UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Petrographic study of sandstones from measured sections of the Morrison Formation and related units, southwestern San Juan Basin, New Mexico

By

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INTRODUCTION

In this study certain petrographic features, grain size, roundness and sphericity and modal petrographic analysis were determined for outcropping sandstones of the Jurassic Morrison Formation and related stratigraphic units in the southwestern part of the San Juan Basin about midway between Gallup and Crownpoint, New Mexico (fig. 1). Here the Morrison Formation is divided into three members: the Recapture (Jmr), the Westwater Canyon (Jmw), and the Brushy Basin (Jmb), in ascending order. The Morrison is overlain by the Cretaceous Dakota Sandstone and underlain by the Jurassic Cow Springs Sandstone (Jcs) and Summerville(?) Formation (Js?). The formation and member symbols are used on some figures and in Appendix A. The sequence of stratigraphic units and brief descriptions are given in table 1. Samples were taken from two measured sections of the Summerville(?) or Cow Springs through the Morrison and into the Brushy Basin Member. The stratigraphic sections were measured and sampled by A. Curtis Huffman and Allan Kirk of the U.S. Geological Survey during the summer of 1980. Sampling of sandstones was not entirely systematic but was representative of available outcrops. The two measured sections, referred to as Pinedale East and Pinedale West, were chosen because they are the nearest outcrops of the Morrison Formation to a series of drill holes testing the Morrison Formation in the subsurface.

Grain size was measured directly under the microscope as the maximum dimension in millimeters and converted to phi values. The phi values are negative logarithms to the base two of the millimeter class limits. Use of the phi scale is advantageous when making statistical measurements. A mimimum of 100 grains were measured for each sample. Roundness and sphericity of sand grains were measured under the microscope by comparing grain shapes with those in a chart prepared by Krumbein and Sloss (1963, p. 111). At least 100 grains

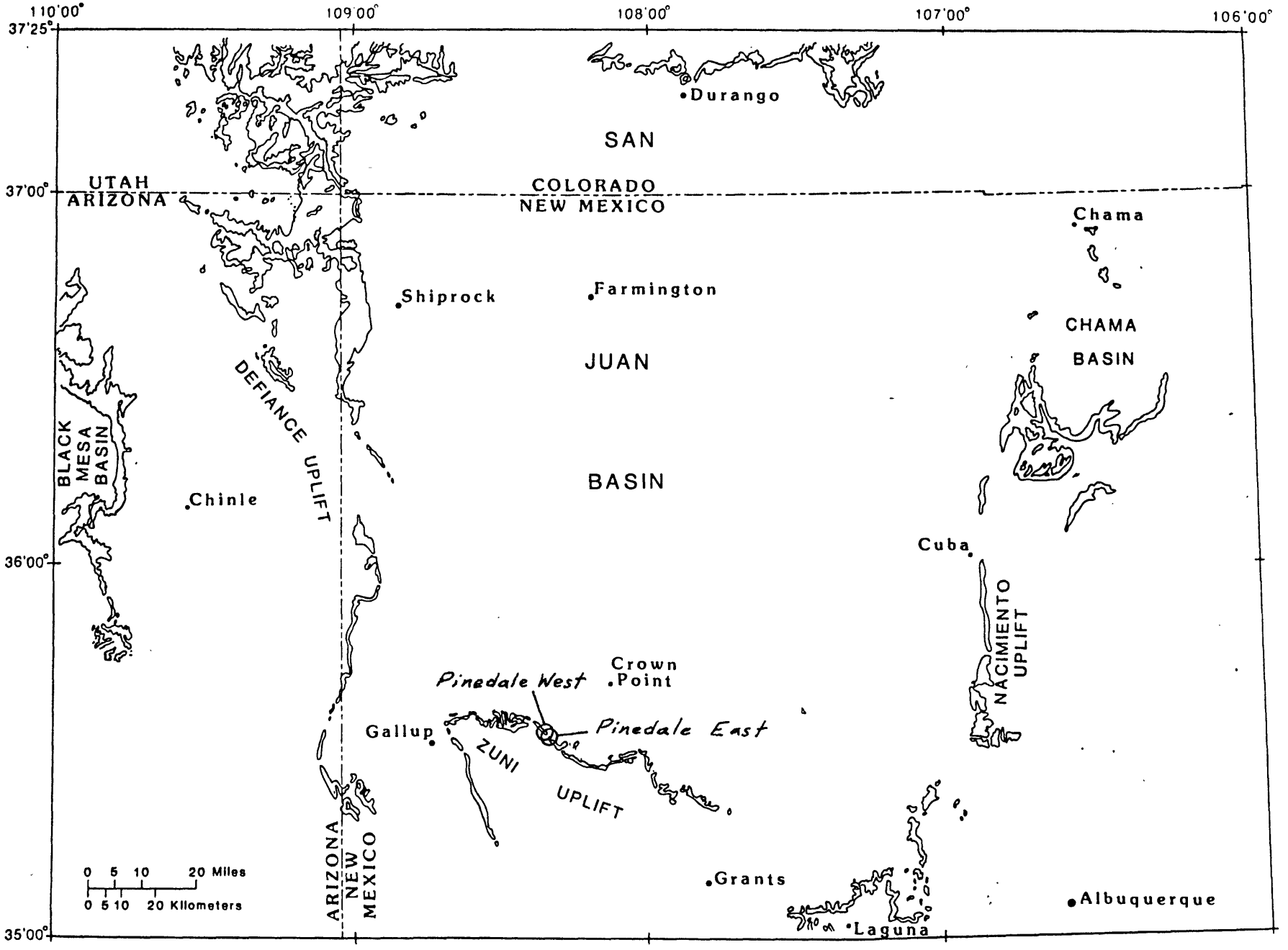


Figure 1.--Outline map of the San Juan Basin showing outcrops of the Morrison Formation and locations of measured sections.

Table 1. Sequence of stratigraphic units (modified from Green and Jackson, 1975).

Age	Formation	Thickness in meters	Description
Cretaceous	Dakota Sandstone	17-43	Yellowish-brown to buff fine- to medium-grained well-sorted massive to thin-bedded planar and trough crossbedded siliceous sandstone. Laminated black to dark-gray carbonaceous shale occurs at the base and is interbedded locally. Lower contact is sharp and unconformable.
	Unconformity		
Late Jurassic	Morrison Formation	124-135	Brushy Basin Member: greenish- to purplish-gray claystone and sandy siltstone; thinly bedded to laminated; contains lenses of yellowish-brown, pink, and white fine- to coarse-grained poorly sorted feldspathic sandstone; intertongues with Westwater Canyon Member.
			Westwater Canyon Member: light- to deep-reddish-orange fine- to coarse-grained poorly sorted friable trough crossbedded feldspathic sandstone. Contains lenses of conglomeratic sandstone and a few thin lenses of siltstone and claystone.
			Recapture Member: complexly interbedded reddish-brown clayey siltstone and light-pink to white very fine- to medium-grained well-sorted sandstone. Interbedded with underlying Cow Springs Sandstone.
	Cow Springs Sandstone	101	Light-greenish-gray to light-gray, pale-orange, and light-reddish-brown fine- to medium-grained well-sorted sandstone. Thick cosets of cross-strata are interbedded with thick cosets of flat strata.
	Summerville (?) Formation	40	Reddish-brown to light-orange very fine- to fine-grained well-rounded massive to laminated parallel stratified silty sandstone.

were measured for each sample. The composition of the sandstones was determined by modal analysis using a point counting technique according to the method of Chayes (1949). At least 300 points were counted for each sample.

This work is part of a task force approach to the study of the geology, mineralogy, geochemistry, geophysics and uranium resources of the San Juan Basin. The primary goal of the task force is to further an understanding of uranium geology in the basin. Since sandstones of the Morrison Formation are the main host for uranium it was hoped that a study of the petrography of Morrison sandstones would shed some light on uranium favorability.

PETROGRAPHY

Grain Size Data

In the Pinedale East measured section (Appendix A) the dominant grain size of sandstones from the Brushy Basin Member of the Morrison Formation was fine to very fine sand. The dominant grain size for sandstones from the Westwater Canyon Member ranged from very fine sand to coarse sand. The main grain size for sandstones from the Recapture was fine to medium sand. The prevailing grain size for all the sandstone samples from the Cow Springs Sandstone was fine sand. For sandstones of the Summerville(?) Formation the dominant grain size was fine to very fine sand. In the Pinedale West measured section (Appendix A) the principal grain size of sandstone from the Brushy Basin (one sample) was fine sand. The dominant grain size of sandstones from the Westwater Canyon ranged from very fine sand to coarse sand, the same range as in the Pinedale East section. In the Recapture the main grain size of sandstones was fine to medium sand, again the same range as in the Pinedale East section. In the Cow Springs the principal grain size of sandstones was fine to medium sand.

Sandstones of the Westwater Canyon Member of the Morrison Formation, principal host for uranium deposits in the area, have the greatest range in dominant grain size. Whether this range in grain size is meaningful with regard to uranium favorability is unknown.

Roundness and Sphericity

Roundness is defined by the A.G.I. Glossary of Geology (1960) as the ratio of the average radius of curvature of the several corners or edges of a solid to the radius of curvature of the maximum inscribed sphere. Sphericity is defined by the same source as the degree in which the shape of a fragment approaches the form of a sphere. Therefore, a grain that is highly rounded does not necessarily have high sphericity.

The grain shape data for both Pinedale East and Pinedale West sections for all stratigraphic units that were measured are very similar. The grains are only moderately well rounded but have high sphericity. Why this is the case regardless of stratigraphic unit is unclear.

Modal Analysis

The sandstones were studied under the microscope by the methods of petrographic volumetric modal analysis to determine composition. For purposes of discussion the composition is divided into framework constituents, matrix, cement, alteration products and pores.

Framework constituents.--Framework constituents include quartz, feldspar, lithic fragments, mica and heavy minerals. Quartz was further divided into monocrystalline and polycrystalline varieties as well as the cryptocrystalline varieties, chert and chalcedony. Feldspar was subdivided into microcline, other K-spar and plagioclase. Lithic fragments were classified as igneous, both volcanic and plutonic types, metamorphic and sedimentary. Mica is either biotite or muscovite. Heavy minerals were only rarely encountered in thin

sections but include all common varieties such as zircon, tourmaline and opaques.

In the Pinedale East measured section (Appendix A) monocrystalline quartz in Brushy Basin sandstones ranges from 39.6 percent to 51.0 percent and averages 45.6 percent. In Westwater Canyon sandstones monocrystalline quartz ranges from 31.2 percent to 57.7 percent and averages 46.1 percent. Recapture sandstones contain 41.5 percent to 65.3 percent quartz and average 50.4 percent. Cow Springs sandstones contain 48.3 percent to 71.0 percent monocrystalline quartz and average 58.5 percent. Sandstones in the Summerville(?) Formation contain 55.0 percent to 62.0 percent, averaging 59.4 percent.

In the Pinedale West measured section (Appendix A) there was only one sample of Brushy Basin sandstone and it contained 45.2 percent monocrystalline quartz. There were sixteen sandstone samples from the Westwater Canyon which contained 33.3 percent to 78.7 percent monocrystalline quartz, averaging 53.6 percent. Recapture sandstones contained 48.7 percent to 55.0 percent quartz with an average of 51.1 percent. There were only two samples of Cow Springs sandstones and they averaged 58.6 percent quartz.

Comparison of the data from Pinedale East and Pinedale West sections shows that Morrison sandstones average about 50 percent monocrystalline quartz. Perhaps Brushy Basin sandstones average somewhat less quartz than Westwater Canyon and Recapture sandstones but more samples of Brushy Basin would be needed to confirm this. Cow Springs sandstones average more monocrystalline quartz than Morrison sandstones.

Generally these sandstones contain a few percent or less of polycrystalline quartz, chert and chalcedony. Polycrystalline quartz is encountered in nearly all samples, chert is encountered in many and chalcedony

in a few.

