. Regis Fm 1,100 ft	Empire and Spokane Fms 2,300+ ft	Base not exposed	
Revett Fm 2,000 ft	Base not exposed		
Burke Fm 3,200 ft			
Prichard Fm 22,000+ ft			
			
Base not exposed			

FIGURE 2.—Correlation chart for part of the Belt Super-group, northern Idaho and western Montana.

Belt rocks exposed in the Mission Mountains Primitive Area (Helena Formation and strata above) result from a period of sedimentation about 1,100 m.y. old. Presumably, the lithostratigraphic equivalents of those rocks in the Pend Oreille area are approximately the same age. Rocks approximately 2,000 feet below the Helena and Wallace Formations are dated at about 1,300 m.y. at the eastern edge of the Belt terrane. Correlation of these dated rocks with those of the Pend Oreille area is not well established, but the general 1,800-m.y. age for the metamorphosed basement rocks in western Montana provides a maximum possible age of the Belt Supergroup.

Geologic differences and similarities between the two study areas are outlined in table 1, which lists samples collected according to area, formation, rock type, and metamorphic grade. The Mission Mountains Primitive Area contains strata probably laid down closer to shore than those of the Pend Oreille area, and subsequent diagenesis and metamorphism of the Mission Mountains strata were low grade. Many carbonate rocks in the Mission Mountains area are relatively pure, and carbonate cement is common. The Pend Oreille area contains strata whose relations to shore are less well defined. The stratigraphic units above the Wallace Formation are more similar in appearance to their equivalents in the Mission Mountains Primitive Area than are the Wallace and lower formations. Regional metamorphism is evident in the rocks in the Pend Oreille area; those rocks below the Revett Formation are clearly in the biotite zone of the greenschist facies. Effects of contact metamorphism, also of the biotite zone, are apparent near the granodiorite intrusions (fig. 3). Carbonate rocks are rarely pure, and carbonate cement or minerals are uncommon in most units.

## METHODS OF INVESTIGATION

### SAMPLING PROCEDURE

The sample localities for the Pend Oreille area are shown in figure 3, whereas those for the Mission Mountains are in a report by Harrison, Reynolds, Kleinkopf, and Pattee (1969, pl. 1B). The locality number on the maps is the same as the sample number listed in the tables of analytical data. The number of samples in table 1 is crudely proportional to the thickness and abundance of the rock types in a given formation. For the Mission Mountain samples, an exception to this generality is an overemphasis on quartzite and siltite in the Empire and Spokane and on quartzite in the Helena; stratabound copper minerals have been found in those rock types. Exceptions for the Pend Oreille samples are (1) a smaller than proportional number of samples of minor rock types in some formations, such as argillite in the Revett Formation and in member 4 of the Striped Peak Formation and quartzite in the Burke Formation, and (2) a larger than proportional number of samples for the Striped Peak because of the different character of each of its members.





TABLE 1.—Sample distribution by area, formation, rock type, and metamorphic grade

Formation and thickness (ft)	Mission Mountains Primitive Area				Metamorphic grade <sup>1</sup>	Pend Oreille area				Formation and thickness (ft)
	Mudstone equivalent <sup>2</sup>	Siltite	Quartzite	Carbonate rocks		Mudstone equivalent <sup>1</sup>	Siltite	Quartzite	Carbonate rocks	
Shields of McGill and Sommers (1967) 1,400+	6		3		C Bd	1 1			2	Libby 1,900+
Shepard 2,500	9	9	8	9	C	1	7			Member 4 700
Snowslip 3,800	12	14	18		C		1		2	Members 3 and 2 700
Helena 9,800	29	30	18	53	C Bb	8 4	1 1		9	Member 1 600
Empire and Spokane 2,300+	6	9	21		C Bb	6 3				Wallace 10,200
					C Bb					St. Regis 1,100
					C Bb	4 3	5 5			Revelt 2,000
					C Bb					Burke 3,200
					C Bb Bgn	1 8 5				Pritchard 22,000+
	62	62	68	62	Total samples	71	32		13	

<sup>1</sup> Includes argillite, silty argillite, and laminated argillite and siltite.

<sup>2</sup> C, chlorite-sericite grade rocks that may contain minor secondary biotite; Bb, bedded rocks containing abundant secondary biotite in rocks of appropriate composition; Bgn, gneisses and schists of the biotite zone of metamorphism.

The field classification of the rocks into five rock types (argillite, laminated argillite and siltite, siltite, quartzite, and carbonate rocks) and into three metamorphic grades (simply defined as chlorite-sericite, biotite, and gneissic or schistose) was supported by study of thin sections of each sample from the Pend Oreille area and about half the samples from the Mission Mountains. The final classification for this study grouped most of the laminated rocks with the argillites into a rock group that is equivalent to mudstone.

#### ANALYTICAL TECHNIQUE FOR MINERALOGY

Mineralogical study of Belt rocks is complicated by (1) fine grain size, which makes microscopic modal analysis extremely difficult, and (2) low-grade metamorphic recrystallization, which effectively prevents simple separation into pure mineralogical components. Various staining techniques were tried in thin section, but they met with only partial success on the coarsest rocks; several standard mineral separation techniques were tried, again with only partial success in unmetamorphosed rocks. We resorted to X-ray diffraction as a method for mineralogical analysis that would give comparable results in all rocks regardless of grain size or degree of metamorphism.

Quantitative mineralogic data for most Belt rocks can be obtained by X-ray analysis. The simple mineral suite in most Belt rocks led Jobin and Harrison to experiment with quantitative X-ray spectrographic analyses in 1958. The first results of continuing studies were published a few years later (Harrison and Campbell, 1963). Studies by others—for example, Tatlock (1966), who made a thorough investigation of X-ray analysis of felsic rocks—verify that quantitative mineralogic data of even more complex rocks also can be obtained by X-ray analysis.

The analytical technique used for mineralogical determinations was specifically designed for Belt rocks and their low-grade metamorphic mineralogy. Replicate X-ray diffraction analyses on various rock types commonly fell within 5 percent of each other and always within 10 percent. Such precision is more than adequate for use in our studies because of the much greater differences observed among samples. In addition, the mineralogy was checked against partial or total chemical analyses for many samples with the result that the X-ray mineralogy appears to be not only reasonably precise but also reasonably accurate. All such chemical checks were within 10 percent of the X-ray values.

Each sample was crushed, ground for 15 minutes on a power mortar and pestle, spooned or dumped (to help avoid mica orientation) into an aluminum slotted powder holder, and run on the X-ray spectrometer from  $2^{\circ}$  to  $62^{\circ}$  at  $2^{\circ} 2\theta$  per minute. Peak heights above background on the spectrometer trace were then measured: the 10 Å peak for mica (and illite), the 7 Å peak for chlorite, the 3.35 Å peak for quartz, the 3.25 Å peak for

potassium feldspar, the 3.2 A peak for plagioclase, the 3.05 A peak for calcite, and the 2.9 A peak for dolomite. The ratio of the 10 A mica peak and the 5 A mica peak was also determined.

General formulas for relating peak heights to mineralogy were devised by comparing X-ray spectrometer data with some complete chemical analyses, with K and Na analyses on most rocks, and with Ca and Mg analyses on carbonate rocks. In addition, estimates of biotite content were made from thin sections of all rocks showing visible metamorphic effects. Standard chemical formulas for each mineral were used to compute chemical content from rock mineralogy; the dark-green chlorite characteristic of the rocks was assumed to be iron rich, and the plagioclase (albite-oligoclase) was assumed to contain essentially all the Na in the rocks. From these data and assumptions, the following basic formulas for translating peak heights into quantitative mineralogy of nonbiotitic rocks emerged:

$$\text{Quartz} = \frac{3.35 A - \frac{1}{2}(10 A)}{4}$$

(Subtraction required because of interference between main quartz peak and secondary mica peak);

$$\text{Potassium feldspar} = \frac{3.25 A}{3};$$

$$\text{Sericite (plus muscovite plus illite)} = \frac{2(10 A)}{3};$$

$$\text{Chlorite} = \frac{7 A}{2};$$

$$\text{Calcite} = \frac{3.05 A}{2};$$

$$\text{Dolomite} = \frac{2.9 A}{3}.$$

Estimates derived from these formulas were then recalculated to 100 percent. We consider that the simplified formulas given above are justified in this study because of the relatively simple mineralogy of the bulk of the Belt rocks and the limited interference between principal and secondary peaks of the minerals. The ratio of the 10 A peak to the 5 A peak may be used to detect either preferred orientation of mica or presence of biotite in the sample. Biotite tends to give a higher 10 A and lower 5 A peak than an equal amount of sericite, whereas mica orientation gives an anomalously high 10 A peak. A microscopic scan of powdered rock or thin section usually distinguished which factor was affecting the normal peak ratio. Mica orientation necessitated a rerun of the sample; the detection of minor biotite required a decrease in the amount of the 10 A peak used in the calculation. Excessive biotite totally disrupts the mica formula, but the general formulas were found satisfactory for proportions of minerals other than mica. Mica content was determined from thin sections where biotite is a major constituent, where the metamorphic grade is relatively high, and where the grain size of the micas is sufficiently large.



TABLE 2.—Average modes, in volume percent, of Belt rocks from the Mission Mountains Primitive Area

Rock type <sup>1</sup>	Number of samples	Quartz	Plagio- clase	Potassium feldspar	Illite- sericite	Chlorite	Calcite	Dolomite
<b>Shields Formation</b>								
Dolomitic laminated argillite and siltite.	3	41	11	6	20	9	0	13
Dolomitic siltite.	2	45	15	8	12	7	0	13
Quartzite.	3	73	4	2	10	9	0	2
<b>Shepard Formation</b>								
Carbonatic argillite or laminated argillite and siltite.	5	38	16	3	16	14	8	5
Carbonatic siltite.	3	38	16	5	13	9	7	12
Carbonatic quartzite.	2	44	22	4	7	5	9	9
Impure limestone.	6	18	10	Trace	9	8	53	2
<b>Snowslip Formation</b>								
Argillite or laminated argillite and siltite.	6	38	21	1	26	11	1	1
Siltite.	5	42	22	3	24	6	3	0
Quartzite.	5	58	19	0	9	6	8	Trace
<b>Helena Formation</b>								
Silty argillite.	5	33	14	3	29	13	7	1
Calcareous silty argillite.	2	34	13	0	16	6	30	1
Carbonatic siltite.	13	33	14	3	17	6	15	12
Calcareous quartzite.	6	46	19	4	7	6	16	2
Dolomitic limestone.	17	17	6	Trace	8	4	51	14
<b>Empire and Spokane Formations</b>								
Carbonatic argillite or argillite and siltite.	3	27	14	0	30	15	3	11
Calcareous siltite.	2	35	18	0	20	11	12	4
Quartzite.	7	62	15	0	12	6	3	2
<b>All formations named above</b>								
Carbonatic argillite or argillite and siltite.	24	35	16	2	24	12	6	5
Carbonatic siltite.	25	36	16	4	18	7	10	9
Carbonatic quartzite.	23	57	16	2	9	6	8	2
Carbonate rocks.	23	18	7	Trace	8	5	51	11

<sup>1</sup> Rock types within stratigraphic units are not necessarily in order of stratigraphic sequence or abundance.

Average modes of rocks from the Mission Mountains are given in table 2, and average modes for some rocks from the Pend Oreille area have previously been published (Harrison and Campbell, 1963, table 1).

#### ANALYTICAL TECHNIQUE AND CALCULATIONS FOR GEOCHEMISTRY

Semiquantitative spectrographic analyses presented in this report (table 3) and similar analyses on rocks from the Mission Mountains (Harrison and others, 1969) were done using methods outlined by Grimes and Marzantino (1968). Analytical results were reported as approximate geometric midpoints of ranges whose boundaries are 1.2, 0.83, 0.56, 0.38, and 0.18 (or multiples of those numbers); results are reported as 1, 0.7, 0.5, 0.3, 0.2, and 0.15 (or appropriate multiples).

TABLE 3.—*Semiquantitative spectrographic analyses*

[Number in parentheses indicates sensitivity limit for method used. Metamorphic grade: C, bedding; Bgn, biotite zone in gneiss or schist. >, undetermined amount of element is limit; N, element was looked for but not found. Also looked for but not found in any all samples were reported as N(5) for Mo, N(200) for Zn, N(0.5) for Ag, and N(10) for

Sample	(percent)				(ppm)							
	Fe (.05)	Mg (.01)	Ca (.05)	Ti (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La (20)
<u>Libby Formation</u>												
071 <sup>1/</sup>	1.5	0.7	0.05	0.2	70	70	300	L	L	30	7	50
072	3	1	.1	.2	300	50	150	L	5	20	70	20
073	3	1	.07	.3	200	100	500	L	7	50	7	L
074	3	1	.05	.3	200	100	500	1	7	50	5	20
075	2	1	.05	.5	300	500	500	2	10	70	30	50
083	3	3	.2	.2	300	100	200	1	5	20	L	50
108 <sup>2/</sup>	3	2	.7	.2	300	30	500	1	5	20	50	50
120	2	1.5	.05	.5	200	100	700	2	N	30	L	50
121	3	1.5	.07	.5	200	100	700	1.5	5	30	7	30
128	3	1.5	1.5	.3	500	50	300	2	N	30	50	30
129	3	1	.05	.5	200	700	500	1.5	L	50	30	50
116	1	.7	L	1	15	30	500	1.5	N	30	5	70
118	3	1	.1	.3	150	50	500	1.5	10	30	10	L
119	5	1.5	.07	.5	300	70	500	2	N	50	30	N
082	1.5	2	.15	.2	150	200	700	1.5	L	15	L	50
117	1	.5	N	.5	20	30	500	1.5	N	30	15	100
080	.7	.5	>20	.1	>5,000	20	150	L	10	15	5	70
081	.7	.2	10	.02	1,500	30	200	L	10	5	15	L
<u>Striped Peak Formation</u>												
067	3	1.5	.07	.3	15	150	700	1.5	L	50	L	50
069	3	1	.07	.5	30	500	300	1.5	5	70	20	50
097	3	1.5	.07	.5	150	500	300	2	7	70	30	50
102	3	1.5	.07	1	15	300	700	2	5	50	L	50
103	5	1.5	.05	.2	15	100	700	1.5	5	7	N	70
110	3	1.5	.05	.5	30	2,000	300	2	L	70	10	70
113	3	1.5	.05	.3	15	100	500	1.5	5	70	7	50
064	1.5	.7	.05	.3	15	1,500	200	1	N	30	5	50
055	3	1.5	.07	.7	15	300	300	1	7	70	5	70
068	1	5	10	.2	300	150	300	L	L	30	15	50
078	1.5	3	.1	.2	50	70	300	1.5	7	30	L	30
095	2	1.5	.07	.2	50	50	200	L	7	50	7	30
098	1	5	7	.2	200	100	700	L	5	50	20	30
105	1	.3	.07	.7	15	1,500	150	2	L	30	7	30
106	.7	.7	.05	.7	20	2,000	300	1.5	N	30	7	50
107 <sup>3/</sup>	1	.7	.05	1	15	2,000	500	1.5	N	50	10	70
109	3	1.5	L	.3	30	200	300	1.5	10	50	5	70
122	3	3	.1	.7	50	200	500	1.5	7	70	5	50
125	3	2	.15	.5	70	2,000	500	1	N	50	15	50
062	1	.3	.05	.3	30	50	150	1.5	5	20	L	50
063	2	1	.05	.5	100	300	200	1.5	10	30	L	50
070	1.5	2	1.5	.3	300	150	150	1	7	30	L	30
076	.7	.15	.07	.2	30	30	100	1	N	15	L	20
100	.7	.1	L	.2	300	150	200	L	L	20	30	30
114	.5	.5	L	.05	70	15	300	L	L	5	5	N
126	2	.7	.07	.15	100	300	150	1	L	20	15	30
127	3	1	.1	.5	150	150	200	1.5	15	50	7	50
211	1.5	.5	L	.15	50	30	500	L	5	20	15	50
111	1	7	15	.1	500	150	70	300	L	20	10	N
124 <sup>4/</sup>	2	10	20	.15	5,000	500	500	L	L	30	3,000	30
<u>Wallace Formation</u>												
004	.7	.5	L	.2	10	30	300	L	5	20	L	30
005	2	3	.15	.2	30	70	500	1.5	7	30	L	70
008	1.5	1.5	L	.3	20	50	300	L	7	50	7	70
012	3	1.5	L	.2	70	50	300	1	10	50	30	50
013	1.5	2	L	.3	50	30	500	1	10	30	5	30

See footnotes at end of table.

