COMPARISON OF THE PEBBLES OF THE SHINARUMP AND MOSS BACK MEMBERS OF THE CHINLE FORMATION

By Howard F. Albee

Trace Elements Memorandum Report 832

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

AEC - 758/6 May 23, 1956

Mr. Robert D. Nininger, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEM-832, "Comparison of the pebbles of the Shinarump and Moss Back members of the Chinle formation," by Howard F. Albee, March 1956.

We are asking Mr. Hosted to approve our plan to submit this report for publication in the Journal of Sedimentary Petrology.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

Geology and Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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By

Howard F. Albee

March 1956

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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CONTENTS

	Page
Abstract	4
Introduction	5
Methods of pebble analysis	6
Sampling.	6
Sphericity and roundness.	6
Size.	7
Lithology and color	7
Geologic relationship of the Shinarump and Moss Back members of the Chinle formation	8
Pebbles in the Shinarump member of the Chinle formation . . .	11
Pebbles in the Moss Back member of the Chinle formation	14
Comparison of pebbles in the Shinarump and Moss Back members of the Chinle formation	15
Fossils in the Shinarump and Moss Back pebbles.	18
Summary.	19
Literature cited	21
Unpublished report	21

ILLUSTRATIONS

Figure 1. Distribution of the Moss Back member and the northern limit of the Shinarump member of the Chinle formation	9
2. Generalized stratigraphic relationship of the Shinarump and Moss Back members of the Chinle formation	10

TABLE

Table 1. Location of sample sites and the composition, size, roundness, and sphericity of pebbles from each site	12

COMPARISON OF THE PEBBLES OF THE SHINARUMP AND MOSS BACK MEMBERS OF THE CHINLE FORMATION

By Howard F. Albee

ABSTRACT

Lithology, color, size, sphericity, and roundness of pebbles from the Shinarump and Moss Back members of the Chinle formation were analyzed and compared. The difference in the quartz:quartzite:chert ratios of the pebbles, the presence of limestone and siltstone pebbles, and to a lesser degree, the difference in color of pebbles serve to distinguish the Moss Back from the Shinarump. In areas where both the Moss Back and Shinarump are present, the average ratios of quartz, quartzite, and chert are respectively about 12:37:51 and 82:16:2. Limestone and siltstone pebbles are commonly found in the Moss Back, whereas they are rarely found in the Shinarump. The colors of the Moss Back pebbles are generally darker than those of the Shinarump pebbles. The Moss Back contains more gray to black pebbles and fewer light-colored pebbles, such as red, orange, and white, than the Shinarump. Size, sphericity, and roundness of pebbles do not show a significant difference between the two units.

Fossiliferous pebbles in the Moss Back and Shinarump were derived chiefly from sediments of Carboniferous and Permian ages and could have had common sources.

INTRODUCTION

A pebble study of the Shinarump and Moss Back members of the Chinle formation is being made as a part of a detailed stratigraphic study of the Triassic and associated formations of the Colorado Plateau. The detailed stratigraphic study is being made by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The use of the term "pebble" in this paper denotes the coarse rounded fragments of granule and larger size contained in the conglomeratic units.

The pebble studies are designed to determine whether regional differences exist in composition, size, and varietal ratios of pebbles in conglomeratic units and to aid in the determination of the source rocks and source directions of the sediments comprising Triassic and associated formations.

Properties used for the comparison of the pebbles of the Shinarump and Moss Back members of the Chinle formation are lithology, color, size, sphericity, roundness, and contained fossils. Of these properties, only lithology and color can be used to distinguish the Shinarump from the Moss Back.

The Shinarump member of the Chinle formation was formerly known as the Shinarump conglomerate. The change from formation to member rank has recently been adopted by the U. S. Geological Survey (Stewart and others, 1956).

METHODS OF PEBBLE ANALYSIS

Sampling

The method used to sample the pebbles and the number of pebbles per sample were suggested by Churchill Eisenhart of the U. S. Bureau of Standards. It was suggested that two adjoining rectangles of a size to enclose at least 150 pebbles each be marked on the ground, and a sample of 150 pebbles be collected from each rectangle.

