Dennis G. Lewellen, Department of Geology
University of Kentucky, Lexington, Kentucky 40506-0059

Petrographic Differences Between Two Sedimentary Rock Bodies of the Eocene-Age Manastash Formation, Kittitas County, Washington

Abstract

Regression analysis of grain size on quartz and feldspar content of 27 sandstone samples from two adjacent sedimentary rock bodies of the Manastash Formation show that as grain size increases, quartz content increases, and as grain size decreases, feldspar content increases. T-tests, comparing the slopes and intercepts of similar regression equations for quartz versus grain-size and for feldspar versus grain-size of the rock bodies, indicate compositional variations unrelated to grain-size differences. Mineralogical variations are probably caused by petrographic differences in the source rock related to uplift and erosion that exposed rocks of differing composition.

Introduction

Although sedimentary rocks are fairly widespread along the flanks of the north and central Cascade Mountains of Washington, the lateral relationships between geographically separate deposits are not well understood. Correlations are difficult to establish, because of a lack of either prominent marker beds or obvious guide fossils within these lithologically similar units. The sedimentary rocks are predominantly composed of arkosic sandstones which are 18-48 percent feldspar (mostly plagioclase) and 40-78 percent quartz (Frizzell 1979). Plant fossil remains in intercalated shales suggest that most of the sedimentary rock bodies are Eocene to Paleocene (?) in age (Newman 1981). Radiometric dates of volcanic rocks interbedded with the sedimentary rocks are generally Eocene in age, but the results vary widely due to alteration of the volcanic material after deposition (Frizzell 1979, Tabor *et al.* 1984).

Recent studies have shown that the mineral composition of sand changes with grain size and that this relationship may be useful in solving problems in the Manastash Formation concerning the source rocks, climate, depositional environment, or age relationships between sedimentary rock bodies (Flores 1967, Davis and Ehrlich 1974, Basu 1976). This study utilizes similar methods in order to resolve a problem of origin and age relationships of two separate, but proximal, bodies of Tertiary sedimentary rocks in central Washington.

The study area is located about 8 km south of Cle Elum, Washington, where 1.6 to 3 km of younger volcanic flows, tuffs, and volcaniclastic rocks separate two sedimentary rock bodies of the Eocene-age Manastash Formation (see areas A and B on Figure 1). Sedimentary rocks in area A have a thickness of approximately 1,000 m, while the rocks in area B have a maximum thickness of 750 m. Both areas unconformably overlie crystalline rocks composed of schist, phyllite, and quartz-diorite gneiss (Stout 1962), and both are unconformably overlain by Eocene-age volcanic flows, tuffs, and volcaniclastic rocks. Both rock bodies are composed mostly of arkosic sandstone with minor amounts of shale, siltstone, conglomerate, and coal. However, area B rocks are substantially coarser grained and more quartzose than area A rocks, which are comparatively feldspar-rich. Previous studies indicate that these rocks were deposited by fluvial processes (Lewellen 1983) within a warm, temperate to subtropical climate (Stout 1957), and that area B rocks may be older than area A rocks (Newman 1981).

Differences in the trends of grain size versus mineral composition of the sedimentary rocks of area A and B were analyzed in an effort to resolve the problems of depositional and age relationships. The presently disjunct bodies may be remnants of a once larger sedimentary unit, if differences in mineral contents are a reflection of differing grain sizes caused by depositional processes. Conversely, mineralogical differences greater than those associated with grain-size variations may indicate that the sandstones represent different ages, source areas, or other unrelated depositional factors.

Methods

Fourteen sandstone samples from area A and thirteen from area B were collected at sites that reflect the areal and stratigraphic variations in the two rock bodies (Figure 1). Thin sections were prepared and stained for potassium feldspar and plagioclase according to the techniques of Lainz *et al.* (1964) and Norman (1974). The approximate grain size of each sample was expressed accord-

Figure 1. Location map of the study area and the sandstone samples.