*of Belt rocks from the Pend Oreille area*

chlorite-sericite zone including minor secondary biotite; Bb, biotite Zone in rock with prominent present above number shown; L, undetermined amount of element is present below sensitivity sample were As(200), Au(10), Cd(20), Sb(100), and W(50). Except as indicated by footnotes, Bi and Sn. D. J. Grimes, analyst]

Sample	(ppm)								Metamorphic Grade	Sample description
	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)	Zr (10)		
<u>Libby Formation</u>										
071	L	10	N	5	N	70	15	100	C	Black silty argillite.
072	L	15	15	5	N	70	20	100	C	Calcareous silty argillite.
073	L	15	L	5	N	70	15	150	C	Black silty argillite.
074	L	20	L	7	N	70	30	100	C	Green silty argillite.
075	10	20	L	10	N	100	30	150	C	Black silty argillite.
083	L	30	N	7	N	50	30	150	C	Green silty argillite.
108	L	15	N	5	N	50	30	150	C	Calcareous green argillite.
120	10	L	N	10	N	70	30	150	C	Black silty argillite.
121	10	20	10	10	N	100	30	150	C	Do.
128	10	20	L	10	N	70	30	200	C	Green calcareous argillite.
129	15	20	N	15	N	100	30	200	C	Black silty argillite.
116	15	L	L	15	N	100	50	200	Bb	Do.
118	L	20	N	7	N	70	20	150	Bb	Do.
119	10	30	N	10	N	70	30	150	Bb	Do.
082	L	5	N	7	N	30	30	150	C	Green argillitic siltite.
117	10	L	30	10	N	70	30	150	Bb	Argillitic siltite.
080	N	L	30	5	200	30	50	150	C	Stromatolite.
081	N	5	30	L	N	15	30	15	C	Cherty oolite.
<u>Striped Peak Formation</u>										
057	L	10	L	10	N	70	30	200	C	Green silty argillite.
069	10	30	L	15	N	70	30	150	C	Black silty argillite.
097	10	30	L	10	N	70	30	150	C	Do.
102	L	7	N	15	N	70	50	200	C	Green silty argillite.
103	L	5	N	7	N	50	50	150	C	Maroon argillite.
110	10	50	N	10	N	70	30	200	C	Black silty argillite.
113	10	15	L	7	N	70	30	200	C	Red silty argillite.
064	L	L	L	7	N	30	30	700	C	Olive siltite.
065	10	10	L	10	N	70	50	1,000	C	Red siltite with salt casts.
068	L	7	15	5	N	30	15	200	C	Dolomitic siltite.
078	10	20	N	7	N	50	30	150	C	Dolomitic argillitic siltite.
095	L	20	N	L	N	30	30	200	C	Red and green siltite.
098	L	15	10	5	N	50	20	150	C	Dolomitic siltite.
105	L	5	N	7	N	70	30	200	C	Green siltite.
106	10	L	50	7	N	70	30	200	C	Black argillitic siltite.
107	10	N	30	10	N	70	50	300	C	Do.
109	L	30	N	7	N	70	30	150	C	Red feldspathic siltite.
122	10	20	N	7	N	70	30	700	C	Green argillitic siltite.
125	10	7	10	15	N	70	30	300	C	Black argillitic siltite.
062	L	5	N	5	N	30	20	700	C	Red feldspathic quartzite.
063	L	15	N	7	N	50	20	700	C	Green quartzite.
070	L	15	N	5	N	70	30	300	C	Calcareous red quartzite.
076	L	L	N	L	N	15	15	700	C	Red feldspathic quartzite.
100	L	L	N	5	N	50	20	200	C	Do.
114	L	L	L	N	N	20	10	100	C	Do.
126	L	20	N	5	N	70	20	300	C	Green quartzite.
127	10	20	N	10	N	70	30	1,000	C	Red feldspathic quartzite.
211	10	10	N	5	N	50	20	200	Bb	Green quartzite.
111	N	10	20	L	N	20	10	20	C	Silty dolomite.
124	L	15	N	5	N	50	30	150	C	Argillitic dolomite.
<u>Wallace Formation</u>										
004	N	5	N	7	N	50	20	150	C	Black silty argillite.
005	L	20	N	10	N	50	30	100	C	Waxy green argillite.
008	N	15	N	10	N	70	20	100	C	Green silty argillite.
012	10	20	N	10	N	50	20	100	C	Black silty argillite.
013	L	15	N	7	N	50	15	100	C	Waxy green argillite.

TABLE 3.—*Semiquantitative spectrographic analyses*

Sample	(percent)				(ppm)							
	Fe (.05)	Mg (.01)	Ca (.05)	Ti (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La (20)
<u>Wallace Formation--Continued</u>												
039	3.0	5.0	7.0	0.15	500	30	500	1.0	10	30	15	50
051	2	2	.15	.2	70	150	300	L	10	50	5	20
057	2	1.5	L	.5	15	100	500	1.5	10	70	10	50
058	2	1	L	.5	100	100	500	1.5	5	50	20	50
059	3	1	.05	.5	70	70	300	1	7	50	5	50
061	2	1	.07	.2	20	50	500	L	7	50	7	50
094	3	1.5	L	.3	30	500	200	L	5	70	7	30
096	3	5	7	.3	700	150	700	1.5	10	50	20	50
151	3	3	.07	.2	50	100	500	3	7	20	20	50
168	3	5	.1	.3	50	70	500	2	10	30	L	50
180	3	1	.07	.3	70	50	500	1.5	7	20	20	100
186	2	1	.05	.3	150	50	300	1.5	7	70	7	50
187	2	1.5	.07	.2	100	30	300	1	7	30	30	50
188	2	.5	.05	.2	50	20	150	L	5	30	30	20
197	2	1.5	.15	.3	70	70	700	3	5	30	30	70
207	3	1.5	.07	.2	30	50	700	2	L	50	20	50
115	3	3	.05	.5	70	200	500	1.5	L	70	20	50
175	1.5	3	5	.2	300	50	700	3	N	7	L	50
206	3	.7	.05	.3	150	50	500	2	7	50	30	150
001	1.5	.7	.05	.15	50	30	300	1	10	30	5	50
052	2	1	.05	.2	20	20	300	N	15	15	20	30
054	3	.5	.1	.3	100	30	200	1.5	7	30	15	30
056	2	1.5	.1	.2	30	30	300	L	L	30	7	20
143	1	3	7	.2	150	50	700	1	N	15	15	30
166	1.5	3	7	.2	70	30	700	1.5	5	15	300	70
190	2	5	7	.2	300	70	700	1	5	50	L	50
192	5	1	.07	.2	300	30	150	L	10	20	30	30
162	2	3	1.5	.2	150	50	500	1.5	5	20	15	50
201	1.5	.2	.07	.3	50	30	150	1	L	30	10	70
204	2	1.5	.05	.2	20	30	500	1.5	N	15	10	50
205	5	1	.07	.5	200	50	300	2	10	50	30	100
146	.5	.5	10	.15	300	15	500	L	L	15	7	30
003	.5	.3	1.5	.15	70	15	500	L	L	20	7	50
002	1	3	20	.1	500	20	300	L	5	30	7	50
038	2	5	>20	.1	1,000	30	500	5	7	30	20	30
053	5	5	10	.3	3,000	50	200	L	7	50	30	30
060	1.5	5	10	.2	500	30	700	L	5	30	L	30
079	1	>10	>20	.07	1,000	50	50	N	N	10	L	N
104	.7	>10	20	.05	1,500	50	200	L	N	7	L	L
144	1.5	3	10	.2	500	70	300	1.5	5	30	7	30
147	3	10	10	.1	1,000	70	200	1	L	15	N	50
165	1.5	5	20	.15	300	50	700	1	5	15	7	30
<u>St. Regis Formation</u>												
006	3	2	.07	.2	70	30	700	L	10	50	L	70
046	3	1.5	2	.2	1,000	30	700	1.5	7	50	L	50
152	3	2	.1	.5	50	70	500	1.5	7	20	L	50
169	3	2	.07	.5	30	100	500	2	5	50	10	70
193	2	.5	.05	.2	30	30	300	1	7	50	10	50
195	3	1.5	.5	.3	200	70	700	2	7	50	L	70
176	3	1.5	.1	.5	300	70	700	3	10	30	L	70
007	.7	.5	.15	.15	100	15	300	N	L	15	L	20
084	3	3	.1	.3	300	70	700	1.5	10	50	30	50
153	3	.5	.2	.3	300	30	500	1	L	20	20	L

See footnotes at end of table.

## of Belt rocks from the Pend Oreille area—Continued

Sample	(ppm)							Metamorphic Grade	Sample description	
	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)			Zr (10)
<u>Wallace Formation--Continued</u>										
039	L	20	10	7	N	50	20	150	C	Dolomitic silty argillite.
051	N	30	20	10	N	50	15	150	C	Black silty argillite.
057	L	30	15	10	N	70	30	200	C	Do.
058	10	30	15	10	N	70	30	200	C	Do.
059	L	30	N	7	N	70	50	300	C	Do.
061	L	30	N	7	N	50	30	150	C	Do.
094	L	20	15	10	N	70	30	150	C	Do.
096	L	20	N	7	N	70	30	150	C	Dolomitic silty argillite.
151	10	20	N	10	N	70	30	150	C	Waxy green argillite.
168	L	20	N	10	N	70	30	150	C	Do.
180	10	30	L	10	N	70	30	150	C	Black silty argillite.
186	10	30	N	10	N	70	30	150	C	Do.
187	L	20	20	10	N	70	30	150	C	Do.
188	L	20	N	7	N	70	20	150	C	Do.
197	10	20	10	15	N	70	30	150	C	Waxy green argillite.
207	10	30	10	10	N	70	30	150	C	Black silty argillite.
115	10	10	L	10	N	70	30	200	Bb	Do.
175	15	5	N	7	N	50	50	150	Bb	Dolomitic silty argillite.
206	10	20	N	10	N	70	30	150	Bb	Black silty argillite.
001	N	30	L	7	N	50	30	150	C	Argillitic siltite.
052	N	30	15	L	N	20	15	100	C	White siltite.
054	L	30	N	10	N	70	30	200	C	Argillitic siltite.
056	L	30	N	7	N	50	20	150	C	Do.
143	L	15	10	7	N	50	20	150	C	Calcareous siltite.
166	L	20	N	7	N	50	30	150	C	Dolomitic argillitic siltite.
190	L	20	N	10	N	70	30	100	C	Do.
192	10	30	L	7	N	50	30	150	C	Argillitic siltite.
162	L	30	L	7	N	70	30	150	Bb	Calcareous siltite.
201	L	10	20	10	N	50	30	300	Bb	Green siltite.
204	10	20	10	7	N	50	20	150	Bb	Do.
205	10	30	L	15	N	70	30	150	Bb	Do.
146	L	L	10	L	100	20	30	100	C	Calcareous silty quartzite.
003	N	L	L	5	N	20	10	150	Bb	Calcareous quartzite.
002	N	15	N	7	150	30	30	50	C	Molar tooth limestone.
038	L	15	N	5	300	30	20	30	C	Do.
053	N	20	L	7	N	50	30	200	C	Stromatolite.
060	L	20	N	5	100	30	20	100	C	Silty dolomite.
079	N	L	15	L	N	30	15	30	C	Do.
104	N	L	N	N	N	10	10	50	C	Stromatolite.
144	L	15	70	7	L	70	20	150	C	Molar tooth limestone.
147	L	15	N	5	100	50	30	50	C	Argillitic dolomite.
165	N	15	50	5	150	50	20	50	C	Molar tooth limestone.
<u>St. Regis Formation</u>										
006	L	15	N	7	N	50	30	100	C	Purple argillite.
046	10	20	L	7	N	70	30	150	C	Do.
152	L	20	N	10	N	70	30	150	C	Do.
169	L	20	N	10	N	70	30	150	C	Do.
193	L	20	N	7	N	70	30	150	C	Do.
195	10	30	N	10	N	70	30	150	C	Purple silty argillite.
176	15	30	L	10	N	70	50	200	Bb	Do.
007	N	10	N	L	N	20	10	70	C	Purple argillitic siltite.
084	L	20	30	10	N	70	30	200	C	Green argillitic siltite.
153	10	10	L	7	N	50	30	200	C	Purple argillitic siltite.

TABLE 3.—*Semiquantitative spectrographic analyses*

Sample	(percent)				(ppm)							
	Fe (.05)	Mg (.01)	Ca (.05)	Ti (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La (20)
<u>St. Regis Formation--Continued</u>												
170	1.5	1.5	1.5	0.2	200	30	300	1.0	L	15	7	50
194	1.5	1.5	2	.2	1,000	30	300	1	5	20	10	50
196	2	1.5	.07	.2	50	30	300	1.5	7	15	20	50
047	1.5	2	1	.2	300	30	300	1	7	30	15	50
163	5	1.5	.15	.3	50	50	500	2	7	50	5	100
184	1.5	3	.1	.3	100	200	150	1.5	5	15	L	50
<u>Revelt Formation</u>												
009	1.5	1	.07	.2	70	20	300	1	10	30	L	20
043	1	.15	L	.5	50	100	300	1	L	30	L	50
048	1	.3	L	.3	20	30	300	1.5	L	30	5	50
171	3	.3	.07	.3	20	20	500	2	L	20	L	30
091	1	.3	.05	.2	200	15	300	1.5	L	15	7	30
174	2	.7	.05	.5	15	30	700	3	N	30	L	50
181	.7	.3	L	.3	20	L	150	1	N	7	N	50
010	1	.07	L	.2	50	15	300	L	N	15	5	50
042	.7	.05	N	.3	100	30	150	1.5	N	20	L	20
050	.7	.07	1	.1	700	15	150	L	L	7	30	30
090	.3	.07	L	.15	30	10	300	L	N	5	L	30
203	.3	.1	L	.05	15	L	200	L	N	7	L	L
087	1	.3	.05	.15	70	10	300	1	7	7	5	30
158	.5	.07	L	.15	20	L	150	L	N	5	5	50
173	.5	.1	.05	.15	50	10	200	1	N	5	5	20
182	.3	.15	L	.2	30	10	150	L	N	5	5	50
200	.2	.05	N	.15	20	10	300	L	N	5	15	50
<u>Burke Formation</u>												
086	3	.7	.15	.5	300	50	700	2	10	50	L	70
149	3	1.5	.05	.7	100	30	700	2	15	50	5	70
210	2	.7	.05	.3	150	30	700	3	7	50	15	70
150	2	.2	.05	.3	70	15	200	7	5	15	5	30
177	2	.2	.07	.5	200	20	700	1.5	5	15	15	50
041	2	.7	.1	.2	300	20	500	1	10	30	7	50
045	1.5	.1	.07	.2	70	15	200	1	5	20	5	30
049	1	.3	.05	.15	70	15	300	L	5	20	5	30
089	3	.7	.07	.2	500	20	300	1	10	30	10	30
092	1	.15	.15	.15	300	15	300	1.5	5	15	5	50
093 2/	3	1	.05	.3	500	30	700	7	10	30	30	50
133	2	.7	1	.2	700	15	150	L	5	15	7	50
148	2	1	.15	.5	200	20	500	1.5	10	20	L	50
155	2	.5	1.5	.3	500	15	500	2	7	20	L	70
161	1.5	.3	.15	.2	500	15	700	1	5	10	15	20
198	2	.5	L	.5	70	30	500	2	7	50	5	50
199	1.5	.2	.07	.2	100	20	300	1	5	10	7	50
209	2	.7	.05	.3	150	20	500	1.5	7	30	10	50
<u>Prichard Formation</u>												
040	3	.7	.05	.2	300	30	500	1.5	L	30	5	30
131	3	1	L	.5	300	50	700	10	N	70	10	50
183	1.5	.3	.05	.2	15	20	500	3	5	7	20	70
017 2/	3	.7	.15	.3	300	15	300	L	20	50	50	30
020	3	1	.05	.5	300	30	700	1.5	15	70	7	100
021	2	.7	.05	.3	300	20	500	1	7	30	20	70
023	1.5	1	.2	.2	200	10	500	L	7	30	10	30
026	2	1	.07	.3	200	30	700	1.5	7	30	5	70
031	3	1	.07	.3	300	15	700	1	7	50	L	70
034	3	1.5	.7	.3	500	15	500	1.5	5	70	7	70

See footnotes at end of table.