In the Pinedale East measured section (Appendix A) Brushy Basin sandstones averaged 2.0 percent total feldspar. Sandstones in the Westwater Canyon averaged 7.5 percent total feldspar. Recapture sandstones averaged 1.6 percent feldspar. Sandstones in the Cow Springs averaged 1.9 percent total feldspar. Summerville(?) sandstones averaged 2.1 percent feldspar. Therefore, all stratigraphic units averaged about 2 percent total feldspar with the exception of the Westwater Canyon which averaged 7.5 percent feldspar. Clearly the Westwater Canyon is more arkosic than any of the other units.

The Brushy Basin sandstone that was sampled in the Pinedale West measured section (Appendix A) contained 6.3 percent feldspar. The Westwater Canyon sandstone averaged 6.5 percent total feldspar and ranged from 0 to 18 percent. The Recapture sandstones averaged 1.5 percent feldspar and the Cow Springs averaged 0.7 percent (two samples).

Generally there was more other K-spar than either microcline or plagioclase for all units sampled. Extinction angles for albite-twinned plagioclase indicate that the plagioclase is either albite or andesine, probably albite.

Most of the samples contained lithic fragments but identification of rock type was uncertain in many cases. When it was possible to identify the lithic fragments they were classified as igneous, metamorphic or sedimentary. Most of the lithics identified were volcanic, indicating that the provenance includes volcanic rocks.

Mica was occasionally present in small amounts as biotite or muscovite. Mica is not common in any of the rocks examined.

Heavy minerals were present in most samples in small amounts but were

only occasionally encountered in point counting. Opaques, tourmaline and zircon were identified.

Matrix.--The matrix of the rocks consists of undifferentiated clay minerals and probably some very fine-grained quartz and feldspar. Samples from the Brushy Basin Member of the Morrison Formation contained more matrix material than any of the other units, ranging from about 38 percent to 48 percent. Samples from the Westwater Canyon contained a highly variable matrix component, ranging from 0 to 33 percent but mostly less than 10 percent.

Cement.--Cementing material for these sandstones includes quartz, calcite, limonite or hematite, and kaolinite. Calcite is the most abundant cement and ranges from 0 to 45.6 percent for all samples. All sandstones from the Recapture Member of the Morrison Formation from both measured sections contained significant amounts of calcite cement whereas many sandstones from the Westwater Canyon contained no calcite at all.

Alteration products.--Alteration minerals that were identified in point counts are sericite and kaolinite. Some of the sericite is an alteration product of plagioclase and some is of unknown derivation. Kaolinite is considered to be an alteration product of an unknown mineral. Kaolinite occurs in the Morrison Formation in amounts of a couple percent or less.

Pores.--The thin sections used in this study were all impregnated with blue-dyed epoxy, which emphasizes voids or pore space. Primary porosity is that which occurs as the true porosity of the rocks; secondary porosity is that which develops as a result of thin section preparation. In some thin sections plucking of grains was extensive and percent voids include a large component of secondary porosity. Porosity of the Westwater Canyon ranges from 1.9 percent to 40.0 percent, whereas porosity of the Brushy Basin ranges from 0.3 percent to 8.3 percent.

Rock Classification

There are numerous schemes that are used to classify sandstones, some of which are reviewed by Scholle (1979, p. 94-96). The system used here is that of Folk (1968, p. 120-125). Folk's classification makes use of a triangular diagram with quartz plus metaquartzite at one apex (Q), feldspar plus granitic rock fragments plus gneissic rock fragments at the second apex (F) and other unstable rock fragments plus chert at the third apex (R). The data for Pinedale East are shown in Figure 2 and that for Pinedale West are shown in Figure 3. Brushy Basin sandstones plot in the quartzarenite and subarkose fields of the triangle. Sandstone from the Westwater Canyon has the greatest amount of variation, plotting as quartzarenite, subarkose, sublitharenite and arkose. Most of the samples from the Westwater Canyon are subarkoses and are more feldspathic than most of the other samples. The more feldspathic sandstones of the Westwater Canyon are also coarser grained than the less feldspathic samples. Recapture sandstones plot as quartzarenite, subarkose and sublitharenite and are not nearly as arkosic as most of the Westwater Canyon. Sandstones of the Cow Springs are mostly quartzarenite while sandstones of the Summerville(?) are quartzarenite and subarkose.

CONCLUSIONS

This work is mostly of a preliminary nature and little can be said about the relationship of the petrography to uranium mineralization. The Pinedale East and Pinedale West measured sections are unmineralized and are therefore representative of barren Morrison sandstones. Comparison of those rocks with mineralized sandstones might show significant differences.

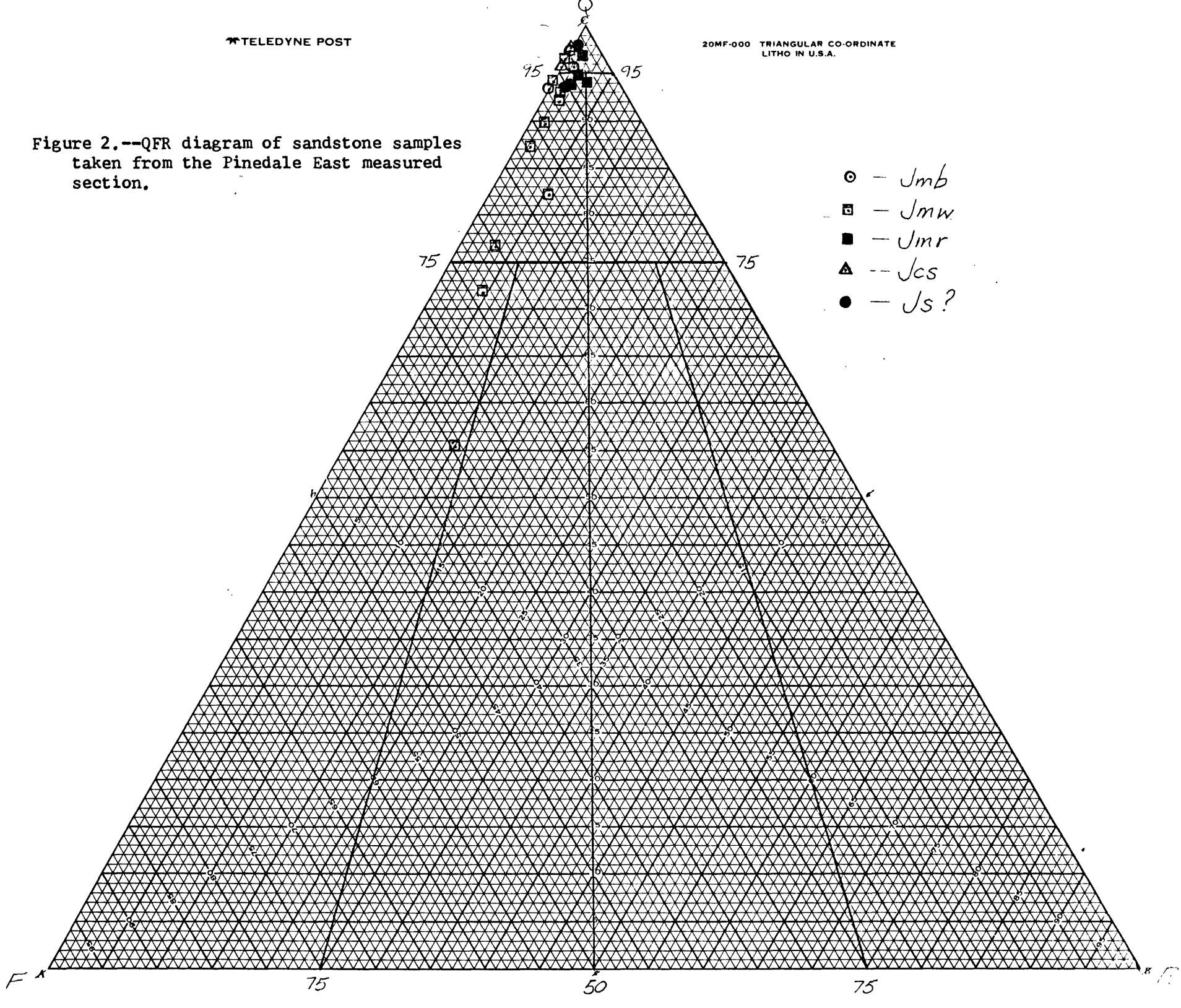
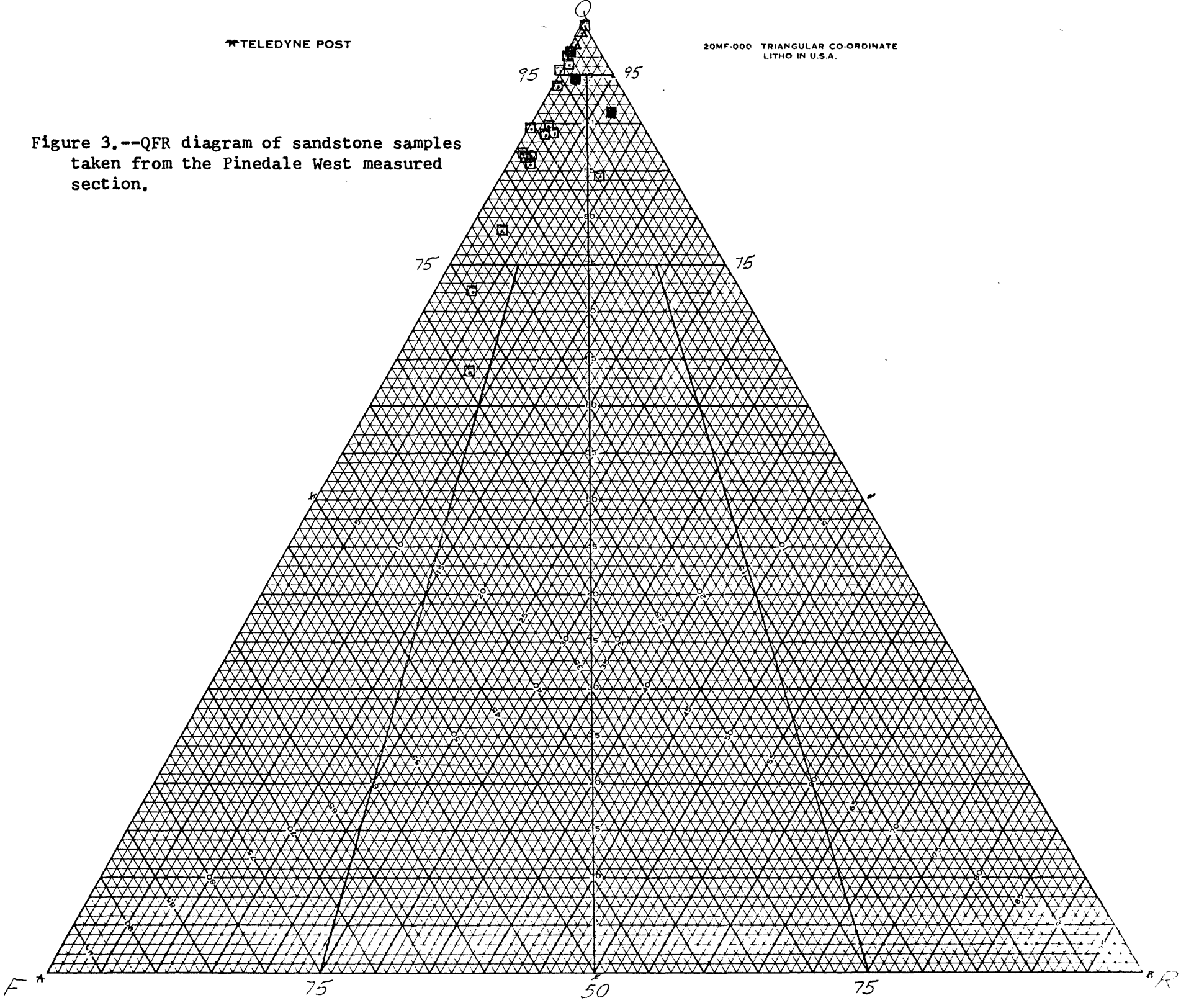


Figure 2.--QFR diagram of sandstone samples taken from the Pinedale East measured section.