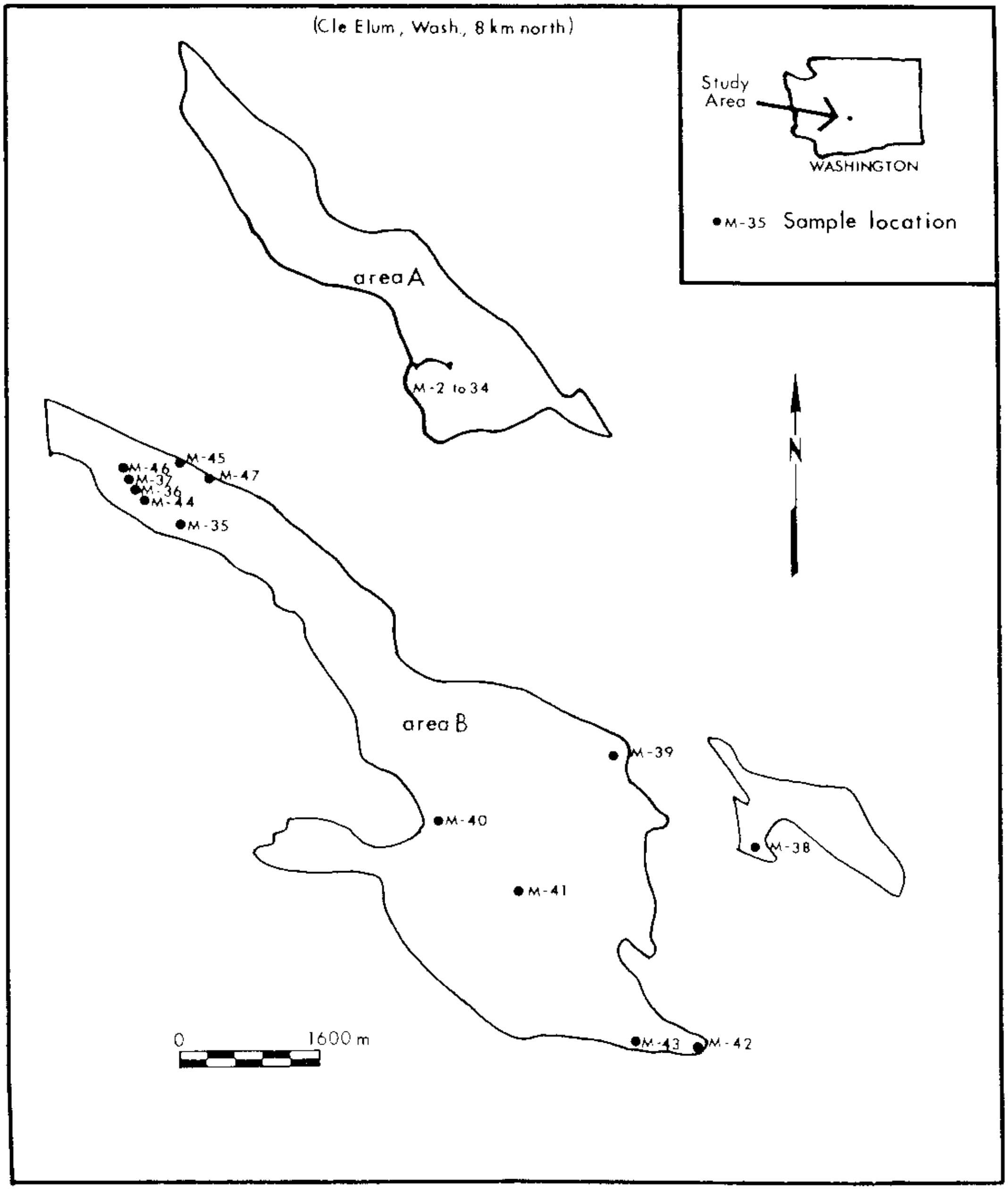

TABLE 1 .Grain size and relative percent quantities of quartz and feldspar measured in each sample.

Location	Quartz	Feldspar	Grain Size
m-2	49	51	very fine
m-4	39	61	very fine
m-6	36	64	fine
m-8	22	78	very fine
m-10	31	69	fine
m-13	49	51	course
m-14	43	57	fine to medium
m-16	46	54	fine
m-17	38	62	very fine
m-23	39	61	very fine
m-27	35	65	very fine
m-29	43	57	fine
m-33	37	63	very fine
m-34	52	48	medium
m-35	91	9	coarse
m-36	88	12	coarse
m-37	67	33	fine
m-38	82	18	coarse
m-39	78	22	medium
m-40	87	13	coarse
m-41	93	7	coarse
m-42	69	31	coarse
m-43	67	33	medium to coarse
m-44	80	20	coarse
m-45	59	41	fine to medium
m-46	80	20	medium to coarse
m-47	68	32	coarse

ing to the Wentworth scale (very-fine, fine, medium, or coarse-grained sandstone) based on average measurement of the long axis of 10 to 15 feldspar or quartz grains randomly selected through the use of a random digit table. Detrital components were determined by point counting an average of 800 points per sample (Chayes 1949). Categories of recognized detritus were monocrystalline quartz, polycrystalline quartz, plagioclase, potassium feldspar, volcanic lithics, sedimentary lithics, metamorphic lithics, microgranular lithics, micas, clay-sized material, and a miscellaneous category for those grains that did not fit into any of the other categories.

In order to determine the grain size and mineral composition relationship of the sandstones within each area, linear-regression equations were derived for grain size versus feldspar and quartz contents.