*of Belt rocks from the Pend Oreille area—Continued*

Sample	(ppm)							Zr (10)	Metamorphic Grade	Sample description
	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)			
<u>St. Regis Formation--Continued</u>										
170	L	10	N	5	N	50	30	150	C	Dolomitic purple siltite.
194	L	20	N	7	N	50	30	150	C	Do.
196	10	20	N	7	N	50	20	150	C	Purple argillitic siltite.
047	L	15	N	7	N	30	30	150	Bb	Dolomitic purple siltite.
163	10	30	N	15	N	100	50	200	Bb	Purple argillitic siltite.
184	L	20	N	7	N	70	30	150	Bb	Waxy green argillitic siltite.
<u>Revett Formation</u>										
009	L	15	N	7	N	50	15	100	C	Green argillitic siltite.
043	10	7	N	7	N	50	30	200	C	Do.
048	L	5	N	10	N	30	50	1,000	C	Do.
171	10	20	N	7	N	70	30	300	C	Green siltite.
091	L	5	N	5	N	20	20	150	Bb	Do.
174	10	L	N	15	N	70	30	700	Bb	Do.
181	10	L	N	7	N	30	20	1,000	Bb	Do.
010	N	N	N	L	N	10	15	300	C	Purple streaked quartzite.
042	L	L	N	7	N	20	20	>1,000	C	White quartzite.
050	N	L	N	L	N	10	20	300	C	Calcareous quartzite.
090	L	L	N	L	N	10	10	150	C	White quartzite.
203	N	L	N	L	N	L	15	100	C	Do.
087	N	15	L	L	N	30	15	150	Bb	Do.
158	L	N	N	L	N	30	30	500	Bb	Do.
173	L	L	N	N	N	30	20	700	Bb	Purple streaked quartzite.
182	L	L	N	L	N	20	20	200	Bb	White quartzite.
200	L	L	N	L	N	15	20	1,000	Bb	Do.
<u>Burke Formation</u>										
086	10	30	10	10	N	70	30	150	Bb	Gray silty argillite
149	15	30	N	10	N	70	50	300	Bb	Do.
210	10	20	N	10	N	70	30	150	Bb	Do.
150	L	15	N	5	N	50	30	150	C	Purple streaked siltite.
177	L	10	N	7	N	70	30	150	C	Gray argillitic siltite.
041	L	10	L	7	N	30	30	150	Bb	Do.
045	L	5	N	5	N	30	20	150	Bb	Purple streaked siltite.
049	N	10	N	5	N	20	20	200	Bb	Gray argillitic siltite.
089	N	20	10	5	N	30	15	150	Bb	Do.
092	L	L	L	5	L	30	15	150	Bb	Purple streaked siltite.
093	L	30	30	10	N	70	30	150	Bb	Gray-green argillitic siltite.
133	L	L	L	5	L	50	30	200	Bb	Gray argillitic siltite.
148	15	20	N	7	N	70	30	300	Bb	Do.
155	10	7	N	10	L	50	30	200	Bb	Do.
161	10	15	10	5	N	50	30	150	Bb	Purple and green siltite.
198	10	20	N	10	N	50	20	150	Bb	Purple argillitic siltite.
199	L	20	L	5	N	50	20	150	Bb	Do.
209	10	20	N	7	N	50	30	150	Bb	Gray-green argillitic siltite.
<u>Prichard Formation</u>										
040	10	L	10	7	N	50	20	150	C	Black and white argillite.
131	10	L	30	15	N	100	30	150	C	Do.
183	L	15	N	5	N	30	30	150	C	Do.
017	L	30	20	7	N	50	15	100	Bb	Gray pyrrhotitic argillite.
020	15	20	L	15	N	100	30	150	Bb	Do.
021	L	10	15	7	N	70	30	100	Bb	Black and white argillite.
023	L	20	15	7	N	50	15	70	Bb	Pyrrhotitic silty argillite.
026	15	15	15	10	N	50	30	150	Bb	Gray silty argillite.
031	L	15	10	15	N	70	30	100	Bb	Spotted silty argillite.
034	L	7	15	10	200	70	30	150	Bb	Do.

TABLE 3.—*Semiquantitative spectrographic analyses*

Sample	(percent)				(ppm)							
	Fe (.05)	Mg (.01)	Ca (.05)	Ti (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La (20)
Prichard Formation--Continued												
035	3.0	1.0	0.2	0.5	300	15	700	L	10	70	L	70
037	3	.7	L	.2	200	15	700	1	7	30	7	30
085	3	.7	.05	.3	300	20	500	1	10	30	20	50
132	3	1	.15	.5	500	50	700	2	15	70	10	70
135	3	.7	.3	.5	500	30	700	3	10	50	10	50
136	5	.7	.07	.5	300	30	700	2	5	50	20	30
137	3	.7	.15	.5	500	30	700	2	10	30	5	50
138	2	.5	.07	.3	300	30	500	2	L	20	7	30
139	3	1	.07	.5	300	100	500	3	10	50	30	50
140	3	.7	.07	.5	300	100	700	3	10	70	20	70
141	3	1	.05	.5	300	70	500	2	L	50	15	50
154	3	.7	.07	.3	300	30	700	2	7	50	20	50
157	3	.7	.1	.3	300	30	700	3	10	50	15	70
159	3	.7	.07	.7	300	50	700	2	10	50	20	70
160	1.5	.7	.05	.2	150	15	700	2	5	15	L	20
164	3	1	.07	.5	300	30	700	1.5	7	50	20	70
172	3	1.5	.05	.5	300	20	700	3	L	70	15	70
179	3	.7	.07	.7	300	50	700	2	7	50	15	30
185	1.5	1	.07	.3	200	20	300	1.5	5	30	15	30
208	3	.7	.05	.5	200	30	700	2	10	70	15	70
216	2	.2	.5	.2	200	L	500	1.5	5	15	20	50
218	2	.7	.3	.3	500	15	500	1.5	L	50	20	70
220	3	.7	.1	.3	300	70	500	1	7	50	20	70
222	3	.5	.3	.3	300	30	700	2	10	50	30	70
228	3	.5	L	.3	150	10	500	1	L	50	15	50
229	2	.5	L	.2	20	30	700	1	N	50	30	50
230	3	.7	.05	.3	300	50	700	1.5	7	50	20	70
233	3	.7	.05	.5	300	15	500	3	N	70	20	30
234	3	.3	.05	.3	50	10	500	2	N	50	15	50
236	2	.7	.1	.5	300	15	700	2	L	70	20	20
215	3	.7	.15	.3	300	15	700	1	L	50	30	50
217	1.5	.3	.2	.2	200	15	300	1.5	5	15	30	50
219	3	.7	.2	.3	300	15	500	1.5	7	50	10	70
226	1.5	.2	.3	.2	100	10	200	1.5	L	10	15	50
227	1	.2	.2	.15	150	10	300	1.5	N	10	7	30
232	3	1	.07	.3	300	30	500	3	L	50	20	N
248	3	.5	.2	.5	300	20	500	1.5	5	50	7	70
249	5	1	.15	.7	500	20	700	1.5	7	70	30	70
251	3	.7	.15	.3	300	20	700	1.5	N	50	20	70
252	1	.3	.3	.2	200	10	700	L	10	30	20	30
255	3	1.5	2	.7	700	L	300	1	15	100	20	70
256	2	1	.15	.5	300	10	700	1	L	70	15	50
257	2	.5	.3	.2	200	20	700	1.5	L	70	10	50
258	1.5	.5	1	.3	200	L	500	1.5	L	30	10	50
259	3	.7	.7	.3	300	10	500	1.5	L	50	15	30
260	2	.5	.7	.3	200	30	500	1.5	N	30	10	50
261	3	.7	.05	.5	300	30	500	1.5	5	70	30	50
130	3	.7	.3	.2	300	20	500	1.5	10	20	15	50
014	3	.7	.05	.3	200	30	500	L	15	30	30	50
015	3	.5	.07	.3	150	L	500	1	10	50	L	50
019	1.5	.3	.07	.2	200	15	300	1.5	7	30	10	50
025	3	1.5	.5	.2	300	30	500	2	10	30	50	50
028	2	.7	.05	.2	150	L	300	L	N	30	5	30
029	1	.3	.07	.15	100	L	300	L	N	15	7	L
036	1.5	.5	.1	.15	200	L	300	L	L	20	10	30
142	2	.7	.1	.2	200	30	200	1	7	15	20	30
214	.7	.5	1.5	.2	100	15	70	2	N	20	10	30
225	.5	.2	.15	.1	100	L	500	N	N	5	7	20
250	.7	.15	.2	.2	200	20	300	1	L	20	7	50
262	.7	.2	.1	.2	100	15	500	1.5	N	20	5	30

See footnotes at end of table.



*of Belt rocks from the Pend Oreille' area—Continued*

Sample	(ppm)								Metamorphic Grade	Sample description
	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)	Zr (10)		
<u>Prichard Formation--Continued</u>										
035	L	15	10	15	L	70	30	150	Bb	Argillite with andalusite.
037	10	7	N	7	N	50	20	150	Bb	Gray pyrrhotitic argillite.
085	L	20	10	7	N	70	30	150	Bb	Black and white argillite.
132	15	30	30	15	N	70	30	150	Bb	Do.
135	L	20	10	10	L	100	30	150	Bb	Slaty black argillite.
136	L	15	L	15	N	100	20	150	Bb	Gray argillite.
137	10	20	10	10	N	70	30	200	Bb	Do.
138	10	L	N	7	L	70	20	150	Bb	Slaty black argillite.
139	L	30	L	15	N	70	30	150	Bb	Black and white argillite.
140	L	30	L	15	N	70	30	150	Bb	Do.
141	10	L	L	10	N	70	30	200	Bb	Slaty black argillite.
154	10	20	10	10	N	70	30	150	Bb	Black and white argillite.
157	10	30	L	15	N	70	50	150	Bb	Do.
159	10	30	20	15	N	100	50	150	Bb	Do.
160	L	15	L	7	N	70	20	150	Bb	Spotted black argillite.
164	L	30	L	15	N	70	30	150	Bb	Black and white argillite.
172	10	5	L	15	N	100	30	100	Bb	Spotted black argillite.
179	15	20	L	10	N	70	30	150	Bb	Black and white argillite.
185	10	20	50	10	N	70	30	150	Bb	Spotted black argillite.
208	15	20	N	15	N	70	30	150	Bb	Black and white argillite.
216	10	10	L	7	L	50	30	150	Bb	Do.
218	10	L	10	10	L	70	30	150	Bb	Do.
220	10	15	L	15	N	70	30	150	Bb	Do.
222	10	30	10	15	N	70	30	150	Bb	Do.
228	L	7	L	10	N	70	30	100	Bb	Do.
229	L	L	10	7	N	70	30	150	Bb	Do.
230	10	15	N	10	N	50	30	150	Bb	Gray argillite.
233	15	L	L	10	N	70	30	150	Bb	Black and white argillite.
234	10	5	N	10	N	70	30	150	Bb	Do.
236	10	L	15	15	N	70	30	150	Bb	Do.
215	10	7	L	15	N	70	30	150	Bgn	Schistose argillite.
217	10	7	L	7	N	50	30	150	Bgn	Gneissic argillite.
219	10	15	L	10	N	70	30	150	Bgn	Schistose argillite.
226	L	L	N	5	N	30	30	150	Bgn	Gneissic argillite.
227	L	5	N	7	100	30	20	150	Bgn	Do.
232	15	5	15	10	N	70	30	150	Bgn	Do.
248	L	L	L	10	L	70	30	150	Bgn	Black and white gneiss.
249	10	15	30	15	L	70	50	150	Bgn	Black and white schist.
251	L	L	L	10	L	70	30	150	Bgn	Coarse mica schist.
252	L	20	L	7	L	50	20	150	Bgn	Coarse mica gneiss.
255	10	50	15	15	500	70	50	200	Bgn	Biotite gneiss.
256	10	L	15	15	L	70	30	150	Bgn	Black and white schist.
257	L	L	10	7	100	70	30	150	Bgn	Gneissic argillite.
258	10	5	L	7	300	50	30	150	Bgn	Gneissic silty argillite.
259	L	5	N	10	150	70	30	150	Bgn	Schistose argillite.
260	10	L	L	10	100	70	30	150	Bgn	Gneissic argillite.
261	10	10	N	15	N	70	30	150	Bgn	Schistose argillite.
130	10	20	10	7	L	70	50	150	C	Gray argillitic siltite.
014	L	30	L	7	N	50	20	150	Bb	Gray siltite.
015	L	15	N	7	N	50	30	150	Bb	Dark gray siltite.
019	L	10	L	5	N	30	20	150	Bb	Gray argillitic siltite.
025	L	30	20	7	N	50	30	150	Bb	Gray pyrrhotitic siltite.
028	L	L	10	7	N	50	20	150	Bb	Spotted siltite.
029	L	L	L	5	N	30	15	150	Bb	Do.
036	L	L	L	5	N	30	20	150	Bb	Salt and pepper siltite.
142	L	20	15	5	N	50	20	100	Bb	Black and white siltite.
214	10	L	L	5	200	50	30	150	Bgn	Gneissic siltite.
225	L	L	20	L	N	15	15	150	Bgn	Do.
250	L	L	L	5	200	30	30	700	Bgn	Do.
262	L	L	L	7	N	50	30	150	Bgn	Do.

TABLE 3.—*Semiquantitative spectrographic analyses*

Sample	(percent)				(ppm)							
	Fe (.05)	Mg (.01)	Ca (.05)	Tl (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La (20)
Prichard Formation--Continued												
263	1.0	0.2	0.15	0.2	100	10	300	1.5	L	15	7	30
016	.7	.2	.15	.15	100	10	200	L	5	20	L	30
018	.7	.1	1	.2	300	L	200	10	L	20	10	70
024	1	.2	.3	.2	300	10	200	1	N	20	7	30
027	1	.2	L	.15	70	L	200	N	5	20	7	30
030	.7	.2	.5	.2	200	L	200	1	N	20	5	50
032	.7	.1	1.5	.15	300	L	70	L	N	10	L	30
221	1	.2	.15	.2	200	10	300	1	N	10	15	50
237	1	.3	.2	.2	200	10	500	1	5	30	20	50
212	.7	.3	1.5	.15	150	L	100	1	N	15	7	50
231	.5	.1	.3	.15	150	L	70	1	N	20	30	30
254	.7	.5	1.5	.1	200	L	70	3	L	20	L	50
223 <sup>1/</sup>	15	.1	20	.03	>5,000	N	20	N	15	5	15	N
253 <sup>2/</sup>	5	.5	>20	.1	>5,000	L	L	3	10	20	20	30

1/ Reported as L(5) for Mo.

2/ Reported as L(200) for Zn.

3/ Contains 0.7 ppm Ag.

4/ Contains 20 ppm Mo, 0.7 ppm Ag, and 10 ppm Bi.

*of Belt rocks from the Pend Oreille area—Continued*

Sample	(ppm)								Metamorphic Grade	Sample description
	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)	Zr (10)		
Prichard Formation--Continued										
263	L	15	N	5	N	30	20	150	Bgn	Gneissic siltite.
016	N	L	L	L	L	20	15	150	Bb	White silty quartzite.
018	L	L	10	5	200	30	30	150	Bb	Gray green quartzite.
024	L	5	15	5	L	20	15	150	Bb	Do.
027	N	10	N	L	N	20	15	100	Bb	Salt and pepper quartzite.
030	10	L	10	5	L	20	30	150	Bb	Gray green quartzite.
032	L	L	N	L	N	15	15	200	Bb	Do.
221	L	L	L	5	N	30	20	150	Bb	Do.
237	10	10	L	7	L	50	30	150	Bb	Do.
212	L	L	N	L	N	20	20	150	Bgn	Gneissic quartzite.
231	L	L	L	5	L	30	20	500	Bgn	Biotitic quartzite.
254	L	7	L	L	L	30	20	200	Bgn	Quartz gneiss.
223	L	20	N	L	N	700	30	N	Bgn	Skarn.
253	10	7	N	7	N	70	30	150	Bgn	Do.

5j Contains 5 ppm Mo.

6j Contains 7 ppm Mo.

7j Contains 15 ppm Sn.

8j Contains 200 ppm Zn and 15 ppm Sn.