Figure 3.--QFR diagram of sandstone samples taken from the Pinedale West measured section.



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Appendix A

Pinedale *East* measured section

Sample No. *80-SCH-2PEP* Stratigraphic Unit *Us?*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	1
.25	2	27
.125	3	72
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	2	12	13	10	4
0.7	7	18	15	4	
0.5		8	7		
0.3					

100 counts

monocrystalline quartz *171 – 55.0%*

polycrystalline quartz *6 – 1.9%*

chert *3 – 1.0%*

chalcedony

microcline *1 – 0.3%*

other K-spar *8 – 2.6%*

plagioclase *1 – 0.3%*

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite) *2 – 0.6%*

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite *16 – 5.1%*

limonite/hematite

sericite *1 – 0.3%*

kaolinite

pores *102 – 32.8%*

311 counts

Pinedale *East* measured section

Sample No. *80-SCH-3PEP* Stratigraphic Unit *Js?*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	1
.25	2	53
.125	3	46
.0625	4	
.0313	5	
.0156	6	

100 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	3	12	13	10	1
0.7	3	19	21	10	2
0.5		4	2		
0.3					

100 counts

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monocrystalline quartz *184 – 61.1 %*

polycrystalline quartz

chert *1 – 0.3 %*

chalcedony

microcline *1 – 0.3 %*

other K-spar *5 – 1.7 %*

plagioclase

plutonic lithic fragment

volcanic lithic fragment *3 – 1.0 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite *72 – 23.9 %*

limonite/hematite

sericite

kaolinite

pores *35 – 11.6 %*

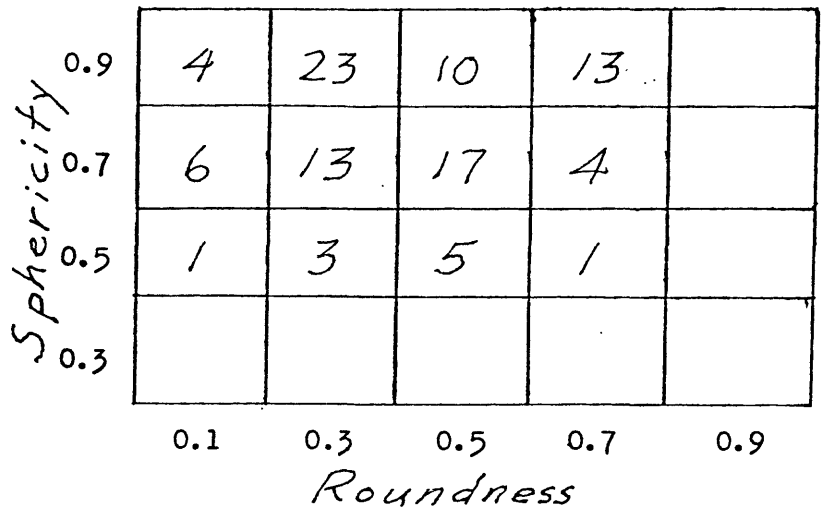
301 counts

Pinedale East measured section

Sample No. 80-SCH-4PEP Stratigraphic Unit Us?

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	1
.25	2	48
.125	3	51
.0625	4	
.0313	5	100 counts
.0156	6	



100 counts

monocrystalline quartz 186 - 62.0 %

polycrystalline quartz 2 - 0.7 %

chert

chalcedony

microcline 2 - 0.7 %

other K-spar

plagioclase 1 - 0.3 %

plutonic lithic fragment

volcanic lithic fragment 1 - 0.3 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite 1 - 0.3 %

zircon 1 - 0.3 %

tourmaline

opaques 3 - 1.0 %

matrix

quartz cement 4 - 1.3 %

calcite 45 - 15.0 %

limonite/hematite

sericite

kaolinite

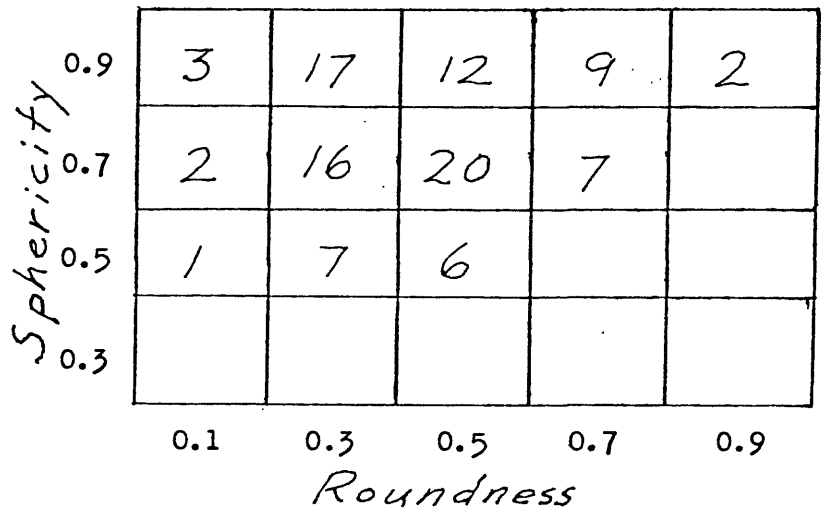
pores 54 - 18.0 %

Pinedale East measured section

Sample No. 80-5CH-5PEP Stratigraphic Unit Jcs

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	
.25	2	51
.125	3	
.0625	4	49
.0313	5	100 counts
.0156	6	



102 counts

monocrystalline quartz 188 - 61.8%

polycrystalline quartz 4 - 1.3%

chert 1 - 0.3%

chalcedony

microcline

other K-spar 4 - 1.3%

plagioclase

plutonic lithic fragment

volcanic lithic fragment 1 - 0.3%

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

304 counts

biotite

muscovite

zircon

tourmaline

opaques 2 - 0.7%

matrix

quartz cement

calcite 31 - 10.2%

limonite/hematite

sericite 1 - 0.3%

kaolinite

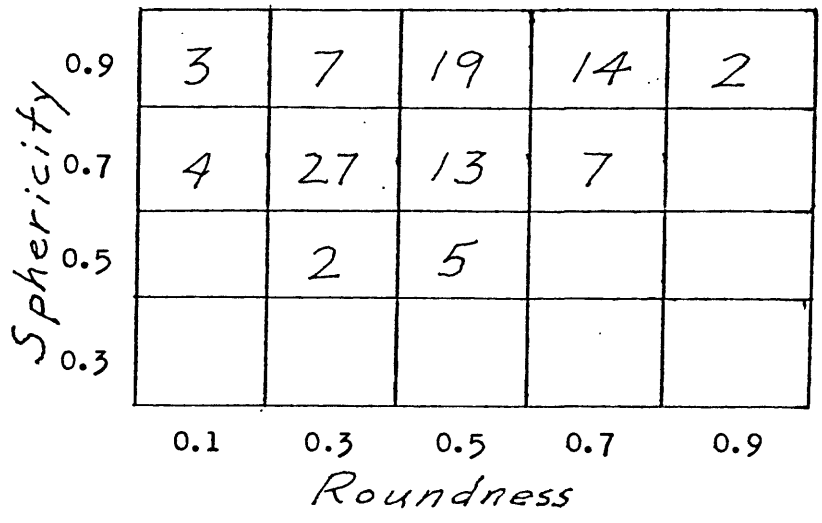
pores 72 - 23.7%

Pinedale *East* measured section

Sample No. *80-SCH-6PEP* Stratigraphic Unit *Ucs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	*100 counts*
0.5	1	
.25	2	68
.125	3	
.0625	4	30
.0313	5	2
.0156	6	



103 counts

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monocrystalline quartz *213 – 71.0 %*

polycrystalline quartz *3 – 1.0 %*

chert *2 – 0.7 %*

chalcedony

microcline *2 – 0.7 %*

other K-spar *4 – 1.3 %*

plagioclase *1 – 0.3 %*

plutonic lithic fragment

volcanic lithic fragment *1 – 0.3 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques *6 – 2.0 %*

matrix *10 – 3.3 %*

quartz cement

calcite

limonite/hematite *1 – 0.3 %*

sericite

kaolinite

pores *57 – 19.0 %*

Pinedale *East* measured section

Sample No. *80-SCH-7PEP* Stratigraphic Unit *Ucs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	*100 counts*
0.5	1	
.25	2	*95*
.125	3	*5*
.0625	4	
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	1	16	18	14	2
0.7	1	20	18	3	
0.5		1	6		
0.3					

100 counts

monocrystalline quartz *203 – 67.7 %*

polycrystalline quartz *4 – 1.3 %*

chert

chalcedony

microcline *2 – 0.7 %*

other K-spar *4 – 1.3 %*

plagioclase *1 – 0.3 %*

plutonic lithic fragment

volcanic lithic fragment *1 – 0.3 %*

metamorphic lithic fragment (metaquartzite) *1 – 0.3 %*

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix *3 – 1.0 %*

quartz cement

calcite

limonite/hematite *2 – 0.7 %*

sericite

kaolinite

pores *79 – 26.3 %*

Pinedale *East* measured section

Sample No. *80-SCH-9PEP* Stratigraphic Unit *Ucs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	*100 counts*
2	-1	
1	0	*1*
0.5	1	*42*
.25	2	*52*
.125	3	*4*
.0625	4	*1*
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	1	13	11	22	7
0.7	1	8	23	6	
0.5		2	5		
0.3			1		

100 counts

monocrystalline quartz *147 — 49.0 %*

polycrystalline quartz *2 — 0.7 %*

chert

chalcedony

microcline

other K-spar *4 — 1.3 %*

plagioclase

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix *75 — 25.0 %*

quartz cement

calcite *1 — 0.3 %*

limonite/hematite

sericite

kaolinite

pores *71 — 23.7 %*

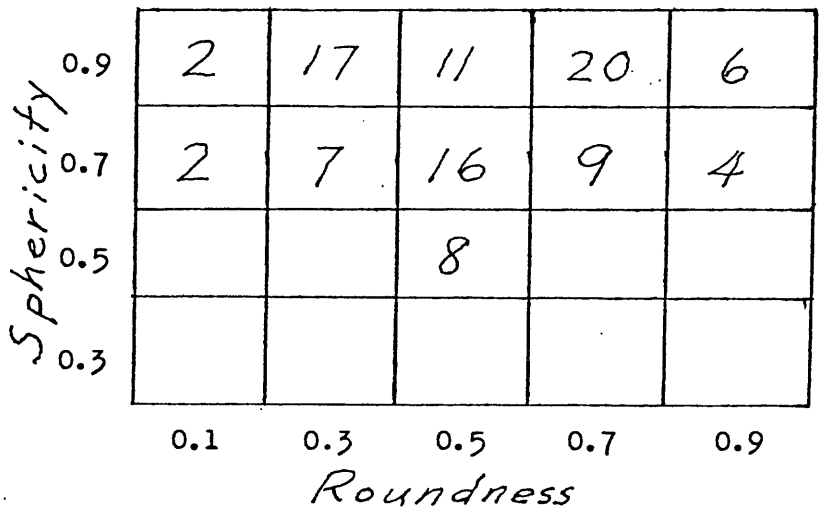
300 counts

Pinedale *East* measured section

Sample No. *80-SCH-10 PEP* Stratigraphic Unit *Jcs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	100 counts
0.5	1	26
.25	2	62
.125	3	12
.0625	4	
.0313	5	
.0156	6	