Data consisting of the lithologic classification of 2 samples of 150 pebbles each from 6 sites were submitted to the Statistical Engineering Laboratory of the National Bureau of Standards. A chi square test, first described by Pearson (1900), was applied to the data from each sample to determine whether the paired samples differed more than might be expected on the basis of random sampling variation. The results obtained for these 6 sites indicate that, on the whole, the two samples from a site are homogeneous and, therefore, the sampling technique is a satisfactory one. As a result of these conclusions and in order to save time, only one sample of 150 pebbles now is collected from each site.

Sphericity and roundness

Wadell (1932) defined roundness and sphericity and was the first to show that these terms were not synonymous. For practical purposes, the index of roundness may be expressed as a ratio of the curvature of the corners and edges of a pebble to the curvature of a circle inscribed within the projection plane of that pebble. The sphericity of a pebble is defined as the ratio of the surface area of a sphere having the same volume as the pebble to the actual surface area of the pebble.

Krumbein (1941a) has devised rapid methods to determine roundness and sphericity; these methods give results within 5 percent of Wadell's methods. For roundness, a pebble is compared with standard images of known roundness, and a roundness value is assigned to the pebble. Sphericity is determined from ratios of the length of the a, b, and c axes, or the long, intermediate, and short diameters of the pebbles; the diameters do not necessarily intersect but must be mutually perpendicular. Two ratios, b/a and c/b, from each pebble are determined and located on the axes of a chart given by Krumbein (1941a, fig. 5) from which sphericity can be read directly.

Size

Two measures of pebble size are used for comparative purposes; these are the length of the longest pebble that can be found at each collection site, and the mean intermediate diameter of all pebbles at the collection site.

Lithology and color

Each pebble is broken to determine the lithology. Composition of the quartzose-pebble assemblage is expressed in terms of the relative amounts of quartz, quartzite, and chert. The color of the fresh surface is compared with colors in the National Research Council Rock Color Chart (Goddard and others, 1948). The color is recorded by the color chart symbol which permits a quantitative comparison of samples.

GEOLOGIC RELATIONSHIP OF THE SHINARUMP AND MOSS BACK MEMBERS OF THE CHINLE FORMATION

The Shinarump member of the Chinle formation crops out over large areas in northern Arizona and southern Utah, and less extensively in northwestern New Mexico and southeastern Nevada (fig. 1). It has a maximum thickness of about 250 feet, but at many places in southeastern Utah it is absent and Chinle siltstone and claystone rest on the Moenkopi formation. The Shinarump member commonly weathers to form a prominent ledge or vertical cliff. It is generally a grayish- to pale yellowish-orange medium- to coarse-grained sandstone composed of subround clear quartz grains. Conglomerate and conglomeratic sandstone are common. The pebbles are composed almost entirely of quartz, quartzite, and chert, but the proportions of these types differ greatly from area to area.

The Moss Back member of the Chinle formation crops out in parts of central and southwestern Utah and probably in a small area in western Colorado (fig. 1). It is a yellowish-gray and very pale-orange fine- to medium-grained well-sorted sandstone composed of subround clear quartz grains. Lenses of conglomerate and conglomeratic sandstone are common. The Moss Back typically weathers to form a vertical cliff.

Parts of Elk Ridge and White Canyon, Utah, are the only areas in which both the Moss Back and Shinarump crop out.

In the White Canyon area, Utah, the Triassic section, in ascending order, consists of the Moenkopi formation, the Chinle formation, and the Wingate sandstone. The Moss Back member lies about 200 feet above the Shinarump member (fig. 2). North of White Canyon the Shinarump pinches out and the Moss Back is closer to the base of the Chinle. About 15 miles north of White Canyon the Moss Back is at the base of the Chinle.