TABLE 4.—*Replicate semiquantitative spectrographic*

[Number in parentheses indicates sensitivity limit of method used. L, undetermined amount of for but not found in any sample were As(200), Au(10), Cd(20), Sb(100), Sn(10), W(50), N(10) for Bi, and N(5) for Mo. D. J. Grimes, analyst]

Sample	(percent)								
	Fe (.05)	Mg (.01)	Ca (.05)	Ti (.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Cc (5)
001	1.5	0.7	0.05	0.15	50	30	300	1.0	10
011	2	1.5	.05	.3	70	70	500	1.5	15
012	3	1.5	L	.2	70	50	300	1	10
022	3	1.5	.05	.3	100	50	500	1.5	10
023	1.5	1	.2	.2	200	10	500	L	7
033	3	1.5	.5	.15	300	15	500	L	10
034	3	1.5	.7	.3	500	15	500	1.5	5
044	3	1	.5	.3	300	15	300	1	5
045	1.5	.1	.07	.2	70	15	200	1	5
055	1.5	.1	.05	.2	50	15	200	L	5
056	2	1.5	.1	.2	30	30	300	L	L
066	2	1.5	.1	.3	20	20	300	L	N
067	3	1.5	.07	.3	15	150	700	1.5	L
077	3	2	.07	.3	20	300	700	2	5
078	1.5	3	.1	.2	50	70	300	1.5	7
088	2	2	.1	.2	50	70	500	1.5	7
089	3	.7	.07	.2	500	20	300	1	10
099	2	.7	.07	.2	300	20	500	1	10
091	1	.3	.05	.2	200	15	300	1.5	L
101	.7	.2	L	.15	150	10	200	1	L
102	3	1.5	.07	1	15	300	700	2	5
112	5	1.5	.07	1	15	500	700	3	5
113	3	1.5	.05	.3	15	100	500	1.5	5
123	5	3	.15	.7	50	200	700	2	7
124 <sup>1/</sup>	2	10	20	.15	5,000	500	500	L	L
134 <sup>2/</sup>	1.5	7	20	.15	3,000	700	300	L	N
135	3	.7	.3	.5	500	30	700	3	10
145	3	1.5	.5	.5	500	50	700	2	10
146	.5	.5	10	.15	300	15	500	L	L
156	.5	.3	15	.15	300	10	500	L	L
157	3	.7	.1	.3	300	30	700	3	10
167	3	1	.1	.3	300	30	700	2	10
168	3	5	.1	.3	50	70	500	2	10
178	3	3	.07	.5	50	50	500	2	7
179	3	.7	.07	.7	300	50	700	2	7
189	3	.7	.07	.3	300	30	700	1.5	5
181	.7	.3	L	.3	20	L	150	1	N
191	.7	.3	.05	.2	15	L	150	L	L
192	5	1	.07	.2	300	30	150	L	10
202	5	1	.07	.2	300	30	150	1	10
203	.3	.1	L	.05	15	L	200	L	N
213	.3	.07	L	.05	70	10	150	L	N
214	.7	.5	1.5	.2	100	15	70	2	N
224	.5	.3	.7	.15	100	L	50	1.5	N
225	.5	.2	.15	.1	100	L	500	N	N
235	.7	.3	.2	.2	200	L	500	L	N

<sup>1/</sup> Reported as 0.7 ppm Ag, 10 ppm Bi, and 20 ppm Mo.

*analyses of Belt rocks from the Pend Oreille area*

element present below sensitivity limit; N, element was looked for but not found. Also looked and Zn(200). Except as indicated by footnotes, all samples were reported as N(0.5) for Ag,

Sample	(ppm)										
	Cr (5)	Cu (2)	La (20)	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)	Zr (10)
001	30	5	50	N	30	L	7	N	50	30	150
011	30	7	70	N	30	L	10	N	70	30	150
012	50	30	50	10	20	N	10	N	50	20	100
022	70	50	70	15	30	L	10	N	70	30	150
023	30	10	50	L	20	15	7	N	50	15	70
033	30	15	30	L	30	15	7	N	50	20	150
034	70	7	70	L	7	15	10	200	70	30	150
044	50	5	70	10	10	15	10	150	70	30	100
045	20	5	30	L	5	N	5	N	30	20	150
055	15	5	30	L	5	N	5	N	30	20	150
056	30	7	20	L	30	N	7	N	50	20	150
066	20	5	20	L	20	N	7	N	50	20	150
067	50	L	50	L	10	L	10	N	70	30	200
077	70	L	50	10	15	N	15	N	70	30	200
078	30	L	30	10	20	N	7	N	50	30	150
088	30	L	50	L	20	N	5	N	50	30	150
089	30	10	30	N	20	10	5	N	30	15	150
099	30	15	30	L	30	15	5	N	50	20	150
091	15	7	30	L	5	N	5	N	20	20	150
101	15	L	20	L	5	N	5	N	30	15	100
102	50	L	50	L	7	N	15	N	70	50	200
112	50	L	70	10	30	L	15	N	70	50	200
113	70	7	50	10	15	L	7	N	70	30	200
123	100	7	70	10	20	N	15	N	100	70	300
124	30	3,000	30	L	15	N	5	N	50	30	150
134	20	3,000	30	L	15	L	L	N	50	30	100
135	50	10	50	L	20	10	10	L	100	30	150
145	50	10	70	10	30	10	10	L	70	30	150
146	15	7	30	L	L	10	L	100	20	30	100
156	15	5	50	L	L	L	5	L	20	30	100
157	50	15	70	10	30	L	15	N	70	50	150
167	50	20	70	10	30	10	10	N	100	50	150
168	30	L	50	L	20	N	10	N	70	30	150
178	50	N	70	10	20	N	10	N	70	30	150
179	50	15	30	15	20	L	10	N	70	30	150
189	30	10	20	10	20	L	10	N	70	30	150
181	7	N	50	10	L	N	7	N	30	20	1,000
191	7	15	50	L	L	N	5	N	20	20	700
192	20	30	30	10	30	L	7	N	50	30	150
202	30	30	50	10	30	L	10	N	70	30	200
203	7	L	L	N	L	N	L	N	L	15	100
213	5	7	30	L	L	N	N	N	15	15	100
214	20	10	30	10	L	L	5	200	50	30	150
224	7	7	30	L	L	L	5	100	20	20	150
225	5	7	20	L	L	20	L	N	15	15	150
235	20	15	20	L	L	15	L	N	50	20	150

2/ Reported as 0.7 ppm Ag, 10 ppm Bi, and 15 ppm Mo.

Precision of the sampling and analytical technique was measured by analysis of blind replicates of every eleventh sample from the Pend Oreille area. The replicate samples, which include a range of element concentrations, were taken from a 1-pint crushed control sample representing a split of the 2-pound or larger sample collected of a given rock type. The precision thus includes errors in sampling as well as errors inherent in the preparation and analysis of each sample. Analytical results on the 23 pairs of replications are given in table 4.

Analytical precision is shown graphically in figure 4. The solid bars show the number of replicate samples having identical analyses for a given element; the open bars show the number of replicate samples differing by one or more steps in the reported results. Step differences were determined by comparing values from the first split with those from the second. Values reported as N (no line seen for the elements) and L (element present in an amount less than the sensitivity limit) were arbitrarily counted as two and one steps below the limit of sensitivity, respectively, for purposes of comparison. However, a pair of N's was excluded as a valid measure of similarity. For elements having a relatively high limit of sensitivity (*many reported N's or L's*), these arbitrary comparisons will tend to result in an artificially high precision. Such elements as Pb and Sr are particularly suspect in this regard. The precision of Nb and Co and perhaps of Be, Ni, and Cu should also be viewed with caution.

The remaining elements exhibit quite satisfactory precisions in that more than 80 percent of the comparisons fall within plus or minus one step. Of particular interest, however, is the occasional large difference reported for replicates of Mn, Cr, Cu, and Ni. To the extent that such disparity is not due strictly to analytical imprecision, it may be due to the particulate character of small amounts of minerals containing those elements in the sample. Such errors then, may reflect sample inhomogeneity which, in turn, may provide clues for interpretation of element distributions in these rocks.

One factor aids in maintaining high precision for the spectrographic method. A split of sample G-1 was shot on each plate as a reference standard. If the G-1 values were not sufficiently close to the known values, then that plate was discarded and another made. Values of G-1 for 12 plates used for the Pend Oreille samples are given in table 5. If we assume that the bottle of G-1 used as the reference standard in this study was an exact duplicate of the original G-1, then table 5 can be used by other workers to estimate accuracy of the reported values. The table also shows that our selected use of N and L in the calculations for table 4 is reasonable, considering the "best value" content of elements in G-1 that are below the sensitivity limit of the method we used. In other words, L on table 5 is reported for elements whose true value is about one reporting step below the sensitivity limit, and N is reported for elements more than one step

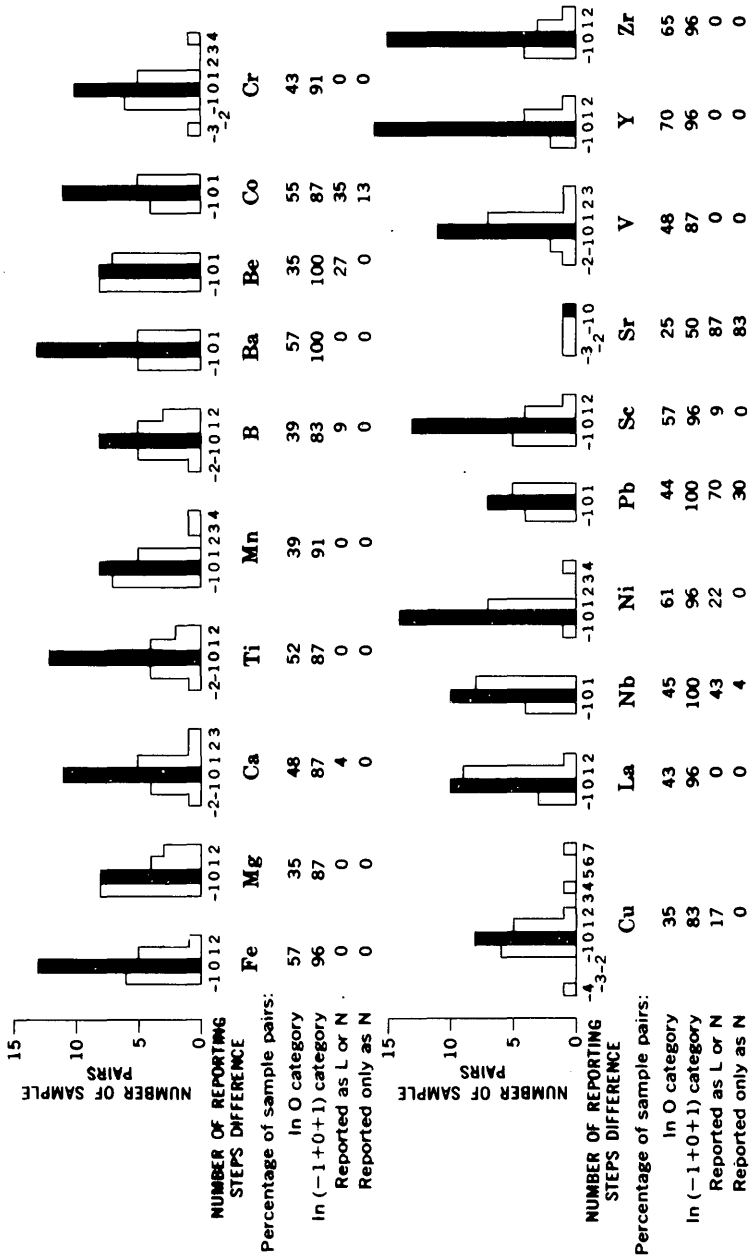


FIGURE 4.—Precision of semiquantitative spectrographic analyses of some Belt rocks based on splits of the outcrop sample. Solid bar, number of replicate samples having identical analyses; N, no line seen for element; L, element present in an amount less than the sensitivity limit.

TABLE 5.—*Replicate analyses of standard sample G-1*

[Number in parentheses indicates sensitivity limit of method used. L, an undetermined amount of the element is present below the sensitivity limit; N, the element was looked for but not found]

Percent		Parts per million																		
Fe (0.05)	Mg (0.01)	Ca (0.05)	Ti (0.001)	Mn (10)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (5)	Cu (2)	La <sup>a</sup> (20)	Nb (10)	Ni (2)	Pb (10)	Sc (5)	Sr (50)	V (10)	Y (5)	Zr (10)	
<b>G-1, "Best value" (Fleischer, 1965) of original splits</b>																				
1.5	0.2	0.7	0.15	150	N	700	1.5	N	20	20	100	10	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	1	N	20	20	100	10	L	50	L	300	15	15	150	
1.5	.2	.5	.15	100	N	700	1	N	15	15	100	15	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	1.5	N	20	20	100	10	L	50	L	300	20	15	150	
1.5	.2	.5	.15	150	N	700	1.5	N	20	15	100	10	L	30	L	300	15	10	150	
1.5	.2	.7	.15	150	N	700	2	N	30	20	100	15	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	1.5	N	15	15	100	15	L	50	L	300	15	10	150	
1.5	.2	.7	.15	150	N	700	1.5	N	20	20	100	15	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	1	N	20	15	100	10	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	2	N	20	30	100	10	L	50	L	300	15	15	150	
1.5	.2	.7	.15	150	N	700	1.5	N	20	20	100	10	L	50	L	200	15	15	150	
1.5	.2	.7	.15	150	N	700	1.5	N	20	15	100	10	L	50	L	300	15	15	150	
<b>G-1, "Best value" (Fleischer, 1965) of original splits</b>																				
1.37	0.25	0.99	0.16	230	1.5?	1,220	3	2.4	22	13	120	20	1-2	49	3	250	16	13	210	



below. Thus L's and N's for the same sample are probably only about one reporting step apart, but two N's could reflect any value from about two steps below the sensitivity limit down to zero.

Finally, high-calcium samples alter the excitation conditions of the arc in the spectrographic method used here. Comparison with mineralogic and wet chemical data indicates that values reported as 10 percent and more calcium are consistently low. This suggests that in high-calcium samples trace elements may also be affected by the altered arcing conditions, which could result in a slight positive or negative bias for a given element. This then limits the usefulness of the analytical method on carbonate rocks; the precision of the method is sufficiently good to permit comparison of elements among groups of carbonate rocks, but the potentially poor accuracy may not permit comparison with low-calcium rocks. As a consequence, our geologic analysis is restricted to the pelitic and psammitic rocks of low carbonate content.

Calculations of average contents and dispersions are based on logarithms because the analytical data are reported as midpoints of geometric classes (Miesch, 1967, p. B4). In this study, the average content is estimated by the geometric mean (the antilog of the mean logarithm), and the dispersion or scatter is estimated by the geometric deviation (the antilog of the standard deviation of the log values). Geometric means and geometric deviations for elements in various groups of Belt rocks are given for the Mission Mountains Primitive Area in table 6 and for the Pend Oreille area in table 7. For purposes of these computations, real, but arbitrary, numbers were substituted for the nonnumeric codes N, L, and > (greater than) used in reporting the raw data. (See table 3.) Table 8 lists the numbers substituted and the percentage of the substitution needed for each element. The particular numbers used for L and > were determined largely on the basis of wet chemical or quantitative spectrographic analyses of some samples. Numbers substituted for N are simply small positive numbers between the limit of sensitivity and zero. Use of logarithms precludes the use of zero. Following common practice, results of calculations are given to two significant figures.

### MINERALOGY OF ROCK TYPES

Mineral data on most of the clastic rocks of the Mission Mountains (table 2) and Pend Oreille (Harrison and Campbell, 1963, table 1) areas are summarized in figure 5. Rock groups containing less than 3 samples are not shown. The ratios among quartz, potassium feldspar, and plagioclase for the siltites shown in figure 5, as well as for the carbonatic siltites from the Pend Oreille area, are summarized in figure 6.

The general uniformity of the Belt rocks is apparent in figure 5; most rocks are graywacke. The grain size and mineralogy are directly related.