102 counts

monocrystalline quartz *179 – 58.7 %*

polycrystalline quartz *2 – 0.7 %*

chert

chalcedony

microcline *2 – 0.7 %*

other K-spar *5 – 1.6 %*

plagioclase *1 – 0.3 %*

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques *1 – 0.3 %*

matrix *2 – 0.7 %*

quartz cement

calcite *96 – 31.5 %*

limonite/hematite

sericite

kaolinite

pores *17 – 5.6 %*

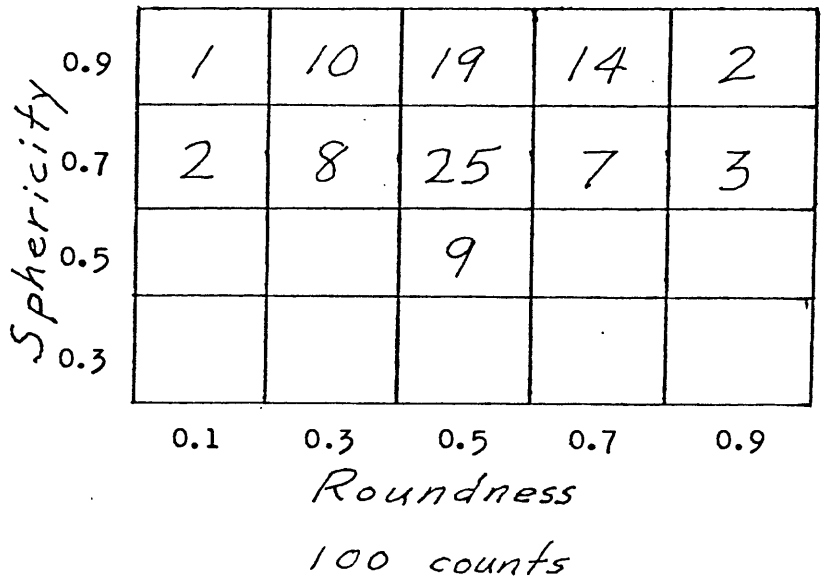
305 counts

Pinedale East measured section

Sample No. 80-SCH-11 PEP Stratigraphic Unit Ucs

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	100 counts
0.5	1	42
.25	2	50
.125	3	8
.0625	4	
.0313	5	
.0156	6	



100 counts

monocrystalline quartz 161 – 52.8 %

polycrystalline quartz 1 – 0.3 %

chert

chalcedony

microcline 1 – 0.3 %

other K-spar 5 – 1.6 %

plagioclase

plutonic lithic fragment

volcanic lithic fragment 3 – 1.0 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix 35 – 11.5 %

quartz cement

calcite 38 – 12.4 %

limonite/hematite

sericite

kaolinite

pores 61 – 20.0 %

305 counts

Pinedale *East* measured section

Sample No. *80-SCH-12 PEP* Stratigraphic Unit *Ucs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	100 counts.
1	0	
0.5	1	25
.25	2	70
.125	3	5
.0625	4	
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	2	17	24	14	3
0.7	3	3	22	7	
0.5		2	2		1
0.3					

100 counts

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monocrystalline quartz *145 — 48.3%*

polycrystalline quartz *1 — 0.3%*

chert *1 — 0.3%*

chalcedony

microcline

other K-spar *4 — 1.3%*

plagioclase *1 — 0.3%*

plutonic lithic fragment

volcanic lithic fragment *2 — 0.7%*

metamorphic lithic fragment *1 — 0.3%*
(metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix *33 — 11.0%*

quartz cement

calcite *1 — 0.3%*

limonite/hematite

sericite *1 — 0.3%*

kaolinite

pores *110 — 36.7%*

Pinedale East measured section

Sample No. 80-SCH-14PEP Stratigraphic Unit Jmr

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	3
0.5	1	46
.25	2	45
.125	3	6
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	1	18	11	5	7
0.7	4	9	27	6	1
0.5		1	7	1	
0.3			2		

100 counts

---

monocrystalline quartz 165 - 47.0 %

polycrystalline quartz 3 - 0.9 %

chert 1 - 0.3 %

chalcedony

microcline

other K-spar 4 - 1.1 %

plagioclase 1 - 0.3 %

plutonic lithic fragment

volcanic lithic fragment 5 - 1.4 %

metamorphic lithic fragment (metaquartzite) 1 - 0.3 %

sedimentary lithic fragment

351 counts

biotite

muscovite

zircon

tourmaline

opaques 2 - 0.6 %

matrix

quartz cement

calcite 160 - 45.6 %

limonite/hematite

sericite

kaolinite

pores 9 - 2.6 %

Pinedale East measured section

Sample No. 80-SCH-16PEP Stratigraphic Unit Umr

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	100 counts
1	0	
0.5	1	14
.25	2	72
.125	3	14
.0625	4	
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	5	16	16	9	2
0.7	3	13	25	1	1
0.5			6		2
0.3			1		

100 counts

monocrystalline quartz 137 - 41.5 %

polycrystalline quartz

chert 1 - 0.3 %

chalcedony

microcline

other K-spar 5 - 1.5 %

plagioclase

plutonic lithic fragment

volcanic lithic fragment 2 - 0.6 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

330 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix 29 - 8.8 %

quartz cement

calcite 54 - 16.4 %

limonite/hematite

sericite

kaolinite

pores 102 - 30.9 %

Pinedale East measured section

Sample No. 80-SCH-17PEP Stratigraphic Unit Jmr

Max. grain size

mm	ϕ	
8	-3	
4	-2	100 counts
2	-1	
1	0	2
0.5	1	42
.25	2	53
.125	3	3
.0625	4	
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	3	13	18	14	3
0.7	2	12	23	4	
0.5			8		
0.3					

100 counts

monocrystalline quartz	143 – 47.7%	biotite	
polycrystalline quartz	2 – 0.7%	muscovite	
chert	2 – 0.7%	zircon	
chalcedony		tourmaline	
microcline		opaques	
other K-spar	7 – 2.3%	matrix	5 – 1.7%
plagioclase		quartz cement	
plutonic lithic fragment		calcite	97 – 32.3%
volcanic lithic fragment	1 – 0.3%	limonite/hematite	
metamorphic lithic fragment (metaquartzite)		sericite	1 – 0.3%
		kaolinite	2 – 0.7%
sedimentary lithic fragment		pores	40 – 13.3%

300 counts

Pinedale East measured section

Sample No. 80-SCH-18PEP Stratigraphic Unit Jmr

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	3
0.5	1	48
.25	2	47
.125	3	2
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	3	11	16	15	5
0.7	5	11	21	4	
0.5			8		
0.3			1		

100 counts

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monocrystalline quartz	196 – 65.3 %	biotite	
polycrystalline quartz	13 – 4.3 %	muscovite	1 – 0.3 %
chert		zircon	
chalcedony	1 – 0.3 %	tourmaline	
microcline	1 – 0.3 %	opaques	1 – 0.3 %
other K-spar	3 – 1.0 %	matrix	24 – 8.0 %
plagioclase		quartz cement	
plutonic lithic fragment		calcite	15 – 5.0 %
volcanic lithic fragment	2 – 0.7 %	limonite/hematite	
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	5 – 1.7 %
sedimentary lithic fragment		pores	38 – 12.7 %

300 counts

Pinedale East measured section

Sample No. 80-SCH-19 PEP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	8
1	0	33
0.5	1	57
.25	2	10
.125	3	
.0625	4	
.0313	5	
.0156	6	

108 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	9	14	12	17	6
0.7	2	6	19	2	2
0.5		4	7		
0.3					

100 counts

monocrystalline quartz	135 - 44.3 %	biotite	
polycrystalline quartz	6 - 2.0 %	muscovite	
chert		zircon	
chalcedony		tourmaline	
microcline	6 - 2.0 %	opaques	
other K-spar	24 - 7.9 %	matrix	
plagioclase	3 - 1.0 %	quartz cement	
plutonic lithic fragment	4 - 1.3 %	calcite	58 - 19.0 %
volcanic lithic fragment	6 - 2.0 %	limonite/hematite	27 - 8.9 %
metamorphic lithic fragment (metaquartzite)		sericite	3 - 1.0 %
		kaolinite	4 - 1.3 %
sedimentary lithic fragment		pores	29 - 9.5 %

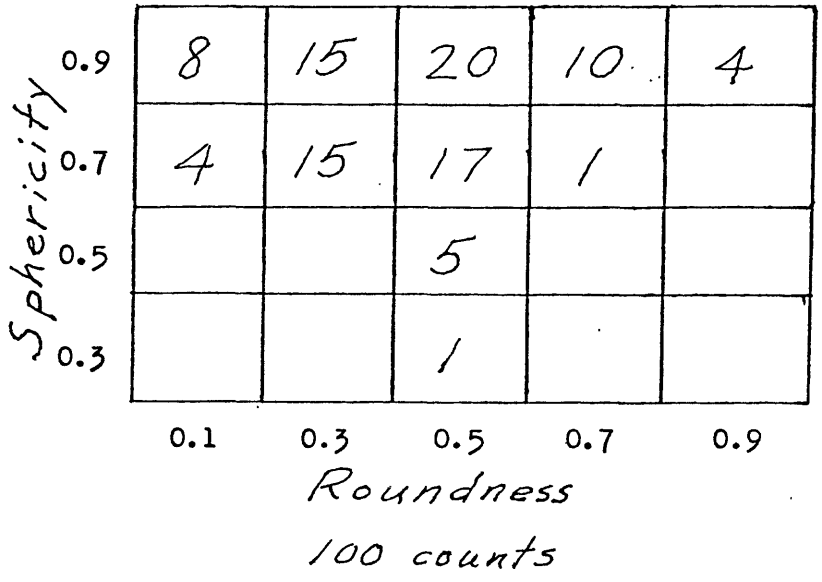
305 counts

Pinedale *East* measured section

Sample No. *80-SCH-20 PEP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	100 counts
1	0	1
0.5	1	21
.25	2	72
.125	3	6
.0625	4	
.0313	5	
.0156	6	



100 counts

monocrystalline quartz *129 — 43.0 %*

polycrystalline quartz *2 — 0.7 %*

chert *1 — 0.3 %*

chalcedony

microcline

other K-spar *11 — 3.7 %*

plagioclase *1 — 0.3 %*

plutonic lithic fragment *1 — 0.3 %*

volcanic lithic fragment *1 — 0.3 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite

limonite/hematite *33 — 11.0 %*

sericite

kaolinite *4 — 1.3 %*

pores *117 — 39.0 %*

300 counts

Pinedale East measured section

Sample No. 80-SCH-21 PEP Stratigraphic Unit Umw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	106 counts
1	0	14
0.5	1	62
.25	2	24
.125	3	5
.0625	4	1
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	4	7	20	21	3
0.7	3	4	14	6	
0.5		1	14	1	1
0.3				1	

100 counts

monocrystalline quartz	144 – 45.9 %	biotite	
polycrystalline quartz	4 – 1.3 %	muscovite	
chert		zircon	
chalcedony	1 – 0.3 %	tourmaline	
microcline	3 – 1.0 %	opaques	
other K-spar	15 – 4.8 %	matrix	
plagioclase	2 – 0.6 %	quartz cement	
plutonic lithic fragment		calcite	127 – 40.4 %
volcanic lithic fragment		limonite/hematite	5 – 1.6 %
metamorphic lithic fragment (metaquartzite)	1 – 0.3 %	sericite	
sedimentary lithic fragment	1 – 0.3 %	kaolinite	5 – 1.6 %
		pores	6 – 1.9 %