T-tests were used to compare the slopes and intercepts of similar regression equations of the different rock bodies so that mineral composition variations not attributable to grain size changes could be ascertained. Nonsignificant t-test results, determined at a 95 percent confidence level, for the comparison of the slope and intercepts of the linear regression equations from the rock bodies indicate that differences in mineral content are attributable to grain-size trends. Significant t-test results for the slope, intercept, or both indicate differences greater than those associated with grain size variations and require other explanations.

Results and Discussion

The mineral composition and the grain-size measurements for each sample are given in Table 1. In general, sandstone samples are very-fine grained in area A and coarse grained in area B. The average composition of the samples in area A is 40 percent quartz, 58 percent feldspar, and 3 percent rock fragments, whereas area B samples average 67 percent quartz, 20 percent feldspar, and 13 percent rock fragments. These sets of averages are very similar to those of the sandstone units derived from uplifted blocks of Holocene to Precambrian age granitic rocks studied by Dickinson and Suczek (1979).

Figure 2 gives the linear-regression data of grain size on quartz and feldspar content for each area. These data indicate that as grain size decreases, feldspar content increases, and quartz content decreases. T-tests indicate that the slopes of like regression equations from each area are not significantly different. However, t-tests of the intercepts of similar regression equations are significantly different. Although some of the variations in mineral composition are attributable to grain size, additional compositional differences not related to grain size exist between the rocks of areas A and B (Table 2).

TABLE 2. Results of t-tests of the slope (b) and the intercepts (a) of the regression equations from areas A and B.

Hypothesis	T-test[a]
$Ho{:}b_A = b_B$ $H_1{:}b_A \neq b_B$	$t = 0.877^b$ df = 23
$H_o{:}a_A = a_B$ $H_1{:}a_A \neq a_B$	$t = 3.021^c$ df – 23

a $\alpha = .05$, t = 2.069
b differences are nonsignificant
c differences are significant