TABLE 6.—*Mean element content of low-grade Belt rocks from the Mission Mountains Primitive Area*

[Geometric means (GM) and geometric deviations (GD) calculated from data given by Harrison, Reynolds, Kleinkeopf, and Pattee (1969, table 1). . . . ., all or most samples reported as N (element was looked for but not found)]

Number of samples	Formation and rock type	Percent										Parts per million									
		Fe		Mg		Ca		Ti		B		Ba		Be		Co		Cr		Cu	
		GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
6	Shields Formation; Argillite and argillitic rocks.	2.9	1.5	2.5	1.4	2.0	1.5	0.30	0	100	1.4	340	1.6	1.3	1.4	15	1.5	43	1.5	8.8	2.1
3	Quartzite.	1.4	1.4	2.1	1.4	.22	3.8	.18	1.2	21	1.4	150	3.8	1.79	1.5	7.9	1.2	16	1.2	11	4.3
9	Shepard Formation; Argillite and argillitic rocks.	3.9	1.4	2.5	1.6	1.7	3.9	.34	1.2	73	1.7	210	1.6	1.4	1.4	14	1.6	47	1.4	16	3.5
9	Siltite.	3.4	1.8	1.5	1.8	.90	4.3	.28	1.3	31	2.0	210	1.7	1.0	0	11	2.5	31	2.0	28	5.4
8	Quartzite.	2.6	2.4	1.2	2.1	3.4	2.8	.07	3.1	16.2	3.7	270	7.8	—	—	14.1	—	42	1.7	24	3.3
9	Carbonate rocks.	3.0	1.3	2.5	1.8	2.2	1.4	.20	1.6	35	2.3	270	3.3	1.74	1.4	12	3.8	14	1.6	78	5.3
12	Snowship Formation; Argillite and argillitic rocks.	3.5	1.5	1.3	1.3	.42	2.6	.39	1.3	85	1.7	250	1.4	1.1	1.3	25	1.4	55	1.4	25	7.4
14	Siltite.	2.8	1.8	.93	2.0	.34	3.7	.35	1.4	53	2.0	280	1.6	1.1	1.3	12	2.1	34	1.6	19	1.9
18	Quartzite.	1.8	2.2	.63	2.9	1.5	4.0	.19	1.8	23	2.8	470	2.2	1.66	2.2	6.5	3.4	17	1.9	22	3.0
29	Helena Formation; Argillite and argillitic rocks.	2.6	1.4	2.7	1.5	1.6	3.8	.28	1.4	60	1.9	560	1.9	1.5	1.7	13	2.2	37	1.6	8.0	2.2
30	Siltite.	2.1	1.6	2.3	1.9	1.8	4.1	.25	1.3	31	1.8	370	1.7	1.1	1.5	11	1.9	25	1.5	13	2.7
18	Quartzite.	.84	2.6	1.0	2.3	2.0	3.2	.15	2.5	17.2	3.2	420	3.1	1.69	2.4	5.3	2.6	12	2.4	35	3.0
53	Carbonate rocks.	1.9	1.7	3.2	1.8	13	1.4	.14	2.0	22	2.4	220	2.5	1.70	1.8	7.9	2.3	18	1.9	11	2.5
6	Empire and Spokane Formations; Argillite.	3.8	1.6	2.5	1.5	.58	4.6	.33	1.4	26	1.2	750	2.7	1.6	1.8	16	1.1	45	1.4	15	5.0
9	Siltite.	2.6	1.4	2.5	1.7	.89	4.4	.26	1.2	18	1.5	490	2.2	1.94	2.7	16	1.4	29	1.4	14	2.0
21	Quartzite.	1.0	1.9	.93	2.0	.67	2.3	.12	2.1	15.3	2.4	260	2.0	1.79	1.5	7.4	1.9	13	1.6	17	3.5
62	All formations listed above; Argillite and argillitic rocks.	3.1	1.5	2.3	1.6	1.0	4.2	.31	1.4	64	1.9	410	2.1	1.4	1.6	16	1.9	43	1.6	12	3.7
62	Siltite.	2.4	1.7	1.8	2.0	1.0	4.6	.28	1.4	32	2.0	340	1.8	1.0	1.6	12	2.0	28	1.6	15	2.8
68	Quartzite.	1.3	2.4	.91	2.4	1.3	3.7	.14	2.3	19.3	2.3	340	3.0	1.69	2.0	6.1	2.5	14	1.9	23	3.2
62	Carbonate rocks.	2.0	1.7	3.1	1.8	13	1.4	.14	1.9	24	2.4	230	2.6	1.71	1.8	8.4	2.5	21	2.0	14	3.5
124	Pelitic rocks.	2.7	1.6	2.0	1.8	1.0	4.4	.30	1.4	46	2.1	370	2.0	1.2	1.6	14	2.0	35	1.6	14	3.2

Number of samples	Formation and rock type	Parts per million																			
		La		Mn		Nb		Ni		Pb		Sc		Sr		V		Y		Zr	
		GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
6	Shields Formation; Argillite and argillitic rocks.	33	1.4	500	1.5	—	—	36	1.5	—	—	11	1.5	131	2.4	59	1.2	21	1.4	280	1.2
3	Quartzite.	10	0	75	2.6	—	—	18	1.7	16.7	4.0	5.0	0	—	—	23	1.3	13	1.3	230	1.3
9	Shepard Formation; Argillite and argillitic rocks.	32	1.4	570	3.5	—	—	41	1.5	18.6	2.7	15	1.2	66	1.6	67	1.1	28	1.6	250	1.4
9	Siltite.	29	1.6	650	2.6	—	—	31	1.4	16.1	2.3	10	1.6	146	1.5	55	1.3	23	1.7	270	1.5
8	Quartzite.	21	2.8	1200	2.6	—	—	8.2	2.5	15.3	2.8	5.8	1.4	68	3.5	82	2.3	23	2.5	110	3.5
9	Carbonate rocks.	41	2.1	1800	2.4	—	—	22	2.2	33	5.6	9.3	1.4	270	2.1	61	1.3	34	2.0	170	1.7

Number of meta-samples grade <sup>1</sup>	Fe		Mg		Ca		Ti		B		Ba		Be		Co		Cr		Cu	
	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
12	34	1.5	380	1.9	—	—	—	—	18.0	4.7	16	1.4	229	1.4	72	1.1	28	2.3	320	1.3
14	27	1.6	400	2.2	—	—	—	21	24.6	2.6	11	1.5	134	1.8	54	1.3	22	1.6	400	1.4
18	18	2.6	740	2.4	—	—	—	14	2.9	44.4	5.6	2.3	52	2.4	36	1.7	22	2.0	260	2.0
29	37	1.5	210	2.1	—	—	—	22	1.6	19.4	3.1	1.4	139	1.7	59	1.4	24	1.5	230	1.5
30	22	1.8	250	2.2	—	—	—	19	1.6	10	3.6	8.2	140	1.9	42	1.5	18	1.5	220	1.5
38	20	1.9	320	2.0	—	—	—	8.4	2.4	14	4.4	4.4	147	2.7	21	2.1	15	1.6	160	1.9
53	25	1.6	740	1.6	—	—	—	13	1.8	24	4.2	5.5	140	1.8	26	1.8	21	1.6	80	2.3
6	39	1.5	450	2.1	—	—	—	28	1.4	18	1.5	12	75	3.1	66	1.2	23	1.2	270	1.3
9	35	1.5	480	2.7	4.1	2.3	—	23	1.6	14	1.5	11	66	3.1	48	1.7	29	1.3	260	1.4
21	30	1.7	290	2.1	—	—	—	12	1.9	18.3	3.7	14.8	228	2.3	23	1.7	21	1.5	190	1.6
62	35	1.4	320	2.4	—	—	—	29	1.6	18.8	3.2	13	143	2.0	63	1.3	25	1.7	250	1.4
62	26	1.7	350	2.4	—	—	—	21	1.6	9.4	3.0	9.4	141	2.0	47	1.5	21	1.6	270	1.5
68	22	2.2	420	2.7	—	—	—	11	2.4	17.6	3.7	5.0	141	2.7	26	2.1	10	1.8	190	2.0
62	27	1.7	840	1.9	—	—	—	14	1.9	25	3.3	5.9	150	1.8	32	1.8	23	1.7	90	2.3
124	30	1.6	330	2.4	—	—	—	25	1.7	18.4	4.1	11	142	2.0	54	1.4	23	1.6	260	1.5

<sup>1</sup> Value is less than the sensitivity limit of the method and results from substitution of numbers for reported values of L (undetermined amount of element is below sensitivity limit) and (or) N; it indicates that many samples have a content of the element near threshold.

<sup>2</sup> Value is less than the sensitivity limit of the method and results from many substitutions of a low number for the reported value N; it indicates only that many samples contained no detectable amount of the element.

TABLE 7.—Mean element content of Belt rocks from the Pend Oreille area

[Geometric means (GM) and geometric deviations (GD) calculated from data in table 3, this report. —, all or most samples reported as N (element was looked for but not found)]

Number Meta-samples grade <sup>1</sup>	Formation and rock type	Percent										Parts per million									
		Fe		Mg		Ca		Ti		B		Ba		Be		Co		Cr		Cu	
		GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
11	C	2.6	1.3	1.3	1.5	0.11	3.3	0.31	1.5	86	3.3	400	1.6	1.1	1.8	23.8	2.1	33	1.5	11	4.5
3	Bb	2.5	2.3	1.0	1.5	.080	1.9	.53	1.8	43	1.5	500	0	1.6	1.2	32.2	3.8	36	1.3	11	2.5
7	C	3.2	1.2	1.4	1.2	.061	1.2	.42	1.7	301	3.0	460	1.5	1.7	1.2	24.5	1.4	46	2.3	3.3	7.7
12	C	1.6	1.7	1.5	2.4	.15	6.8	.40	1.9	387	4.2	320	1.6	1.1	1.6	23.2	2.5	43	1.4	6.8	2.2
8	C	1.2	1.9	.49	2.8	.080	3.5	.23	2.1	95	3.0	170	1.4	1.88	1.6	24.4	2.3	20	1.9	3.4	4.0
7	C	1.4	1.8	.48	3.0	.092	3.6	.28	1.6	124	2.4	160	1.3	1.1	1.5	24.6	2.5	25	1.5	3.2	4.5
3	C	3.0	0	1.3	1.3	.076	1.2	.50	0	794	2.2	300	0	1.8	1.2	24.7	1.5	70	0	18	1.7
6	C	1.2	1.7	2.0	2.6	.33	13	.20	2.0	751	4.1	380	1.6	1.91	1.6	—	—	39	1.3	11	1.7
4	C	3.4	1.3	1.5	0	.060	1.2	.37	2.0	146	1.7	640	1.2	1.6	1.2	24.4	1.3	33	2.9	9.2	2.3
5	C	1.9	1.6	1.4	2.6	.081	1.2	.42	2.0	199	3.8	270	1.6	1.2	1.7	5.9	1.5	47	1.5	4.1	4.1

TABLE 7.—Mean element content of Belt rocks from the Pend Oreille area—Continued

Number Meta- of morphic samples grade <sup>1</sup>	Formation and rock type	Percent										Parts per million									
		Fe		Mg		Ca		Ti		B		Ba		Be		Co		Cr		Cu	
		GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
Wallace Formation;																					
21	C	2.2	1.4	2.0	1.9	.088	4.8	.26	1.4	63	2.0	400	1.5	1.1	1.8	7.0	1.4	39	1.5	9.0	3.1
3	Bb	2.4	1.5	1.8	2.3	.23	14	.31	1.6	79	2.2	560	1.2	2.1	1.4	228	2.6	29	3.5	8.4	6.4
8	C	2.0	1.6	1.5	2.2	.40	11	.20	1.2	34	1.5	360	1.8	1.70	2.4	5.5	2.3	23	1.6	14	5.1
4	Bb	2.3	1.7	.12	3.2	.14	4.9	.28	1.5	39	1.3	330	1.5	1.5	1.3	33.5	2.6	26	1.7	15	1.7
9	C	1.8	1.8	6.2	1.8	17	1.6	1.2	1.8	43	1.5	270	2.3	3.71	2.9	33.6	2.1	20	1.9	3.0	6.1
St. Regis Formation;																					
6	C	2.8	1.2	1.4	1.7	.17	4.3	.29	1.6	49	1.7	540	1.4	1.3	1.7	7.0	1.2	43	1.4	2.7	3.3
6	C	1.8	1.7	1.2	2.0	.29	4.2	.22	1.3	31	1.6	380	1.4	2.78	2.8	4.6	1.7	20	1.6	9.2	3.4
3	Bb	2.2	2.0	2.1	1.4	.25	3.4	.26	1.3	67	2.7	280	1.8	1.4	1.4	6.3	1.2	28	1.8	4.2	3.9
Revelt Formation;																					
4	C	1.5	1.7	.34	2.2	.046	1.6	.31	1.5	33	2.1	340	1.3	1.3	1.4	24.0	1.8	27	1.2	11.5	2.2
3	Bb	1.1	1.7	.40	1.6	.042	1.3	.31	1.6	13	2.4	320	1.2	2.2	1.6	1.7	—	15	2.1	3.89	8.4
5	C	.52	1.7	.070	1.3	.049	5.8	.14	2.0	13	1.9	210	1.4	1.4	1.4	—	—	9.4	1.8	2.7	4.5
5	Bb	.43	1.8	.11	2.0	.030	1.9	.16	1.1	28.7	1.4	210	1.4	1.66	1.5	—	—	5.4	1.2	6.2	1.6
Burke Formation;																					
3	Bb	2.6	1.3	.90	1.6	.072	1.9	.47	1.5	36	1.3	700	0	2.3	1.3	10	1.5	50	0	4.2	3.9
13	Bb	1.8	1.4	.43	2.1	.12	3.2	.24	1.5	19	1.3	380	1.6	1.3	2.0	6.7	1.4	21	1.6	5.9	2.6
Pritchard Formation;																					
3	C	2.4	1.5	.59	1.9	.042	1.3	.27	1.7	31	1.6	560	1.2	3.6	2.6	32.5	2.3	24	3.2	10	2.0
37	Bb	2.7	1.3	.73	1.5	.087	2.2	.36	1.4	25	2.0	590	1.3	1.6	1.6	5.9	2.0	45	1.5	12	2.5
17	Egn	2.2	1.6	.56	1.8	.25	2.5	.32	1.6	14	1.7	490	1.5	1.4	1.4	3.5	2.2	40	2.0	16	1.6
8	Bb	2.0	1.5	.57	1.7	.090	2.1	.21	1.3	11	2.4	340	1.4	1.81	1.8	24.7	2.9	26	1.5	10	3.3
5	Egn	.70	1.3	.23	1.6	.23	2.9	.17	1.4	12	1.7	280	2.2	2.85	2.2	—	—	14	1.8	7.0	1.3
8	Bb	.84	1.2	.18	1.5	.27	3.4	.17	1.1	1.4	1.4	210	1.7	1.84	3.6	32.1	2.2	18	1.5	5.4	3.1
3	Egn	.63	1.2	.20	2.3	.88	2.5	.13	1.3	25.0	0	80	1.2	1.4	1.9	—	—	18	1.2	5.9	5.5
All formations listed above;																					
48	C	2.5	1.4	1.4	1.8	.091	3.7	.30	1.5	79	2.8	430	1.5	1.3	1.9	5.4	1.8	38	1.7	6.8	4.2
31	C	1.7	1.6	1.2	2.5	.19	6.6	.28	1.7	90	4.7	350	1.6	2.87	2.1	24.0	2.2	29	1.6	6.8	3.8
14	C	.85	2.0	.24	3.4	.094	6.8	.18	2.0	41	3.9	200	1.5	1.79	1.6	22.7	2.5	15	2.0	3.3	3.8
13	C	1.4	1.8	4.1	3.5	16	1.6	1.6	2.0	53	2.4	240	2.2	1.1	7.7	24.1	2.1	18	2.0	6.6	1.1
79	C	2.2	1.6	1.3	2.1	.12	4.9	.29	1.6	83	3.5	400	1.6	1.1	1.9	24.8	2.0	34	1.7	6.8	4.0
Parts per million																					
Number Meta- of morphic samples grade <sup>1</sup>	Formation and rock type	La		Mn		Nb		Ni		Pb		Sc		Sr		Y		Zr			
		GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD		
		11	C	33	1.7	230	1.6	37.1	1.5	14	2.5	—	—	7.6	1.5	—	—	73	1.3	26	1.3
3	Bb	213	4.9	88	4.8	49.1	1.7	8.4	6.4	—	—	10	1.5	—	—	79	1.2	31	1.6	160	1.2