314 counts

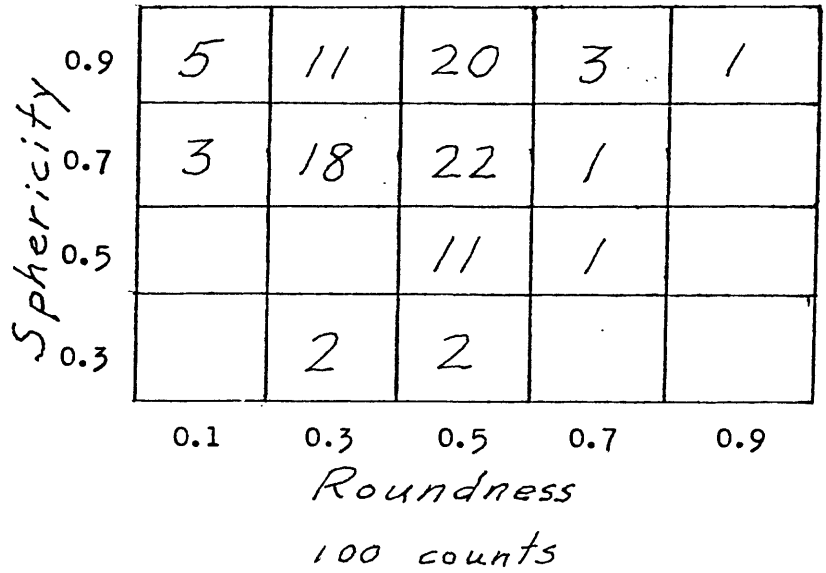
Pinedale *East* measured section

Sample No. *80-SCH-22 PEP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	13
.25	2	76
.125	3	11
.0625	4	
.0313	5	
.0156	6	

100 counts



100 counts

monocrystalline quartz	*159 – 53.0 %*	biotite	
polycrystalline quartz	*2 – 0.7 %*	muscovite	*1 – 0.3 %*
chert		zircon	
chalcedony	*1 – 0.3 %*	tourmaline	
microcline	*1 – 0.3 %*	opaques	
other K-spar	*10 – 3.3 %*	matrix	*10 – 3.3 %*
plagioclase		quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment	*2 – 0.7 %*	limonite/hematite	*5 – 1.7 %*
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	*1 – 0.3 %*
sedimentary lithic fragment		pores	*108 – 36.0 %*

300 counts

Pinedale East measured section

Sample No. 80-SCH-23PEP Stratigraphic Unit JmW

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	11
1	0	63
0.5	1	21
.25	2	5
.125	3	
.0625	4	100 counts
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	7	12	16	19	6
0.7	6	9	16	1	2
0.5		1	5		
0.3					

100 counts

monocrystalline quartz 108 - 36.0 %

polycrystalline quartz 13 - 4.3 %

chert 4 - 1.3 %

chalcedony 1 - 0.3 %

microcline 5 - 1.7 %

other K-spar 32 - 10.7 %

plagioclase 1 - 0.3 %

plutonic lithic fragment 2 - 0.7 %

volcanic lithic fragment 2 - 0.7 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment 1 - 0.3 %

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix 3 - 1.0 %

quartz cement

calcite 37 - 12.3 %

limonite/hematite 7 - 2.3 %

sericite 11 - 3.7 %

kaolinite 9 - 3.0 %

pores 64 - 21.3 %

Pinedale East measured section

Sample No. 80-SCH-24 PEP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	8
0.5	1	64
.25	2	31
.125	3	1
.0625	4	
.0313	5	
.0156	6	

104 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	4	11	17	22	6
0.7	3	7	17	5	1
0.5	1	1	7		
0.3					

102 counts

monocrystalline quartz	153 – 51.0 %	biotite	
polycrystalline quartz	5 – 1.7 %	muscovite	
chert	1 – 0.3 %	zircon	
chalcedony		tourmaline	
microcline	1 – 0.3 %	opaques	
other K-spar	9 – 3.0 %	matrix	87 – 29.0 %
plagioclase		quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	19 – 6.3 %
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	3 – 1.0 %
sedimentary lithic fragment	1 – 0.3 %	pores	21 – 7.0 %

300 counts

Pinedale East measured section

Sample No. 80-SCH-25 PEP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	12
0.5	1	55
.25	2	33
.125	3	
.0625	4	100 counts
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	2	13	21	13	7
0.7	2	11	22		
0.5	1		8		
0.3					

Roundness

100 counts

monocrystalline quartz 130 - 43.3 %

polycrystalline quartz 2 - 0.7 %

chert 2 - 0.7 %

chalcedony

microcline 2 - 0.7 %

other K-spar 17 - 5.7 %

plagioclase

plutonic lithic fragment 1 - 0.3 %

volcanic lithic fragment 7 - 2.3 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix 51 - 17.0 %

quartz cement

calcite

limonite/hematite 23 - 7.7 %

sericite 4 - 1.3 %

kaolinite

pores 61 - 20.3 %

Pinedale East measured section

Sample No. 80-SCH-26PEP Stratigraphic Unit Umw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	1
0.5	1	41
.25	2	47
.125	3	11
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	2	16	21	10	1
0.7	1	10	23	2	
0.5			12		1
0.3			1		

100 counts

monocrystalline quartz	173 – 57.7%	biotite	1 – 0.3%
polycrystalline quartz	1 – 0.3%	muscovite	
chert		zircon	
chalcedony		tourmaline	
microcline	1 – 0.3%	opaques	
other K-spar	10 – 3.3%	matrix	2 – 0.7%
plagioclase		quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	43 – 14.3%
metamorphic lithic fragment (metaquartzite)		sericite	1 – 0.3%
sedimentary lithic fragment		kaolinite	
		pores	68 – 22.7%

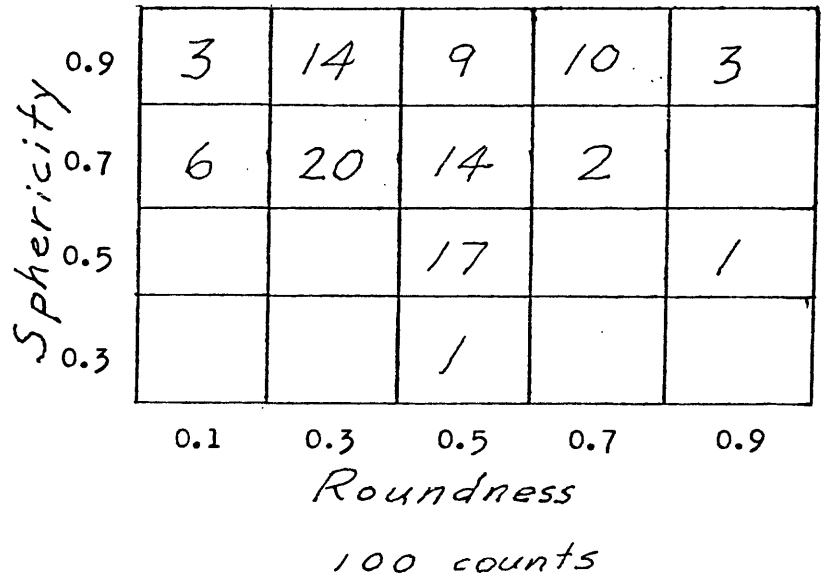
300 counts

Pinedale *East* measured section

Sample No. *80-SCH-27 PEP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	*100 counts*
0.5	1	
.25	2	} 35
.125	3	} 61
.0625	4	} 4
.0313	5	
.0156	6	



100 counts

monocrystalline quartz *168 — 56.0 %*

polycrystalline quartz *1 — 0.3 %*

chert

chalcedony

microcline

other K-spar *4 — 1.3 %*

plagioclase *2 — 0.7 %*

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix *68 — 22.7 %*

quartz cement

calcite

limonite/hematite *50 — 16.7 %*

sericite

kaolinite

pores *7 — 2.3 %*

300 counts

Pinedale *East* measured section

Sample No. *80 - SCH - 28 PEP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	2
4	-2	11
2	-1	34
1	0	38
0.5	1	14
.25	2	1
.125	3	
.0625	4	
.0313	5	
.0156	6	

100 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	8	16	9	21	2
0.7	2	10	18	6	1
0.5			9	1	
0.3					

Roundness

103 counts

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monocrystalline quartz *96 - 31.2 %*

polycrystalline quartz *13 - 4.2 %*

chert *5 - 1.6 %*

chalcedony

microcline *22 - 7.1 %*

other K-spar *43 - 14.0 %*

plagioclase *3 - 1.0 %*

plutonic lithic fragment *1 - 0.3 %*

volcanic lithic fragment *12 - 3.9 %*

metamorphic lithic fragment *1 - 0.3 %*
(metaquartzite)

sedimentary lithic fragment *3 - 1.0 %*

308 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix *12 - 3.9 %*

quartz cement

calcite *50 - 16.2 %*

limonite/hematite *11 - 3.6 %*

sericite *13 - 4.2 %*

kaolinite

pores *23 - 7.5 %*

Pinedale *East* measured section

Sample No. *80-SCH-29 PEP* Stratigraphic Unit *Jmb*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	*100 counts*
0.5	1	
.25	2	11
.125	3	50
.0625	4	35
.0313	5	4
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	3	16	11	7	1
0.7	10	14	19		
0.5	2	2	11		
0.3			4		

100 counts

monocrystalline quartz	*153 — 51.0 %*	biotite	
polycrystalline quartz	*2 — 0.7 %*	muscovite	
chert	*2 — 0.7 %*	zircon	
chalcedony		tourmaline	*1 — 0.3 %*
microcline	*1 — 0.3 %*	opaques	*1 — 0.3 %*
other K-spar	*2 — 0.7 %*	matrix	*133 — 44.3 %*
plagioclase	*2 — 0.7 %*	quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	
metamorphic lithic fragment (metaquartzite)		sericite	*2 — 0.7 %*
sedimentary lithic fragment		kaolinite	
		pores	*1 — 0.3 %*

300 counts

Pinedale *East* measured section

Sample No. *80-SCH-30 PEP* Stratigraphic Unit *Jmb*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	*100 counts*
1	0	
0.5	1	5
.25	2	62
.125	3	31
.0625	4	2
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	6	18	14	4	1
0.7	10	19	17		
0.5		1	8	1	
0.3				1	

100 counts

monocrystalline quartz *122 – 39.6 %*

polycrystalline quartz *1 – 0.3 %*

chert

chalcedony

microcline *2 – 0.6 %*

other K-spar *3 – 1.0 %*

plagioclase *4 – 1.3 %*

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite *2 – 0.6 %*

zircon

tourmaline

opaques

matrix *147 – 47.7 %*

quartz cement

calcite *24 – 7.8 %*

limonite/hematite

sericite

kaolinite

pores *3 – 1.0 %*

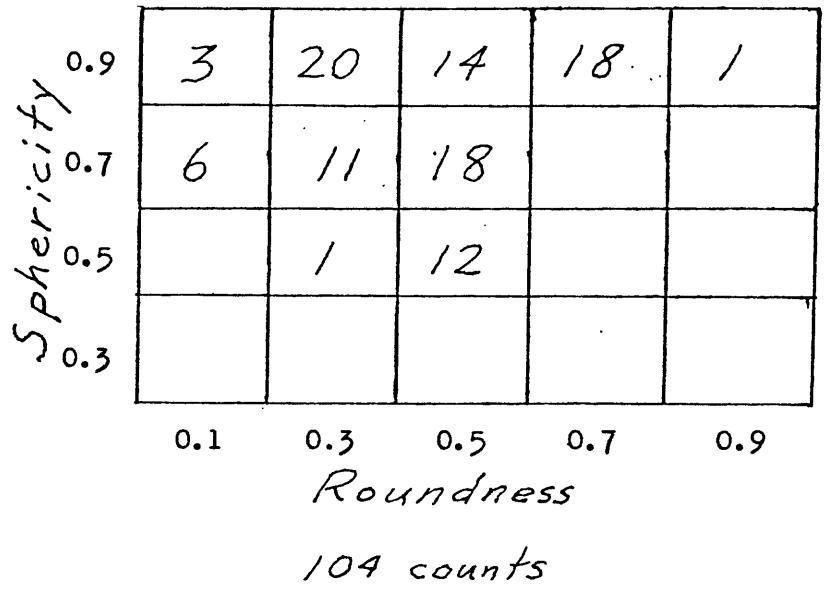
308 counts

Pinedale East measured section

Sample No. 80-SCH-31 PEP Stratigraphic Unit Jmb

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	102 counts
1	0	
0.5	1	3
.25	2	75
.125	3	23
.0625	4	1
.0313	5	
.0156	6	