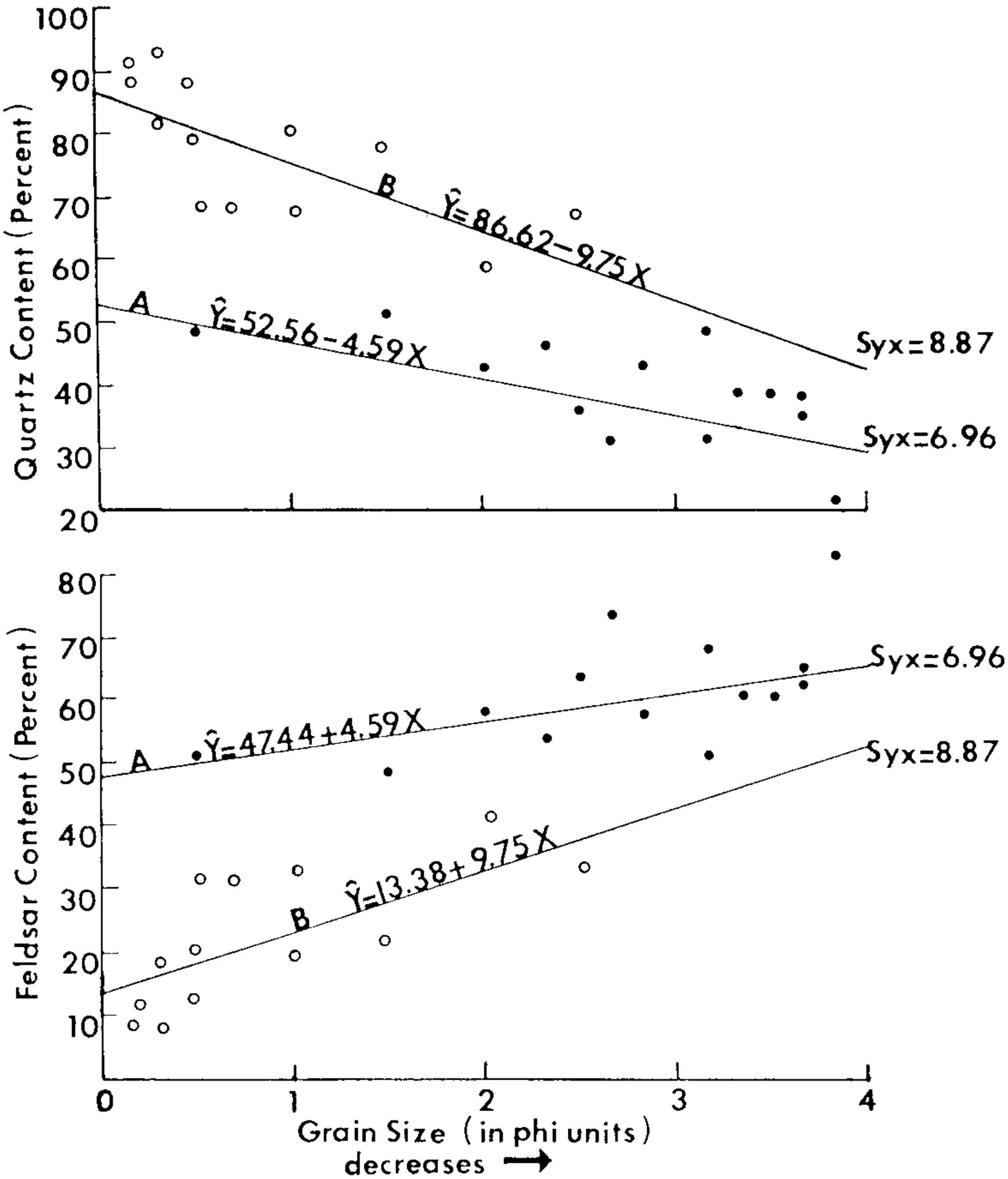

Figure 2. Scatter plot of grain size versus quartz and feldspar content of 27 samples from area A (solid circles) and area B (open circles).

The data indicate that the rocks of areas A and B probably represent two separate depositional events, probably of differing ages. Such a conclusion is consistent with the fossil plant evidence of Newman (1981).

Disregarding grain-size trends, the higher quartz contents of area B sandstone may reflect climatically induced differences in the degree of weathering and soil formation processes in the source rocks. For example, sand samples collected in modern streams draining granitic rocks, not more than 19 km from the source rock, in the warm moist climate of the southern Appalachians, contain less feldspar and more quartz for a given grain size than those from the cool dry northern Rocky Mountains (Basu 1976). Linear-regression equations for the Appalachian data are similar to those of area B, whereas equations for the modern Rocky Mountain data are nearly identical to those of area A (Table 3).

TABLE 3. Comparison of linear-regression equations from this study and from Basu's (1976) study.

Source	Quartz Content Regressed on Grain Size	Feldspar Content Regressed on Grain Size
Appalachians Basu (1976)	$\hat{Y} = 77.83 - 6.33x$	$\hat{Y} = 22.17 + 6.33x$
Area B	$\hat{Y} = 86.62 - 9.75x$	$\hat{Y} = 13.38 + 9.75x$
Rockies Basu (1976)	$\hat{Y} = 48.17 - 3.67x$	$\hat{Y} = 51.83 + 3.67X$
Area A	$\hat{Y} = 52.56 - 4.59x$	$\hat{Y} = 47.44 + 4.59x$

Paleobotanical data from the Manastash rocks indicate a warm, wet climate at the site of deposition, thus the observed compositional differences between areas A and B could reflect climatic differences in the source terranes, particularly if an age difference exists between the two areas. Considering the short distances between the sediment source and the site of deposition, however, the chances of radically different climates seem remote. Basu's sediments were collected within 19 km of their source and the likelihood of rapid climatic changes within 19 km in the Manastash source region appears to be small.

A more likely explanation is that compositional differences in quartz and feldspar content reflect different source rocks. Suitable source terranes include a wide variety of crystalline rocks extending from central Washington to central Idaho. Although most of these rocks are granitic or gneissic, which would yield sediments similar to the composition of the rocks in area A, others are low- to medium-grade metamorphic rocks cut by numerous quartz veins. These quartz-rich rocks could presumably provide substantial quartz detritus, and the accompanying micaceous minerals of the metamorphic rocks could be broken down during transport and carried beyond the area of deposition as fine-silt and clay particles. A mixed source terrane of granitic and low- to medium-grade metamorphic rocks could provide the detritus represented in the Manastash Formation by the rocks of area B, which are nearly 70 percent quartz.

Different source rocks most likely account for the mineralogical differences between the rocks of areas A and B. As such the detritus was either derived from two geographically separate source terranes or from erosion of the same site through time. In the latter case, the older rocks of area B were derived from low- to medium-grade, quartz-rich metamorphic rocks, whereas area A received detritus from an underlying intrusive granitic pluton or gneiss exposed after erosion of the overlying rocks.

Conclusions

Analysis of mineral composition and grain size of two geographically adjacent bodies of early Tertiary arkosic sedimentary rocks separated by younger volcanic rocks in central Washington indicate that the two rock bodies are mineralogically distinct after grain size effects are taken into account. The rock bodies are therefore inferred to be of different ages; a conclusion that is in accord with previously reported paleobotanical findings. Differences in mineral composition of the two bodies can be attributed to differences in climate or petrographic characteristics of the source terrane from which the sediments were derived. However, the most likely explanation is that petrographic differences in the source rock are related to an unroofing sequence caused by uplift and erosion that exposed rocks of differing compositon.

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