7	C	Striped Peak Formation; Argillite and argillitic rocks	55	1.2	25	2.3	77.4	1.4	16	2.3	—	10	1.4	—	—	67	1.1	34	1.3	180	1.2	
12	C	Siltite	46	1.4	40	2.8	77.1	1.4	5.6	5.4	—	7.0	1.5	—	—	54	1.4	30	1.4	280	2.0	
8	C	Quartzite	26	2.5	98	2.4	75.4	1.3	5.1	4.1	—	4.0	2.0	—	—	41	1.8	20	1.4	400	2.2	
7	C	Striped Peak member 4; Quartzite	35	1.4	100	2.6	75.5	1.3	6.4	3.9	—	5.4	1.4	—	—	45	1.8	22	1.3	480	1.8	
3	C	Striped Peak, members 3 & 2; Argillite and argillitic rocks	56	1.2	51	2.5	10	0	36	1.3	—	11	1.3	—	—	70	0	30	0	160	1.2	
6	C	Siltite	49	1.3	52	3.8	77.1	1.5	2.0	6.4	—	7.5	1.5	—	—	50	1.5	27	1.5	270	1.7	
4	C	Striped Peak member 1; Argillite and argillitic rocks	54	1.2	15	0	76.0	1.4	8.5	1.6	—	9.3	1.4	—	—	64	1.2	39	1.3	190	1.2	
5	C	Siltite	39	1.5	31	1.9	77.6	1.5	13	1.9	—	6.4	1.6	—	—	55	1.4	33	1.3	340	2.4	
21	C	Wallace Formation; Argillite and argillitic rocks	46	1.5	58	2.8	75.0	2.1	21	1.5	—	4.4	2.6	—	—	63	1.2	26	1.3	150	1.3	
3	Bb	do	72	1.9	150	2.1	11	1.3	10	2.0	—	8.9	1.2	—	—	63	1.2	36	1.3	160	1.2	
8	C	Siltite	36	1.5	85	2.7	—	—	25	1.2	—	6.9	1.4	—	—	48	1.5	25	1.3	140	1.3	
4	Bb	do	65	1.4	74	2.9	77.1	1.5	21	1.7	—	8.4	1.9	—	—	59	1.2	27	1.2	180	1.4	
9	C	Carbonate rocks	23	2.4	820	2.0	—	—	8.8	3.4	—	4.4	1.8	—	—	39	1.8	20	1.4	64	2.0	
6	C	St. Regis Formation; Argillite and argillitic rocks	59	1.2	93	3.9	76.3	1.4	20	1.2	—	8.4	1.2	—	—	66	1.2	30	0	140	1.2	
3	C	Siltite	63	2.0	210	2.8	—	—	14	1.5	—	1.5	1.5	—	—	45	1.5	23	1.6	140	1.5	
6	Bb	Argillite siltite	33	1.5	110	2.5	76.3	1.5	21	1.4	—	9.0	1.6	—	—	59	1.9	36	1.3	160	1.2	
4	C	Revett Formation; Siltite	35	1.6	34	1.9	77.1	1.5	10	1.9	—	7.6	1.2	—	—	48	1.4	29	1.6	280	2.6	
3	Bb	do	42	1.3	39	4.1	77.9	1.5	1.7	2.5	—	8.1	1.8	—	—	35	1.9	23	1.3	470	2.7	
5	C	Quartzite	25	1.8	69	4.4	—	—	3.68	2.8	—	3.6	1.5	—	—	10	1.6	16	1.3	290	2.8	
5	Bb	do	38	1.5	34	1.8	—	—	11.1	5.9	—	3.2	1.6	—	—	24	1.4	20	1.3	400	2.3	
3	Bb	Burke Formation; Argillite and argillitic rocks	70	0	160	1.7	11	1.3	26	1.3	—	10	0	—	—	70	0	36	1.3	190	1.5	
13	Bb	Siltite	42	1.4	230	2.4	75.3	2.3	9.5	3.0	—	6.3	1.3	—	—	42	1.5	24	1.3	170	1.2	
3	C	Priehard Formation; Argillite and argillitic rocks	47	1.5	110	5.6	77.9	1.5	2.5	4.8	—	4.8	3.9	—	—	53	1.8	26	1.3	150	0	
17	Bb	do	50	1.5	260	1.8	78.1	1.5	10	3.2	—	7.3	2.2	—	—	70	1.2	28	1.3	140	1.2	
8	Bb	do	43	2.1	80	1.6	77.7	1.5	4.3	3.5	—	9.7	1.4	—	—	60	1.3	30	1.3	150	1.1	
5	Bb	Siltite	34	1.7	180	1.4	75.0	0	6.4	4.8	—	5.9	1.2	—	—	41	1.3	21	1.3	140	1.2	
8	Bgn	do	31	1.4	120	1.4	75.7	1.4	11.7	3.4	—	4.8	1.4	—	—	32	1.6	24	1.4	200	2.0	
8	Bb	Quartzite	40	1.4	190	1.7	—	—	2.2	3.0	—	4.3	1.4	—	—	27	2.4	1.5	20	1.5	1.2	
3	Bb	do	42	1.3	160	1.2	75.0	0	11.9	3.1	—	3.6	1.3	—	—	1.9	26	1.3	20	0	250	1.9
48	C	All formations listed above; Argillite and argillitic rocks	45	1.5	77	3.3	76.1	1.8	16	2.3	—	8.9	1.4	—	—	65	1.2	28	1.3	150	1.3	
31	C	Siltite	39	1.6	69	3.1	75.5	1.9	11	3.4	—	4.1	1.4	—	—	49	1.4	27	1.4	200	1.9	
14	C	Quartzite	26	2.1	94	3.0	—	—	2.2	4.8	—	4.0	1.8	—	—	24	2.4	19	1.4	320	2.4	
13	C	Carbonate rocks	20	2.8	1100	2.6	—	—	7.5	3.3	—	4.2	1.7	—	—	32	1.7	22	1.6	59	2.3	
79	C	Pelitic rocks	43	1.6	74	3.2	75.8	1.8	14	2.8	—	7.9	1.4	—	—	58	1.4	27	1.4	170	1.6	

<sup>1</sup> C, chlorite-sericite grade rocks that may contain minor secondary biotite; Bb, bedded rocks containing abundant secondary biotite in rocks of appropriate composition; Bgn, gneisses and schists of the biotite zone of metamorphism.  
<sup>2</sup> Value is less than the sensitivity limit of the method and results from substitution of numbers for reported values of L (undetermined amount of element is below sensitivity limit) and (or) N; it indicates that many samples have a content of the element near threshold.  
<sup>3</sup> Value is less than the sensitivity limit of the method and results from many substitutions of a low number for the reported value N; it indicates only that many samples contained no detectable amount of the element.

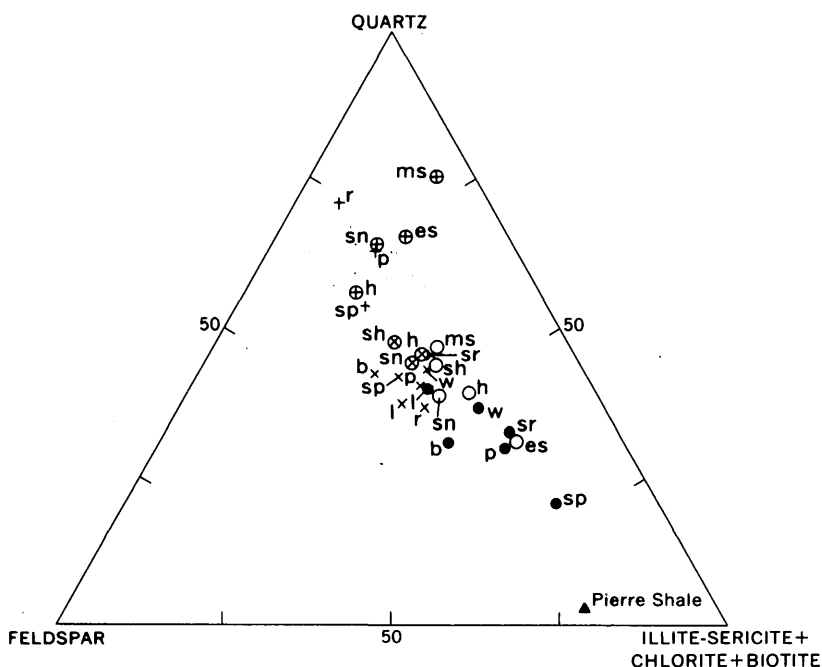
TABLE 8.—Numbers used to replace nonnumeric codes (N, L, and &gt;) prior to geochemical calculations

[N, element looked for but not found; L, undetermined amount of element present below sensitivity limit; and >, undetermined amount of element present above the number shown. Mg and Ca, in percent; other elements, in parts per million]

Element	N		L		>	
	Replacement number	Percentage of samples reported as code	Replacement number	Percentage of samples reported as code	Replacement number	Percentage of samples reported as code
Mg	—	—	—	—	15	0.4
Ca	0.01	0.6	0.03	5.4	30	1.2
Mn	—	—	—	—	7,000	1.0
B	1	2.1	5	8.5	—	—
Ba	—	—	5	.2	10,000	.4
Be	.1	2.9	.5	20.7	—	—
Co	1	12.0	3	12.0	—	—
Cr	1	.2	3	.2	—	—
Cu	.1	.4	1	10.2	—	—
La	3	2.7	10	4.8	—	—
Nb	1	44.4	5	30.3	—	—
Ni	.1	.6	1	10.8	—	—
Pb	2	30.9	5	26.8	—	—
Sc	1	2.9	3	.6	—	—
Sr	10	45.6	30	17.2	—	—
V	—	—	5	1.0	—	—
Y	—	—	—	—	300	.2
Zr	1	.2	—	—	1,500	.2

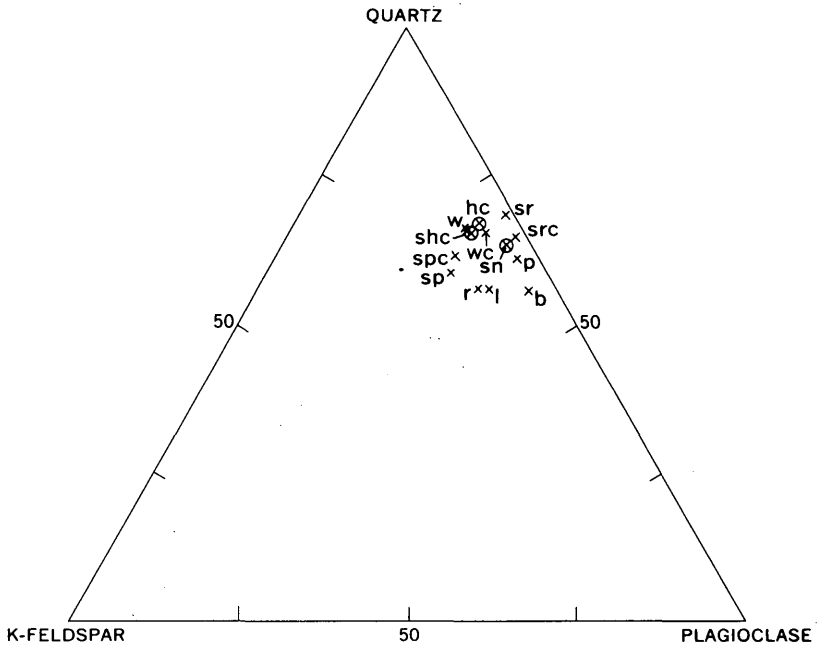
The mudstones from the Mission Mountains, except for those from the Empire and Spokane Formations, probably were deposited nearer an old shoreline and are somewhat siltier than those of the Pend Oreille area. Siltites and quartzites of the Pend Oreille area tend to be slightly more feldspathic than their stratigraphic equivalents in the Mission Mountains. The striking contrast between the Belt mudstones and the Pierre Shale, which many Belt rocks resemble in outcrop and hand specimen, is brought out by figure 5. The position of the Pierre Shale in figure 5 was calculated from information given in table 5 of a report on this shale by Tourtelot (1962). The Pierre also differs from the Belt in that montmorillonite is a principal clay mineral (montmorillonite was included with illite for the calculations used to arrive at the Pierre Shale position in figure 5). Ratios among quartz, potassium feldspar, and plagioclase for Belt siltites are remarkably uniform (fig. 6), even for rocks containing several percent of carbonate minerals, which form the cement.

Mineralogic comparisons that include carbonate minerals in clastic Belt rocks from the two study areas are shown in figure 7. The data used here are from table 2 of this report for the Mission Mountains rocks, from table 1 of Harrison and Campbell (1963) for some Pend Oreille rocks—plus additional data on low-grade metamorphic rocks in the Pend Oreille area accumulated since 1963—and from table 5 of Tourtelot (1962). Here again,



Formation	Number of samples		
	Argillite or shale (●)	Siltite (×)	Quartzite (+)
<b>Pend Oreille area</b>			
Libby (l) .....	4	4	.....
Striped Peak (sp).....	3	11	9
Wallace (w) .....	12	16	.....
St. Regis (sr) .....	6	4	.....
Revett (r) .....	.....	5	10
Burke (b) .....	3	14	.....
Prichard (p) .....	11	7	6
<b>Mission Mountains Primitive Area</b>			
Shields (ms) .....	3	.....	3
Shepard (sh) .....	5	3	.....
Snowslip (sn) .....	6	5	5
Helena (h) .....	5	13	6
Empire and Spokane (es).....	3	.....	7

FIGURE 5.—Average modes, in volume percent, of rocks of the Belt Supergroup, Pend Oreille area (symbol not circled), and Mission Mountains Primitive Area (symbol circled).



Formation	Number of samples
<b>Pend Oreille area</b>	
Libby (l) .....	4
Striped Peak (sp) .....	11
Striped Peak; dolomitic (spc) .....	4
Wallace (w) .....	16
Wallace; dolomitic and calcareous (wc) .....	6
St. Regis (sr) .....	4
St. Regis; dolomitic (src) .....	4
Revelt (r) .....	5
Burke (b) .....	14
Prichard (p) .....	7
<b>Mission Mountains Primitive Area</b>	
Shepard; dolomitic and calcareous (shc) .....	3
Snowslip (sn) .....	5
Helena; calcareous and dolomitic (hc) .....	13

FIGURE 6.—Ratio among quartz, potassium feldspar, and plagioclase (volume percent) in siltite of the Belt Supergroup, Pend Oreille area (symbol not circled) and Mission Mountains Primitive Area (symbol circled). c, siltite contains 10 percent or more of carbonate minerals.



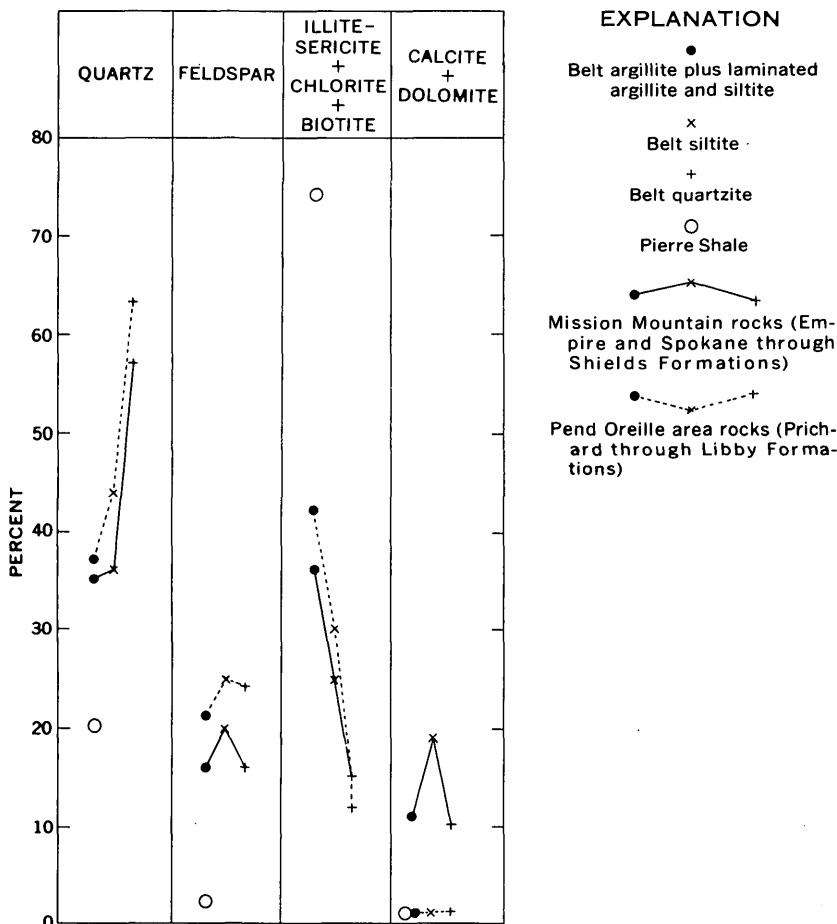


FIGURE 7.—Average mineralogy of clastic Belt rocks. Number of samples from Mission Mountains: argillite, 24; siltite, 25; quartzite, 23. Number of samples from Pend Oreille area: argillite, 120; siltite, 51; quartzite, 20. Also shown for comparison: Pierre Shale, 20 samples.

only slight differences of the Belt rocks from the two widely separated areas are evident. A greater carbonate minerals content (also noticeable in the field) in the Mission Mountains strata is the most striking difference, although the feldspar content of the Pend Oreille rocks is slightly greater than that of the Mission Mountain rocks. Sharp contrast between Belt "shales" and the Pierre Shale is again apparent. The pronounced decrease in the clay mineral-mica-chlorite component with increasing rock grain size is a significant factor in the distribution of many minor elements.