104 counts

monocrystalline quartz	139 – 46.3 %	biotite	
polycrystalline quartz	3 – 1.0 %	muscovite	
chert		zircon	
chalcedony		tourmaline	
microcline	1 – 0.3 %	opaques	
other K-spar	2 – 0.7 %	matrix	119 – 39.7 %
plagioclase	1 – 0.3 %	quartz cement	
plutonic lithic fragment		calcite	9 – 3.0 %
volcanic lithic fragment		limonite/hematite	1 – 0.3 %
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	
sedimentary lithic fragment		pores	25 – 8.3 %

300 counts

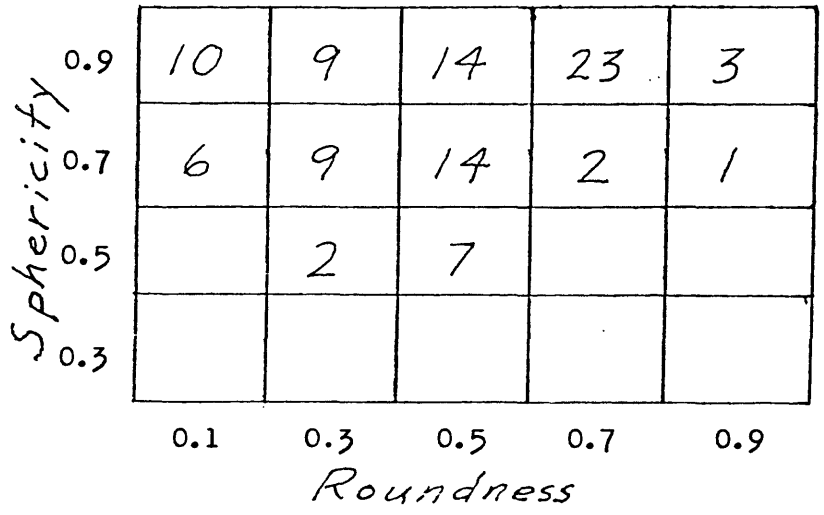
Pinedale *West* measured section

Sample No. *80 - SAK - 1PWP* Stratigraphic Unit *Jcs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	2
0.5	1	72
.25	2	23
.125	3	2
.0625	4	1
.0313	5	
.0156	6	

100 counts



100 counts

monocrystalline quartz *194 — 64.7 %*

polycrystalline quartz *2 — 0.7 %*

chert

chalcedony

microcline

other K-spar *1 — 0.3 %*

plagioclase

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix *32 — 10.7 %*

quartz cement

calcite *15 — 5.0 %*

limonite/hematite

sericite

kaolinite

pores *56 — 18.7 %*

300 counts

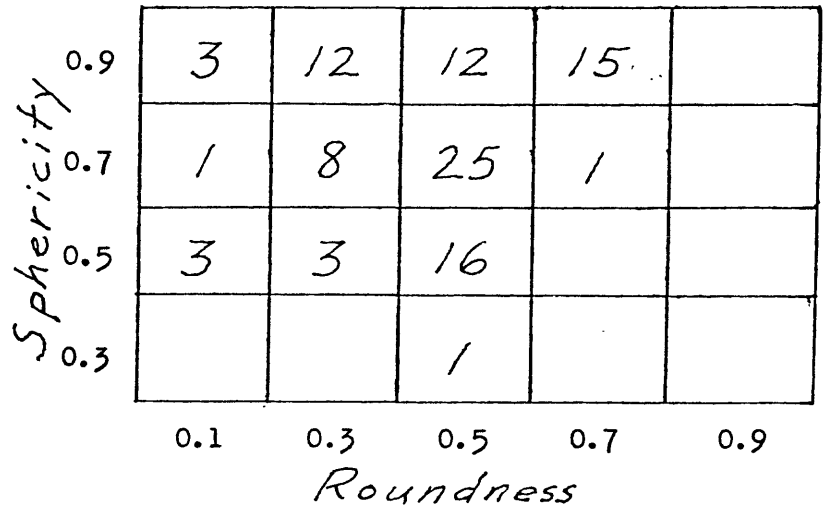
Pinedale *West* measured section

Sample No. *80-SAK-2PWP* Stratigraphic Unit *Jcs*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	9
.25	2	67
.125	3	24
.0625	4	
.0313	5	
.0156	6	

100 counts



100 counts

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monocrystalline quartz *162 – 52.4 %*

polycrystalline quartz *1 – 0.3 %*

chert

chalcedony

microcline

other K-spar *3 – 1.0 %*

plagioclase

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques *2 – 0.6 %*

matrix *29 – 9.4 %*

quartz cement

calcite

limonite/hematite *2 – 0.6 %*

sericite

kaolinite

pores *110 – 35.6 %*

309 counts

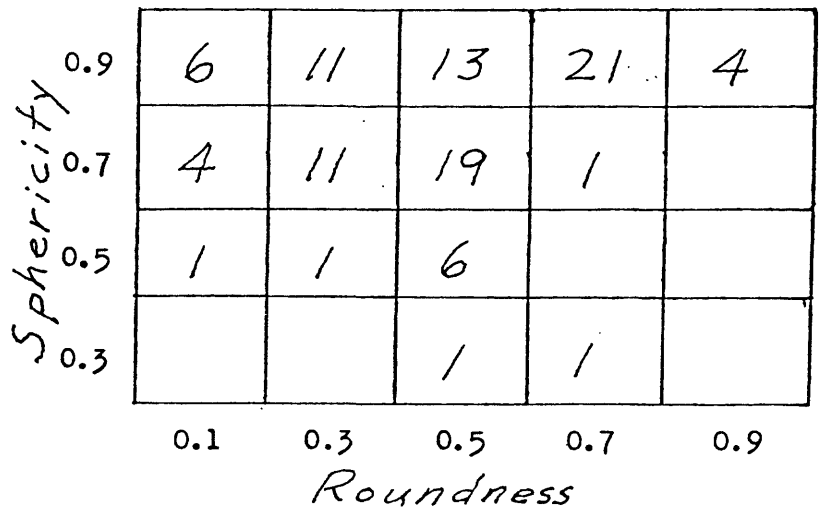
Pinedale *West* measured section

Sample No. *80-SAK-3PWP* Stratigraphic Unit *Jmr*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	40
.25	2	53
.125	3	7
.0625	4	
.0313	5	
.0156	6	

100 counts



100 counts

monocrystalline quartz *151 – 49.5%*

polycrystalline quartz *2 – 0.7%*

chert

chalcedony

microcline *1 – 0.3%*

other K-spar *3 – 1.0%*

plagioclase

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment *1 – 0.3%*
(metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques *1 – 0.3%*

matrix

quartz cement

calcite *114 – 37.4%*

limonite/hematite *10 – 3.3%*

sericite

kaolinite

pores *22 – 7.2%*

305 counts

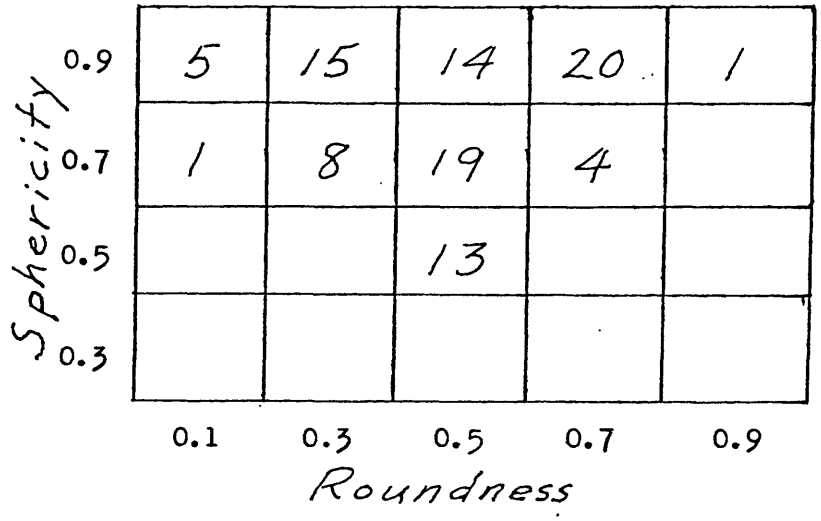
Pinedale West measured section

Sample No. 80-SAK-4PWP Stratigraphic Unit Jmr

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	21
.25	2	69
.125	3	10
.0625	4	
.0313	5	
.0156	6	

100 counts



100 counts

monocrystalline quartz 151 - 48.7 %

polycrystalline quartz 1 - 0.3 %

chert

chalcedony

microcline

other K-spar 6 - 1.9 %

plagioclase

plutonic lithic fragment

volcanic lithic fragment 2 - 0.6 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment 1 - 0.3 %

310 counts

biotite 1 - 0.3 %

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite 126 - 40.6 %

limonite/hematite

sericite

kaolinite

pores 22 - 7.1 %

Pinedale *West* measured section

Sample No. *80 - SAK - 5PWP* Stratigraphic Unit *Jmr*

Max. grain size

mm	ϕ	
8	-3	
4	-2	1
2	-1	1
1	0	26
0.5	1	61
.25	2	11
.125	3	
.0625	4	100 counts
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	10	6	12	20	7
0.7	3	7	17	6	
0.5	1		11		
0.3					

100 counts

monocrystalline quartz *165 - 55.0 %*

polycrystalline quartz *5 - 1.7 %*

chert *5 - 1.7 %*

chalcedony *2 - 0.7 %*

microcline

other K-spar *4 - 1.3 %*

plagioclase

plutonic lithic fragment

volcanic lithic fragment *4 - 1.3 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment *2 - 0.7 %*

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite *91 - 30.3 %*

limonite/hematite

sericite *1 - 0.3 %*

kaolinite *7 - 2.3 %*

pores *14 - 4.7 %*

Pinedale *West* measured section

Sample No. *80-SAK-6PWP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	14
1	0	56
0.5	1	28
.25	2	2
.125	3	
.0625	4	
.0313	5	
.0156	6	

100 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	5	9	16	25	6
0.7	6	7	16	1	
0.5			9		
0.3					

100 counts

monocrystalline quartz *121 – 39.5 %*

polycrystalline quartz *17 – 5.6 %*

chert *1 – 0.3 %*

chalcedony

microcline *16 – 5.2 %*

other K-spar *24 – 7.8 %*

plagioclase *3 – 1.0 %*

plutonic lithic fragment *4 – 1.3 %*

volcanic lithic fragment *4 – 1.3 %*

metamorphic lithic fragment *1 – 0.3 %* (metaquartzite)

sedimentary lithic fragment *2 – 0.7 %*

306 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite *70 – 22.9 %*

limonite/hematite *6 – 2.0 %*

sericite *8 – 2.6 %*

kaolinite *6 – 2.0 %*

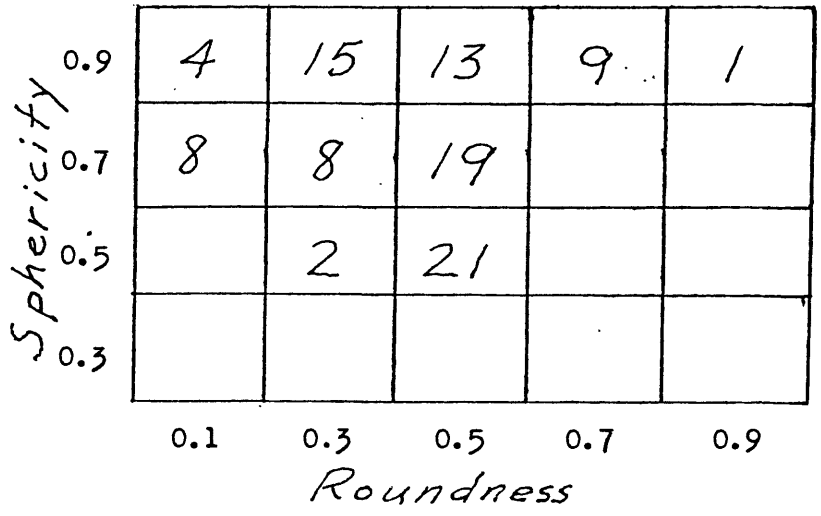
pores *23 – 7.5 %*

Pinedale *West* measured section

Sample No. *80-SAK-7PWP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	3
0.5	1	29
.25	2	65
.125	3	3
.0625	4	
.0313	5	*100 counts*
.0156	6	



100 counts

monocrystalline quartz *162 – 54.0 %*

polycrystalline quartz *4 – 1.3 %*

chert *1 – 0.3 %*

chalcedony

microcline *2 – 0.7 %*

other K-spar *15 – 5.0 %*

plagioclase *1 – 0.3 %*

plutonic lithic fragment *1 – 0.3 %*

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix *3 – 1.0 %*

quartz cement

calcite

limonite/hematite *11 – 3.7 %*

sericite

kaolinite

pores *100 – 33.3 %*

Pinedale West measured section

Sample No. 80-SAK-8PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	11
0.5	1	61
.25	2	27
.125	3	1
.0625	4	
.0313	5	
.0156	6	

100 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	6	16	10	26	6
0.7	3	9	12	4	
0.5			8		
0.3					

100 counts

monocrystalline quartz 199 – 66.3 %

polycrystalline quartz 2 – 0.7 %

chert 1 – 0.3 %

chalcedony

microcline 2 – 0.7 %

other K-spar 15 – 5.0 %

plagioclase 2 – 0.7 %

plutonic lithic fragment

volcanic lithic fragment 3 – 1.0 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

300 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix 7 – 2.3 %

quartz cement

calcite

limonite/hematite 4 – 1.3 %

sericite 2 – 0.7 %

kaolinite 1 – 0.3 %

pores 62 – 20.7 %

Pinedale West measured section

Sample No. 80-SAK-11 PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	1
0.5	1	35
.25	2	56
.125	3	8
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	4	19	19	15	4
0.7	6	2	10	1	
0.5		1	15	2	
0.3			2		

100 counts

monocrystalline quartz 170 - 53.3 %

polycrystalline quartz 5 - 1.6 %

chert 1 - 0.3 %

chalcedony

microcline

other K-spar 10 - 3.1 %

plagioclase 1 - 0.3 %

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

319 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix

quartz cement

calcite 87 - 27.3 %

limonite/hematite 5 - 1.6 %

sericite

kaolinite

pores 40 - 12.5 %

Pinedale *West* measured section

Sample No. *80-SAK-12 PWP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ		
8	-3		
4	-2		
2	-1		
1	0	2	
0.5	1	28	
.25	2	59	
.125	3	11	
.0625	4		
.0313	5	*100 counts*	
.0156	6		

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	5	14	16	27	1
0.7	7	3	14	1	
0.5	1		11		
0.3					

100 counts

monocrystalline quartz	*121 – 40.3 %*	biotite	
polycrystalline quartz	*3 – 1.0 %*	muscovite	
chert	*1 – 0.3 %*	zircon	
chalcedony		tourmaline	
microcline	*3 – 1.0 %*	opaques	
other K-spar	*8 – 2.7 %*	matrix	*99 – 33.0 %*
plagioclase	*2 – 0.7 %*	quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	*6 – 2.0 %*
metamorphic lithic fragment (metaquartzite)		sericite	*2 – 0.7 %*
sedimentary lithic fragment	*2 – 0.7 %*	kaolinite	
		pores	*53 – 17.7 %*

300 counts

Pinedale *West* measured section

Sample No. *80-SAK-13 PWP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	*100 counts*
1	0	
0.5	1	*25*
.25	2	*58*
.125	3	*15*
.0625	4	*2*
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	9	17	17	17	
0.7	9	4	12	1	
0.5		1	11		
0.3			1	1	

100 counts

monocrystalline quartz	*183 – 61.0 %*	biotite	
polycrystalline quartz	*3 – 1.0 %*	muscovite	
chert		zircon	
chalcedony		tourmaline	
microcline	*1 – 0.3 %*	opaques	
other K-spar	*5 – 1.7 %*	matrix	*58 – 19.3 %*
plagioclase		quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	*23 – 7.7 %*
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	
sedimentary lithic fragment		pores	*27 – 9.0 %*

300 counts

Pinedale *West* measured section

Sample No. *80-SAK-14PWP* Stratigraphic Unit *Umw*

Max. grain size

mm	ϕ		
8	-3		
4	-2		
2	-1		
1	0	7	
0.5	1	44	
.25	2	47	
.125	3	2	
.0625	4		
.0313	5		
.0156	6		

100 counts

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	13	15	13	20	
0.7	8	4	13	3	
0.5	1		10		
0.3					

100 counts

monocrystalline quartz	*181 – 55.4 %*	biotite	
polycrystalline quartz	*7 – 2.1 %*	muscovite	
chert	*3 – 0.9 %*	zircon	
chalcedony		tourmaline	
microcline	*2 – 0.6 %*	opaques	
other K-spar	*21 – 6.4 %*	matrix	*20 – 6.1 %*
plagioclase	*4 – 1.2 %*	quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment	*2 – 0.6 %*	limonite/hematite	*9 – 2.8 %*
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	
sedimentary lithic fragment		pores	*78 – 23.9 %*

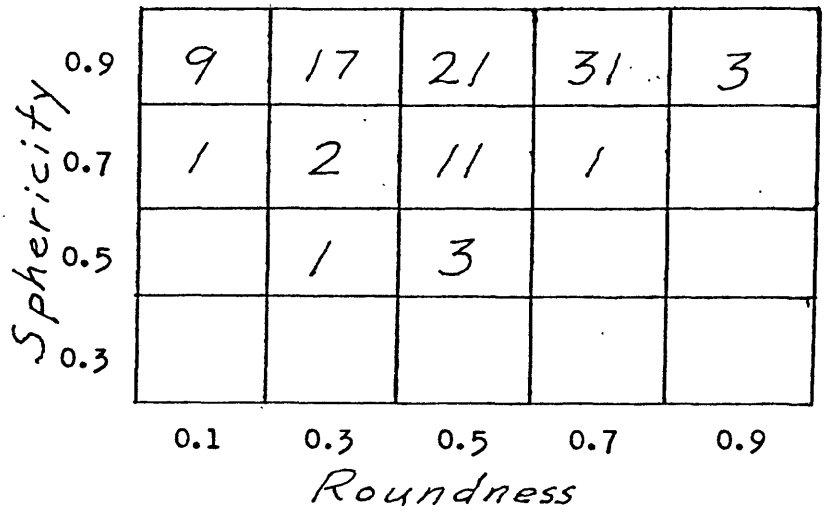
327 counts

Pinedale West measured section

Sample No. 80-SAK-15PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	8
1	0	38
0.5	1	48
.25	2	4
.125	3	2
.0625	4	
.0313	5	100 counts
.0156	6	



100 counts

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monocrystalline quartz 174 – 58.0 %

polycrystalline quartz 15 – 5.0 %

chert

chalcedony

microcline 1 – 0.3 %

other K-spar 25 – 8.3 %

plagioclase 1 – 0.3 %

plutonic lithic fragment

volcanic lithic fragment 2 – 0.7 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite 1 – 0.3 %

muscovite

zircon

tourmaline

opaques

matrix 41 – 13.7 %

quartz cement

calcite

limonite/hematite 8 – 2.7 %

sericite 1 – 0.3 %

kaolinite

pores 31 – 10.3 %

300 counts

Pinedale West measured section

Sample No. 80-SAK-16 PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	17
1	0	62
0.5	1	21
.25	2	
.125	3	100 counts
.0625	4	
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	9	12	12	30	5
0.7	3	3	18	1	
0.5	1		6		
0.3					

100 counts

monocrystalline quartz 107 – 35.7 %

polycrystalline quartz 10 – 3.3 %

chert

chalcedony

microcline 14 – 4.7 %

other K-spar 37 – 12.3 %

plagioclase 3 – 1.0 %

plutonic lithic fragment

volcanic lithic fragment 8 – 2.7 %

metamorphic lithic fragment (metaquartzite) 1 – 0.3 %

sedimentary lithic fragment 6 – 2.0 %

300 counts

biotite

muscovite

zircon

tourmaline

opaques 1 – 0.3 %

matrix

quartz cement

calcite 77 – 25.7 %

limonite/hematite 4 – 1.3 %

sericite 9 – 3.0 %

kaolinite 4 – 1.3 %

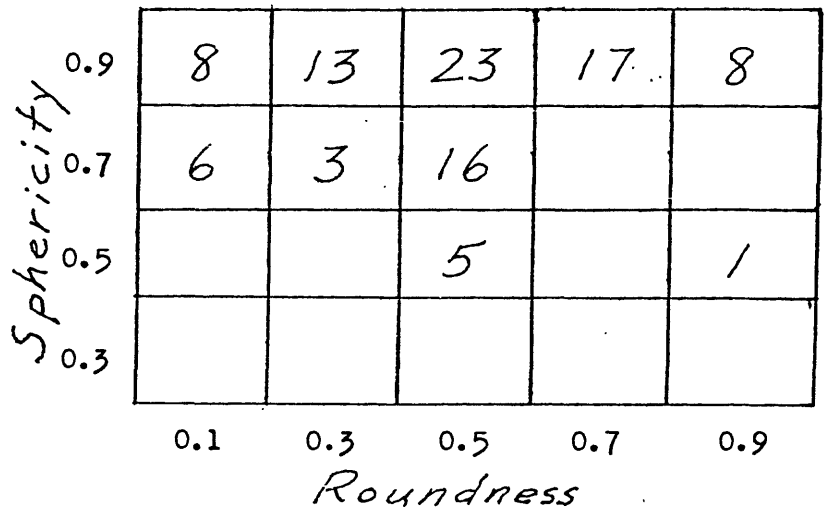
pores 19 – 6.3 %

Pinedale West measured section

Sample No. 80-SAK-17PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	2
1	0	47
0.5	1	48
.25	2	3
.125	3	
.0625	4	100 counts
.0313	5	
.0156	6	