### GEOCHEMISTRY

The geometric deviations for most elements in a rock type represented

by five or more samples with real (not coded) values is about the same. In contrast, the geometric deviation of most elements tends to increase with increasing rock grain size. Thus the quartzites tend to be less homogeneous chemically than the siltites, which in turn tend to be less homogeneous than the argillites. The increased chemical variability of the coarser grained rocks could reflect small-scale variation (differences between closely spaced samples) or large-scale variation (differences from place to place) or both. Field evidence supports the conclusion that the coarser rocks are actually more variable in composition from place to place.

A comparison of the average element content of the four Belt rock types and the metamorphically equivalent (lowest grade) Belt rocks from the two study areas is shown in figure 8. The averages (geometric means) are taken from tables 6 and 7. The clastic rocks from each area are plotted in order of increasing grain size from left to right, and the geometric means for the various clastic rock types are connected with a line. Perhaps the most obvious feature of the element patterns in figure 8 is a striking similarity of the minor element patterns to that of the illite-sericite-chlorite component of these same rocks (fig. 7). These patterns are like that discussed by Krauskopf (1955) but are based on a three-unit system (mudstone, siltstone, sandstone) instead of a two-unit system (shale, sandstone).

Elements that are enriched in the illite-sericite-chlorite-bearing clastic rocks from both areas apparently include B, Co, Cr, Ni, Sc, V, Fe, Mg, and Ti, and possibly La and Y. As these rocks contain no organic compounds, which might form organo-metallic complexes, the elements are probably contained in or adsorbed on the lattice of the micaceous minerals. Copper is more abundant in silty layers of laminated rocks or in siltites and quartzites of the Mission Mountains, and zircon appears concentrated in the coarser rocks in the Striped Peak Formation of the Pend Oreille area. This suggests that Cu and Zr are primarily in grains rather than held in clay minerals in those rocks. Mn, Pb, and Sr are more abundant in the rocks of the Mission Mountains where the Ca content is higher; such associations are common (Mason, 1956, p. 155; Tourtelot, 1962, p. 60) and suggest that some aragonite was originally deposited as part of the carbonate minerals. The higher Mg of the Mission Mountains reflects, in part, the more dolomitic character of these rocks. Similar rock types of the Mission Mountains contain about twice as much Co, Cu, and Ni as their counterparts in the Pend Oreille area. The siltites and quartzites of the Pend Oreille area have a B content distinctly higher than similar rocks of the Mission Mountains.

Tables 6 and 7 show that the metamorphically low-grade rock types within each formation of each area contain similar concentrations of minor elements. The unusually high B content of the Striped Peak Formation, particularly of members 2 and 3 (table 7), is clearly limited to that formation and has displaced upward the graph for B in Pend Oreille rocks in

figure 8. Low-grade rocks of other formations in the Pend Oreille area have the approximate B content of similar rocks in the Mission Mountains.

Comparison of the minor element content of Belt argillitic rocks with that of the Pierre Shale is also shown in figure 8; geometric means for the Pierre were calculated from data given by Tourtelot (1962, fig. 13). Most minor element contents of the Belt mudstones are similar to those of the Pierre Shale. The Pierre is relatively high in Cr, Cu, Sr, and V; Sr is correlated with Ca in the Pierre (Tourtelot, 1962, p. 60); and Cr, Cu, and V are commonly enriched in black shales (Krauskopf, 1955, table 2; Vine, 1966, p. E29). Even though much of the Belt argillitic rock is black, the organic carbon of the usual black shale is missing, as is normal enrichment in black shale suites of trace elements.

Distribution of the elements among constituent minerals was further examined by heavy mineral studies of 45 samples of low-grade rocks from the Pend Oreille area. Heavy mineral fractions were obtained by a simple bromoform separation from ground samples. Splits of the original sample and the heavy and light fractions were analyzed spectrographically. Heavy mineral fractions ranged from 0.1 to 3 percent of the rocks; most contained about 1 percent. The heavy fractions commonly contain compound grains that are mostly silicate minerals enclosing tiny black specks (magnetite). One exceptional sample, a silty carbonate rock of fossil algal forms, contains 11 percent heavy minerals. The minor element content of each split of the original sample was compared with its content as calculated from its fractions and was found to be precise within the limits of the analytical method. Average relative concentrations of elements in the heavy mineral

TABLE 9.—*Relative concentration of elements in the heavy mineral fraction of some Belt rocks from the Pend Oreille area*

[Number in column is the ratio: average amount in heavy fraction divided by average amount in light fraction; 1 indicates equal amounts in the light and heavy fractions. Number in parentheses is number of samples of rock type. ....., the amount of the element in the heavy fraction was below the sensitivity limit of the spectrograph]

Element	Argillite (17)	Siltite (20)	Quartzite (5)	Carbonate rocks (8)
B	1	1	10	1/2
Ba	1	1	1/2	1
Be	1	1	1	1
Co	5	5	5	.....
Cr	1	4	10	1
Cu	10	20	30	.....
Fe	2	3	5	3
La	3	2	5	1
Mg	1	1	1	1
Mn	5	5	20	1
Ni	5	5	20	.....
Pb	3	5	5	5
Sc	1/2	.....	.....	.....
Sr	1	1	1	1/2
Ti	3	2	7	1/2
V	1	1	5	1
Y	5	5	7	1
Zr	5	3	10	2

fraction of various rock types are shown in table 9. The ratios range from about  $\frac{1}{2}$  to 2 times the average shown in the table, except for Mn which is about  $\frac{1}{3}$  to 5 times the average. The relative concentration of B in heavy mineral fractions of Wallace argillites and siltites and of Striped Peak siltites is about 3 (not shown in table 9).

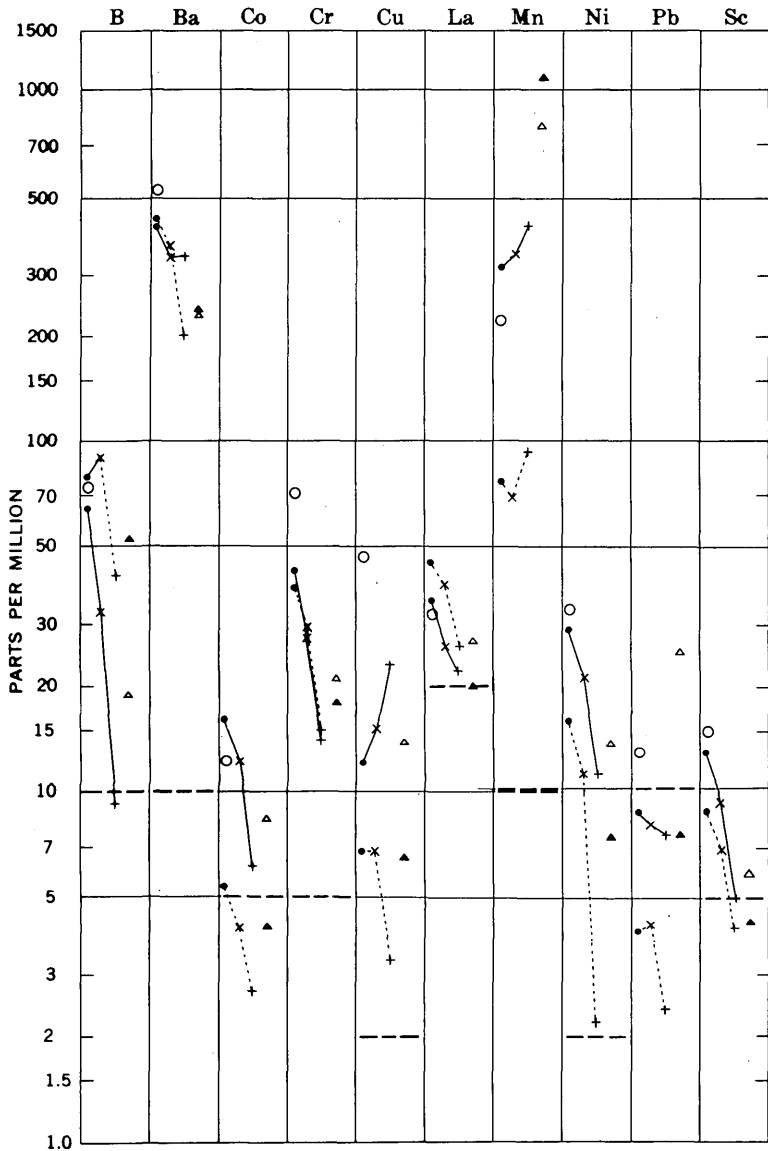
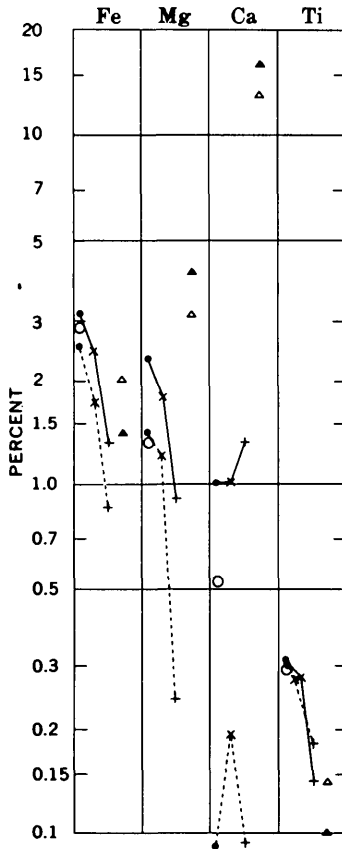
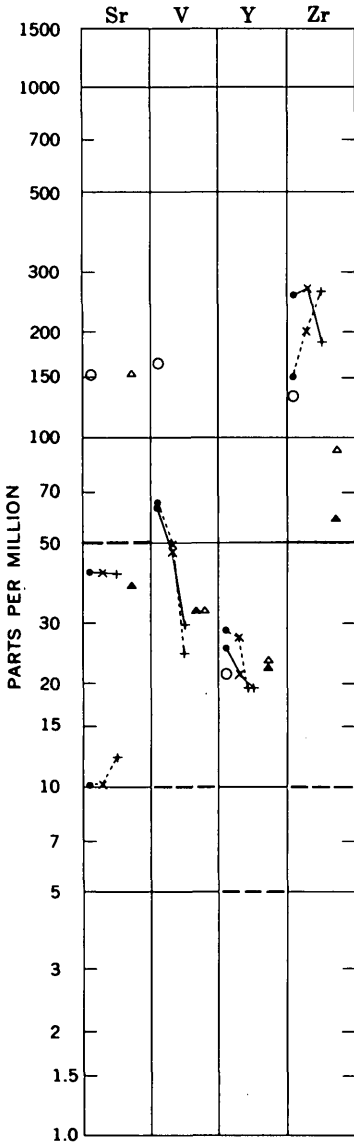


FIGURE 8.—Geometric means of semiquantitative spectrographic analyses of different Belt rock types. Number of samples from Mission Mountains: argillite, 62; siltite, 62; quartzite, 68; carbonate rocks, 62. Number of samples from Pend Oreille area:

EXPLANATION

- Belt argillite plus laminated argillite and siltite
- x Belt siltite
- + Belt quartzite
- △ Mission Mountains Belt carbonate rocks
- Pierre Shale
- Mission Mountains samples (Empire and Spokane through Shields Formations)
- - - Pend Oreille area samples (Revelt through Libby Formations)
- Spectrographic sensitivity limit  
Lower than smallest value on graph where not shown



argillite, 48; siltite, 31; quartzite, 14; carbonate rocks, 13. Also shown for comparison: Pierre Shale, 67 samples.

The principal heavy minerals are magnetite, ilmenite, chalcopyrite, zircon, tourmaline, and iron hydroxides; some bornite, chalcocite, altered biotite, and manganese nodules occur in the coarser grained rocks. The copper minerals are largely in irregular or cup-shaped flakes, but some are in subhedral or broken grains; zircon, tourmaline, magnetite, and ilmenite are generally in broken or abraded crystals; some magnetite, ilmenite, and most pyrite are in discrete euhedral crystals. No significant differences in kinds of minerals in heavy mineral suites were observed for rocks of this study.

The concentration ratios (table 9) show clearly that many elements are about as abundant in the light fraction as in the heavy fraction. Because the light fraction forms about 99 percent of the rock, the bulk of most elements is associated with the principal rock-forming minerals. This then supports the interpretation that those elements shown in figure 8 that have a strong correlation in pattern with the pattern for illite-sericite-chlorite in figure 7 are adsorbed on or held within the lattice of those minerals.

Heavy mineral fractions of quartzites show relatively large concentrations of B, Cr, Cu, Mn, Ni, and Zr. B is in tourmaline; Zr is in zircon; Cu is in chalcopyrite, bornite, or chalcocite; Mn is in small blobs of probable manganese oxides; and Cr and Ni are probably associated with iron or manganese oxides (Krauskopf, 1955, p. 425).

Only copper shows a relatively large concentration in the heavy mineral fraction of all clastic rock types. The somewhat more abundant copper in rocks of the Mission Mountains (fig. 8) is in minerals that form enough of the rock to allow thin section study. Here the copper occurs as chalcopyrite grains and chalcocite flakes and blobs in unfractured rocks that suggest a detrital sedimentary origin; interstitial bornite blobs, however, suggest that diagenetic or other subsequent modification of any original copper is probable. The concentration and occurrence of copper in the heavy mineral fraction of Pend Oreille rocks support this conclusion.

## DISCUSSION AND INTERPRETATION

### IMPLICATIONS ABOUT SEDIMENTATION

The average chemical composition of Belt rocks in the Pend Oreille area is between that of an average granite and that of the Canadian Shield (table 10). The weighted average for Belt rocks was computed from 23 chemical analyses of rocks from all formations in the Pend Oreille area where the stratigraphic section consists of about 80 percent pelitic rock, 15 percent quartzite, and 5 percent impure carbonate rock. Other parts of Belt terrane have a higher percentage of carbonate rock and perhaps slightly more quartzite. Thus the Belt rocks as a whole may be nearer the average composition of the Canadian Shield than is indicated in table 10. The Canadian Shield is, of course, one likely source terrane for Belt sediments.

Two lines of evidence point to a remarkable uniformity of depositional process lasting several hundred million years for Belt rocks. The direct

TABLE 10.—Average granite and average composition of the Canadian Shield compared with average Belt rock from the Pend Oreille area

	Average granite (Daly, 1914, p. 169)	Weighted average of 23 Belt rocks	Canadian Shield (Shaw and others, 1967, p. 829)
SiO <sub>2</sub> .....	70.47	69.32	64.93
Al <sub>2</sub> O <sub>3</sub> .....	14.90	13.65	14.63
Fe <sub>2</sub> O <sub>3</sub> +FeO.....	3.31	3.54	4.11
MgO.....	.98	1.93	2.24
CaO.....	2.09	1.37	4.12
Na <sub>2</sub> O.....	3.31	1.42	3.46
K <sub>2</sub> O.....	4.10	3.74	3.10
H <sub>2</sub> O+.....	.....	1.90	.79
CO <sub>2</sub> .....	.....	1.53	1.28
Other <sup>1</sup> .....	.84	1.16	1.01
Total.....	100.00	99.66	99.67

<sup>1</sup> Includes H<sub>2</sub>O—, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, MnO, Cl, F—, BaO, SrO, C, and acid soluble S as SO<sub>3</sub>.

relation between mineralogy and rock grain size (fig. 6) implies a consistent weathering and transportation system. First, the almost total absence of life during deposition of Belt rocks certainly resulted in a simpler sedimentational history than in later geologic time. No plants covered the surface of the earth to impede erosion, and no humic acids were formed to accelerate leaching or to increase the variety of local weathering products. Little life existed in the oceans to produce clastic shell detritus or organic compounds which might combine with or alter mineral or chemical products brought in from the land. Second, the nearly uniform ratio among quartz, potassium feldspar, and plagioclase in widely separated sediments deposited over hundreds of millions of years requires either a nearly uniform source terrane or a high degree of integration of clastic components during transportation.

The chemical composition of the Belt seas and atmosphere was probably not much different from the composition of today's seas and atmosphere (Rubey, 1951, p. 1111). If the atmosphere of the time had been excessively high in CO<sub>2</sub>, "the rain water would have been so highly carbonated that it would leach much Fe and Si from exposed rocks, and the streams would transport significant amounts of those elements in solution \* \* \*" (Rubey, 1951, p. 1124). Because no iron-formations and only insignificant amounts of chert occur in the Belt rocks, it seems reasonable to assume that no great excess of Fe or Si was transported in solution to or accumulated in Belt areas.

The mineralogy and geochemistry of the Belt rocks suggest either that rocks of the source area were uniform in composition (near that of granite) or that the weathering and transportation processes homogenized the clastic assemblage prior to deposition. Homogenization during transportation is indicated by the remarkable uniformity of Belt rock mineralogy in a given rock type and of the ratio among quartz, potassium feldspar, and plagioclase in siltites. In the few places where the base of the Belt sequence is exposed, the rocks lie unconformably on older, crystalline rocks. Conceivably, part of the Belt strata may have been derived by reworking this base-

ment or older adjacent strata of the thick Belt stratigraphic sequence. However, there are no known older sedimentary rocks that could have provided the tremendous volume of sediment of which the Belt is composed. Moreover, the increase in amount and grain size of feldspar in the upper parts of the supergroup, particularly in the feldspathic red quartzites of the Striped Peak and equivalent formations, suggests a marked change in provenance. The exposed crystalline basement of Montana and the Canadian Shield are not uniformly granitic and do contain mafic rocks. We are led to the conclusion that the weathering and transportation processes of Belt time resulted in homogenization of clastic components. This homogenization requires a chemical weathering of most mafic minerals, a low terrane and low-gradient streams carrying only fine-grained material, and a slow isostatic adjustment between source areas and basins to provide a reasonably stable cycle of erosion and deposition without major tectonic surges to cause folding or faulting within the basins. It is of some interest that the slow isostatic adjustment of a granitic crust over a long period of time resulting in widespread epicontinental seas is a corollary of Rubey's (1951, p. 1140-1142) thoughtful analysis of the geologic history of sea water.

The differences in minor element composition between similar rock types in various formations and in the two areas may be caused by a variation in depositional environment or by a variation in the source areas that supplied the Belt detritus. Carbonate is largely a chemical precipitate in these rocks; therefore, Ca and elements such as Mg, Mn, Pb, and Sr that form carbonate compounds or substitute in mineral lattices of those compounds increase, as expected, in the environment of carbonate deposition.

Other minor elements showing large differences between the two areas are B, Co, and Ni, and they are also related to the illite-sericite-chlorite fraction of the rocks. The high B content of the Striped Peak Formation, particularly members 2 and 3, is in part a reflection of more abundant detrital tourmaline in these rocks than in others. The bulk of the B, however, is in the fine-grained light fraction and probably represents original B-rich clay minerals (Hirst, 1962, p. 1172-1176). Here, then, is an indication of a different source area for part of the Belt strata. The siltites of the formation below the Striped Peak are also somewhat enriched in tourmaline, which may indicate that the source area for these rocks was similar to that of the Striped Peak. If so, the homogenization of clastic components was more thorough in the lower (Wallace) strata.

Co and Ni are more abundant in the Mission Mountains rocks than in the Pend Oreille rocks. If these elements reflect a difference in crystalline source terrane, then we might also expect correspondingly large amounts of V, Cr, and Cu from rocks relatively high in Co and Ni (Parker, 1967, table 19). Cu is present in larger amounts in Mission Mountains rocks. It also is primarily in the form of sulfides in the rocks and thus differs from V and Cr,



which are largely with clay minerals. If we can accept the thesis of the existence of Co, Ni, V, and Cr in a simple chemical environment, then the difference in their behavior may be based on ionic potential because  $\text{Cr}^{+3} > \text{V}^{+3} \gg \text{Ni}^{+2} > \text{Co}^{+2}$ , as measured for behavior of their hydroxides (Goldschmidt, 1937; Krauskopf, 1955, table 9). Thus Cr and V are in about equal amounts in similar rock types of the two areas because of their superior ability to substitute in lattices of the clay minerals which are in equal amounts in the comparable rock types. Excess Ni and Co are left to be absorbed or precipitated primarily in sulfides. Many simplifying assumptions on the chemistry of the environments are required to allow such statements to be made. But the hypothesis is reasonable in terms of the geologic data and permits one further suggestion. The source area for the Mission Mountains strata contained more basic rocks than that for equivalent strata of the Pend Oreille area. This has bearing on the origin of stratabound copper deposits or occurrences.

Copper in all these rocks is primarily in discrete sulfides that occur in greatest abundance in siltites and quartzites of the Mission Mountains. The original copper minerals occur primarily as heavy mineral grains and interstitial flakes, and some diagenetic recrystallization is probable (Harrison and others, 1969, p. D17). In these rocks, sedimentary copper was apparently deposited as heavy mineral grains in the coarser grained rocks or with stromatolites (fossil algal forms) or was subsequently concentrated in more permeable strata. The living algae formed sticky mats that were effective traps for heavy minerals. This is shown by the 11-percent heavy mineral fraction of a Pend Oreille algal sample and by the high clastic copper mineral content of a persistent zone of stromatolitic rocks in the Mission Mountains (Harrison and others, 1969, p. D18). Several Pend Oreille stromatolites examined in thin section tend to have high heavy mineral content, which is mostly clastic grains of magnetite-ilmenite. Apparently, clastic grains of copper minerals were not available in the Pend Oreille area environment at the time of deposition of the stromatolitic rocks. Bornite flakes do occur as interstitial fillings in some quartzites and siltites, but in markedly less amounts than in the Mission Mountains strata.

We did not see a syngenetic copper ore deposit in either study area, although copper may occur in concentrations up to 3 percent in some 1-inch-thick beds. Although part or all of the chalcopyrite and perhaps some chalcocite may be syngenetic, the bornite is not; it is either diagenetic or epigenetic. Because the Helena and younger Belt rocks probably contain more syngenetic copper in the eastern part of the Belt terrane, prospecting for copper in these rocks may be more fruitful in the eastern part of the old Belt basin. We have no data on distribution or occurrences of copper among various areas or formations in the lower (pre-Helena) part of the Belt rocks.

### METAMORPHIC CHANGES

Samples from the Pend Oreille area fall into three subfacies of metamorphism within the greenschist facies. They represent the chlorite-sericite zone and the biotite zone of regional metamorphism (C and Bb in tables 1 and 7), and the biotite zone of contact metamorphism (Bgn in tables 1 and 7).

Chemical changes between the chlorite-sericite and biotite zones of regional metamorphism are shown in table 7. Here we can look only for similar patterns or trends within different formations because of the limited numbers of samples in some groups, large values for geometric deviation, and limits of the analytical method. We conclude that the trends support Shaw's (1956, p. 934) general conclusion that regional metamorphism of shales results in little change in minor element content. One trend is suggested in our data—a loss of boron with increasing metamorphic grade. Boron was not included in Shaw's studies, and so a comparison is not possible.

Effects of contact metamorphism can be examined only in the Prichard Formation. Within this formation, the argillitic rocks give the best measure of metamorphic change because (1) a larger number of samples were collected of this rock type, (2) metamorphic equivalents are more easily recognized, and (3) among the lower-grade rocks, the Prichard argillitic rocks are more nearly uniform in mineralogy from place to place than are the siltites and quartzites. The higher grade argillitic rocks show an increase in Ca and Sr and a decrease in Ni, B, and possibly Co. Co and Ni are commonly associated, as are Ca and Sr. The B loss with increasing metamorphism supports the trend identified in the regional metamorphism. Other elements show no detectable change. Further studies of these metamorphic effects are underway.

### COMPARISON OF BELT ROCKS WITH YOUNGER ROCKS

Table 11 compares the element content of the Mission Mountains and Pend Oreille pelitic rocks with that of similar rocks of different ages and geologic environments. The Ordovician rocks are highly siliceous eugeosynclinal sedimentary rocks; their geometric means have been calculated from analyses given by Ketner (1969, tables 3, 4). The Devonian rocks are largely metamorphosed, and the geometric means were calculated from analyses given by Shaw (1954, tables 7, 10, 13) by assigning his quantitative spectrographic data to the appropriate semiquantitative spectrographic classes used to calculate geometric means for the other groups of rock shown in table 11. The Cretaceous rocks are the marine Pierre Shale, and the geometric means were calculated from analyses given by Tourtelot (1962,

TABLE 11.—Average (geometric means) minor element content of pelitic rocks of different ages and geologic environments

[Results in parts per million. ...., insufficient or no data]

Element	Precambrian		Ordovician	Devonian	Cretaceous
	Mission Mountains Primitive Area: 124 pelitic rocks (this report)	Pend Oreille area: 79 pelitic rocks (this report)	Cordilleran geosyncline: 40 fine-grained nonfissile rocks and shale (Ketner, 1969)	Littleton Formation: 59 pelitic rocks (Shaw, 1954)	Pierre Shale: 67 shales (Tourtelot, 1962)
B	46	83	72	—	73
Ba	370	400	770	—	520
Co	14	4.8	—	18	12
Cr	35	34	52	110	70
Cu	14	6.8	47	9	46
La	30	43	—	—	32
Mn	330	74	220	—	220
Ni	25	14	15	57	33
Pb	8.4	4.0	—	18	13
Sc	11	7.9	—	12	15
Sr	42	25	61	630	150
V	54	58	200	110	160
Y	23	27	—	41	21
Zr	260	170	74	190	130

table 14). Data on the Mission Mountains and Pend Oreille rocks are given in tables 6 and 7 of this report.

Both the Ordovician and Cretaceous rocks contain abundant black shales, and, to choose Krauskopf's (1955, p. 418), careful phrasing, "some elements show a tendency to concentrate\*\*\*" in this particular rock type. The elements listed in table 11 that may show this tendency are Cr, Cu, Ni, Pb, and V (Krauskopf, 1955, table 2). Most of them are more abundant in the Ordovician and Cretaceous rocks than in the Belt rocks. One can cautiously infer that the metamorphosed pelitic rocks of the Devonian Littleton Formation of the Eastern United States originally included black shales, because they are enriched in all but Cu relative to the non-organic Precambrian pelitic rocks. Tourtelot (1962, p. 50-51) noted the close similarity in minor element content between the Pierre Shale and the Littleton Formation, but he chose not to infer that the close relation might be due to similarities among black shales. Perhaps the minor element content of Belt rocks more nearly represents that to be expected in pelitic rocks containing little or no organic material.

### CONCLUSIONS

Relatively inexpensive techniques of quantitative X-ray mineralogic determinations and semiquantitative spectrographic chemical analyses have provided data adequate for meaningful geologic interpretation of Belt rock sedimentation processes. The principal difference in mineralogy of three types of Belt clastic rocks involves presence or absence of carbonate cement, and this is reflected in the chemistry of those rocks containing

carbonate minerals by an increase in Ca, Mn, Sr, and Pb. The abundance of many elements is directly related to the abundance of the illite-sericite-chlorite fraction in the rock. Relative abundances of many elements in this fraction reflect ionic potential of the elements. Other differences in minor element chemistry are inferred to reflect source terrane. The occurrence and distribution of copper are the most significant in terms of economic geology. The more abundant copper appears related to source area of the sediments. Within a broad geographic area, certain strata may either contain stratiform deposits or represent source beds for secondary deposits.

The data obtained by using these techniques do not identify any metamorphic changes from the chlorite-sericite zone to the biotite zone of regional metamorphism except for a probable loss of boron. Contact metamorphism also in the biotite zone but resulting in formation of schists and gneisses was accompanied by an increase in Ca and Sr and a decrease in Ni, B, and possibly Co. The minor element content of pelitic Belt rocks is probably representative in general of nonorganic pelitic rocks as contrasted with black shales or pelitic rocks containing black shales as studied by others (Shaw, 1954; Tourtelot, 1962; Vine, 1966; Ketner, 1969).

#### REFERENCES CITED

- Anderson, A. L., 1930, Geology and ore deposits of the Clark Fork district, Idaho: Idaho Bur. Mines and Geology Bull. 12, 132 p.
- Bayley, R. W., and Muehlberger, W. R., compilers, 1968, Basement rock map of the United States (exclusive of Alaska and Hawaii): U.S. Geol. Survey map.
- Daly, R. A., 1914, Igneous rocks and their origin: New York, McGraw-Hill Book Co., 563 p.
- Fleischer, Michael, 1965, Summary of new data on rock samples G-1 and W-1, 1962-65: *Geochim. et Cosmochim. Acta*, v. 29, no. 12, p. 1263-1283.
- Goldschmidt, V. M., 1937, Principles of distribution of chemical elements in minerals and rocks: *Chem. Soc. London Jour.*, p. 655-673.
- Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for semiquantitative analysis of geologic materials: U.S. Geol. Survey Circ. 591, 6 p.
- Harrison, J. E., and Campbell, A. B., 1963, Correlations and problems in Belt Series stratigraphy, northern Idaho and western Montana: *Geol. Soc. America Bull.*, v. 74, no. 12, p. 1413-1427.
- Harrison, J. E., and Jobin, D. A., 1963, Geology of the Clark Fork quadrangle, Idaho-Montana: U.S. Geol. Survey Bull. 1141-K, 38 p.
- Harrison, J. E., Reynolds, M. W., Kleinkopf, M. D., and Pattee, E. C., 1969, Mineral resources of the Mission Mountains Primitive Area, Missoula and Lake Counties, Montana: U.S. Geol. Survey Bull. 1261-D, 48 p.
- Hirst, D. M., 1962, The geochemistry of modern sediments from the Gulf of Paria—[Pt.] 2, The location and distribution of trace elements: *Geochim. et Cosmochim. Acta*, v. 26, p. 1147-1187.

- Ketner, K. B., 1969, Ordovician bedded chert, argillite, and shale of the Cordilleran eugeosyncline in Nevada and Idaho, *in* Geological Survey research 1969: U.S. Geol. Survey Prof. Paper 650-B, p. B23-B34.
- Krauskopf, K. B., 1955, Sedimentary deposits of rare metals, pt. 1 *of* Bateman, A. M., ed., Economic geology—50th anniversary volume, 1905-55: Urbana, Ill., Econ. Geology Pub. Co., p. 411-463.
- McGill, G. E., and Sommers, D. A., 1967, Stratigraphy and correlation of the Precambrian Belt Supergroup of the southern Lewis and Clark Range, Montana: Geol. Soc. America Bull., v. 78, no. 3, p. 343-351.
- Mason, B. H., 1956, Principles of geochemistry [1st ed.]: New York, John Wiley & Sons, Inc., 276 p.
- Maxwell, D. T., and Hower, John, 1967, High-grade diagenesis and low-grade metamorphism of illite in the Precambrian Belt Series: *Am. Mineralogist*, v. 52, nos. 5-6, p. 843-857.
- Miesch, A. T., 1967, Methods of computation for estimating geochemical abundance: U.S. Geol. Survey Prof. Paper 574-B, 15 p.
- Mudge, M. R., 1970, Origin of the disturbed belt in northwestern Montana: Geol. Soc. America Bull., v. 81, no. 2, p. 377-392.
- Obradovich, J. D., and Peterman, Z. E., 1968, Geochronology of the Belt Series, Montana: *Canadian Jour. Earth Sci.*, v. 5, no. 3, pt. 2, p. 737-747.
- Parker, R. L., 1967, Composition of the earth's crust, *in* Fleischer, Michael, ed., Data of geochemistry [6th ed.]: U.S. Geol. Survey Prof. Paper 440-D, 19 p.
- Ross, C. P., 1963, The Belt series in Montana, *with* a geologic map compiled by B. A. L. Skipp, *and a section on* Paleontologic criteria, by Richard Rezak: U.S. Geol. Survey Prof. Paper 346, 122 p. [1964].
- Rubey, W. W., 1951, Geologic history of sea water: Geol. Soc. America Bull., v. 62, no. 9, 1111-1147.
- 1956, Major elements and general geochemistry, pt. 3 *of* Geochemistry of pelitic rocks [N.H.]: Geol. Soc. America Bull., v. 65, no. 12, p. 1151-1166.
- 1956 Major elements and general geochemistry, pt. 3 *of* Geochemistry of pelitic rocks: Geol. Soc. America Bull., v. 67, no. 7, p. 919-934.
- Shaw, D. M., Reilly, G. A., Muysson, J. R., Pattenden, G. E., and Campbell, F. E., 1967, An estimate of the chemical composition of the Canadian Precambrian Shield: *Canadian Jour. Earth Sci.*, v. 4, no. 5, p. 829-853.
- Tatlock, D. B., 1966, Rapid modal analysis of some felsic rocks from calibrated X-ray diffraction patterns: U.S. Geol. Survey Bull. 1209, 41 p.
- Tourtletot, H. A., 1962, Preliminary investigation of the geologic setting and chemical composition of the Pierre shale, Great Plains region: U.S. Geol. Survey Prof. Paper 390, 74 p.
- Vine, J. D., 1966, Element distribution in some shelf and eugeosynclinal black shales: U.S. Geol. Survey Bull. 1214-E, p. E1-E31.