100 counts

monocrystalline quartz 159 — 51.8 %

polycrystalline quartz 4 — 1.3 %

chert 1 — 0.3 %

chalcedony

microcline 2 — 0.7 %

other K-spar 20 — 6.5 %

plagioclase 1 — 0.3 %

plutonic lithic fragment

volcanic lithic fragment 1 — 0.3 %

metamorphic lithic fragment 1 — 0.3 % (metaquartzite)

sedimentary lithic fragment 1 — 0.3 %

biotite

muscovite

zircon

tourmaline

opaques

matrix 16 — 5.2 %

quartz cement

calcite

limonite/hematite 2 — 0.7 %

sericite 5 — 1.6 %

kaolinite 9 — 2.9 %

pores 85 — 27.7 %

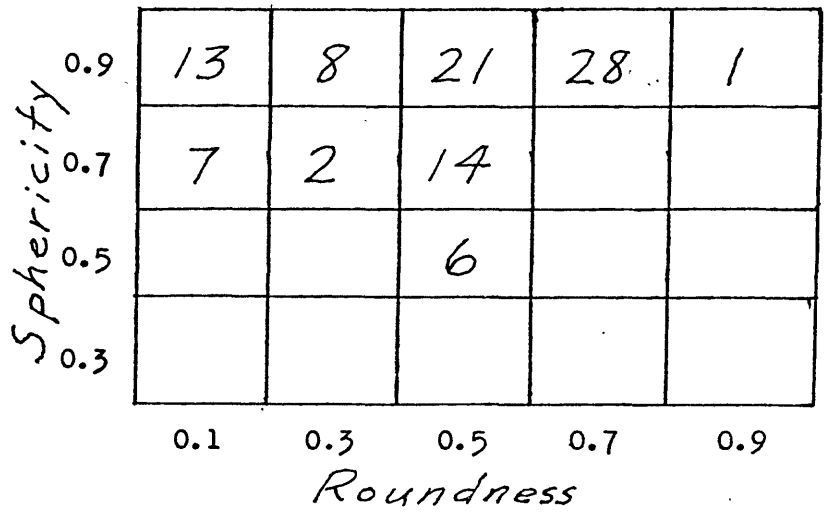
307 counts

Pinedale West measured section

Sample No. 80-SAK-18PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	11
1	0	28
0.5	1	58
.25	2	8
.125	3	
.0625	4	105 counts
.0313	5	
.0156	6	



100 counts

monocrystalline quartz 134 – 43.1 %

polycrystalline quartz 11 – 3.5 %

chert 4 – 1.3 %

chalcedony

microcline 7 – 2.3 %

other K-spar 25 – 8.0 %

plagioclase 1 – 0.3 %

plutonic lithic fragment 1 – 0.3 %

volcanic lithic fragment 1 – 0.3 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment 1 – 0.3 %

311 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix 5 – 1.6 %

quartz cement

calcite 61 – 19.6 %

limonite/hematite 2 – 0.6 %

sericite 7 – 2.3 %

kaolinite 6 – 1.9 %

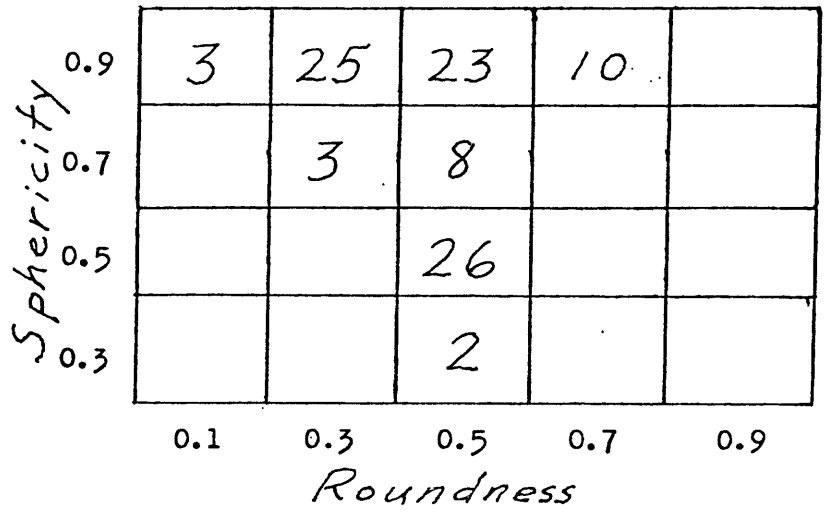
pores 45 – 14.5 %

Pinedale West measured section

Sample No. 80-SAK-19-PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	100 counts
0.5	1	
.25	2	9
.125	3	83
.0625	4	8
.0313	5	
.0156	6	



100 counts

monocrystalline quartz	236 — 78.7 %	biotite	
polycrystalline quartz	3 — 1.0 %	muscovite	
chert		zircon	
chalcedony		tourmaline	
microcline		opaques	2 — 0.7 %
other K-spar		matrix	26 — 8.7 %
plagioclase		quartz cement	
plutonic lithic fragment		calcite	
volcanic lithic fragment		limonite/hematite	4 — 1.3 %
metamorphic lithic fragment (metaquartzite)		sericite	
		kaolinite	
sedimentary lithic fragment		pores	29 — 9.7 %

300 counts

Pinedale *West* measured section

Sample No. *80-SAK-20PNP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ		
8	-3		
4	-2		
2	-1	11	
1	0	16	
0.5	1	27	
.25	2	40	
.125	3	6	
.0625	4		
.0313	5	*100 counts*	
.0156	6		

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	4	7	26	26	4
0.7	2	2	13		
0.5		1	12		
0.3			3		

100 counts

monocrystalline quartz *178 – 57.2 %*

polycrystalline quartz *13 – 4.2 %*

chert *4 – 1.3 %*

chalcedony

microcline *8 – 2.6 %*

other K-spar *9 – 2.9 %*

plagioclase *1 – 0.3 %*

plutonic lithic fragment

volcanic lithic fragment *2 – 0.6 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques *2 – 0.6 %*

matrix *17 – 5.5 %*

quartz cement

calcite

limonite/hematite *2 – 0.6 %*

sericite *6 – 1.9 %*

kaolinite *5 – 1.6 %*

pores *64 – 20.6 %*

311 counts

Pinedale *West* measured section

Sample No. *80-SAK-22 PWP* Stratigraphic Unit *Jmw*

Max. grain size

mm	ϕ	
8	-3	
4	-2	
2	-1	
1	0	
0.5	1	15
.25	2	78
.125	3	7
.0625	4	
.0313	5	100 counts
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	5	14	12	29	
0.7	7	5	8		
0.5	2		15		
0.3			3		

100 counts

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monocrystalline quartz *197 - 65.2 %*

polycrystalline quartz *4 - 1.3 %*

chert

chalcedony

microcline *1 - 0.3 %*

other K-spar *6 - 2.0 %*

plagioclase *3 - 1.0 %*

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment *1 - 0.3 %*
(metaquartzite)

sedimentary lithic fragment

302 counts

biotite *2 - 0.7 %*

muscovite

zircon

tourmaline

opaques

matrix *9 - 3.0 %*

quartz cement

calcite

limonite/hematite *6 - 2.0 %*

sericite

kaolinite

pores *73 - 24.2 %*

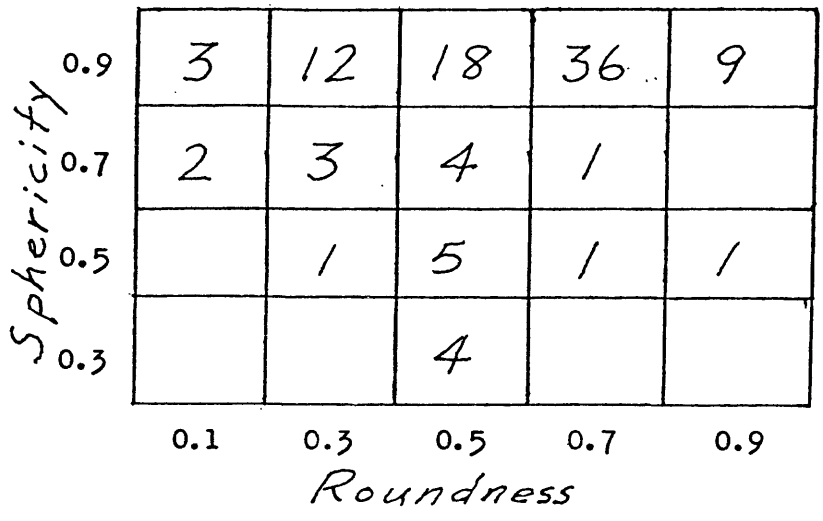
Pinedale West measured section

Sample No. 80-SAK-23 PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ		
8	-3		
4	-2		
2	-1		
1	0	4	
0.5	1	35	
.25	2	58	
.125	3	3	
.0625	4		
.0313	5		
.0156	6		

100 counts



100 counts

monocrystalline quartz 195 — 65.0 %

polycrystalline quartz 5 — 1.7 %

chert 1 — 0.3 %

chalcedony

microcline

other K-spar 6 — 2.0 %

plagioclase 1 — 0.3 %

plutonic lithic fragment

volcanic lithic fragment

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix 30 — 10.0 %

quartz cement

calcite

limonite/hematite 14 — 4.7 %

sericite 3 — 1.0 %

kaolinite

pores 45 — 15.0 %

300 counts

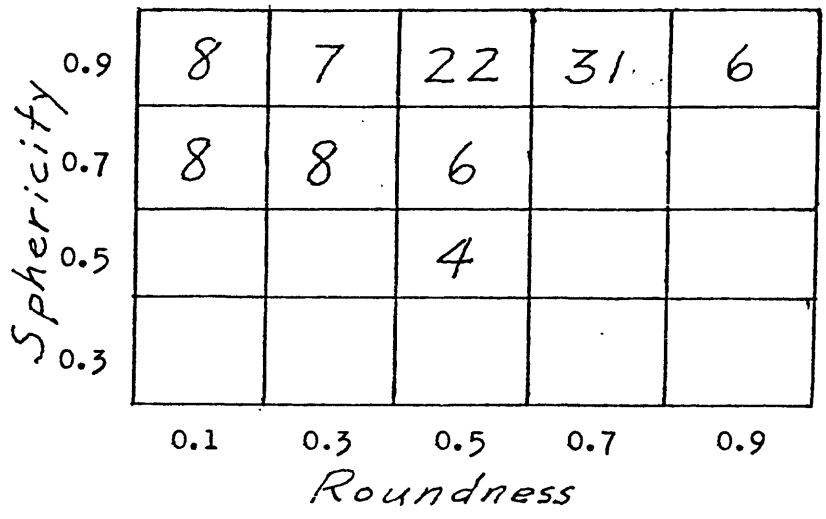
Pinedale West measured section

Sample No: 80-SAK-24 PWP Stratigraphic Unit Jmw

Max. grain size

mm	ϕ	
8	-3	
4	-2	1
2	-1	3
1	0	24
0.5	1	47
.25	2	23
.125	3	2
.0625	4	
.0313	5	
.0156	6	

100 counts



100 counts

monocrystalline quartz 100 – 33.3 %

polycrystalline quartz 1 – 0.3 %

chert 9 – 3.0 %

chalcedony 1 – 0.3 %

microcline 1 – 0.3 %

other K-spar 7 – 2.3 %

plagioclase

plutonic lithic fragment

volcanic lithic fragment 1 – 0.3 %

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

biotite

muscovite

zircon

tourmaline

opaques

matrix 56 – 18.7 %

quartz cement

calcite

limonite/hematite

sericite 4 – 1.3 %

kaolinite

pores 120 – 40.0 %

300 counts

Pinedale *West* measured section

Sample No. *80-SAK-26 PWP* Stratigraphic Unit *Umb*

Max. grain size

mm	ϕ	
8	-3	
4	-2	104 counts
2	-1	
1	0	4
0.5	1	26
.25	2	50
.125	3	18
.0625	4	6
.0313	5	
.0156	6	

Sphericity \ Roundness	0.1	0.3	0.5	0.7	0.9
0.9	8	9	18	28	5
0.7	4	3	2	1	1
0.5	3		16		
0.3			1	1	

100 counts

monocrystalline quartz *136 - 45.2 %*

polycrystalline quartz *3 - 1.0 %*

chert *1 - 0.3 %*

chalcedony

microcline *4 - 1.3 %*

other K-spar *11 - 3.7 %*

plagioclase *4 - 1.3 %*

plutonic lithic fragment

volcanic lithic fragment *2 - 0.7 %*

metamorphic lithic fragment (metaquartzite)

sedimentary lithic fragment

301 counts

biotite

muscovite

zircon

tourmaline

opaques

matrix *115 - 38.2 %*

quartz cement

calcite *1 - 0.3 %*

limonite/hematite *1 - 0.3 %*

sericite *2 - 0.7 %*

kaolinite

pores *21 - 7.0 %*