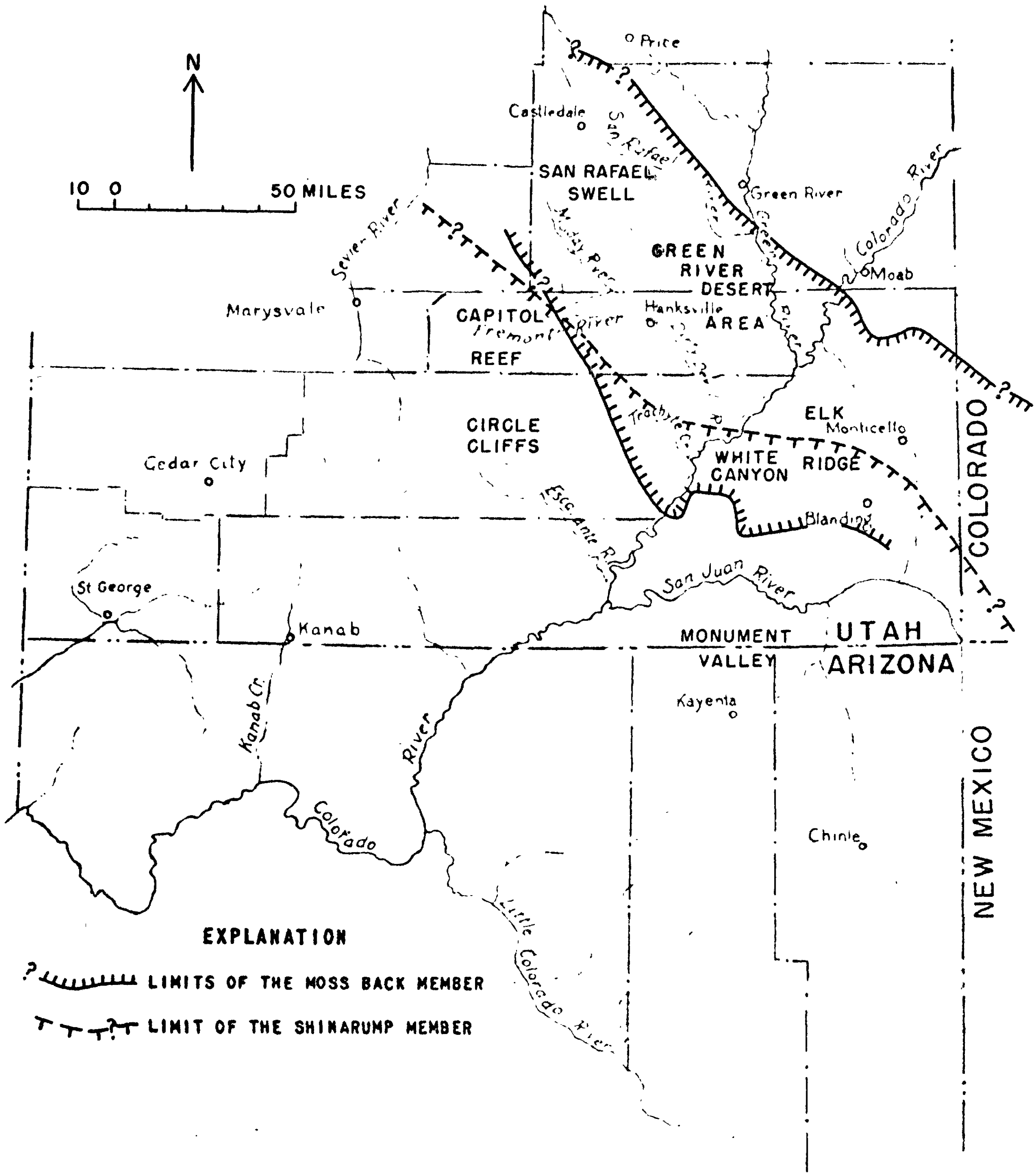

FIGURE 1.--DISTRIBUTION OF THE MOSS BACK MEMBER AND THE NORTHERN LIMIT OF THE SHINARUMP MEMBER OF THE CHINLE FORMATION. (AFTER STEWART AND OTHERS, 1956).

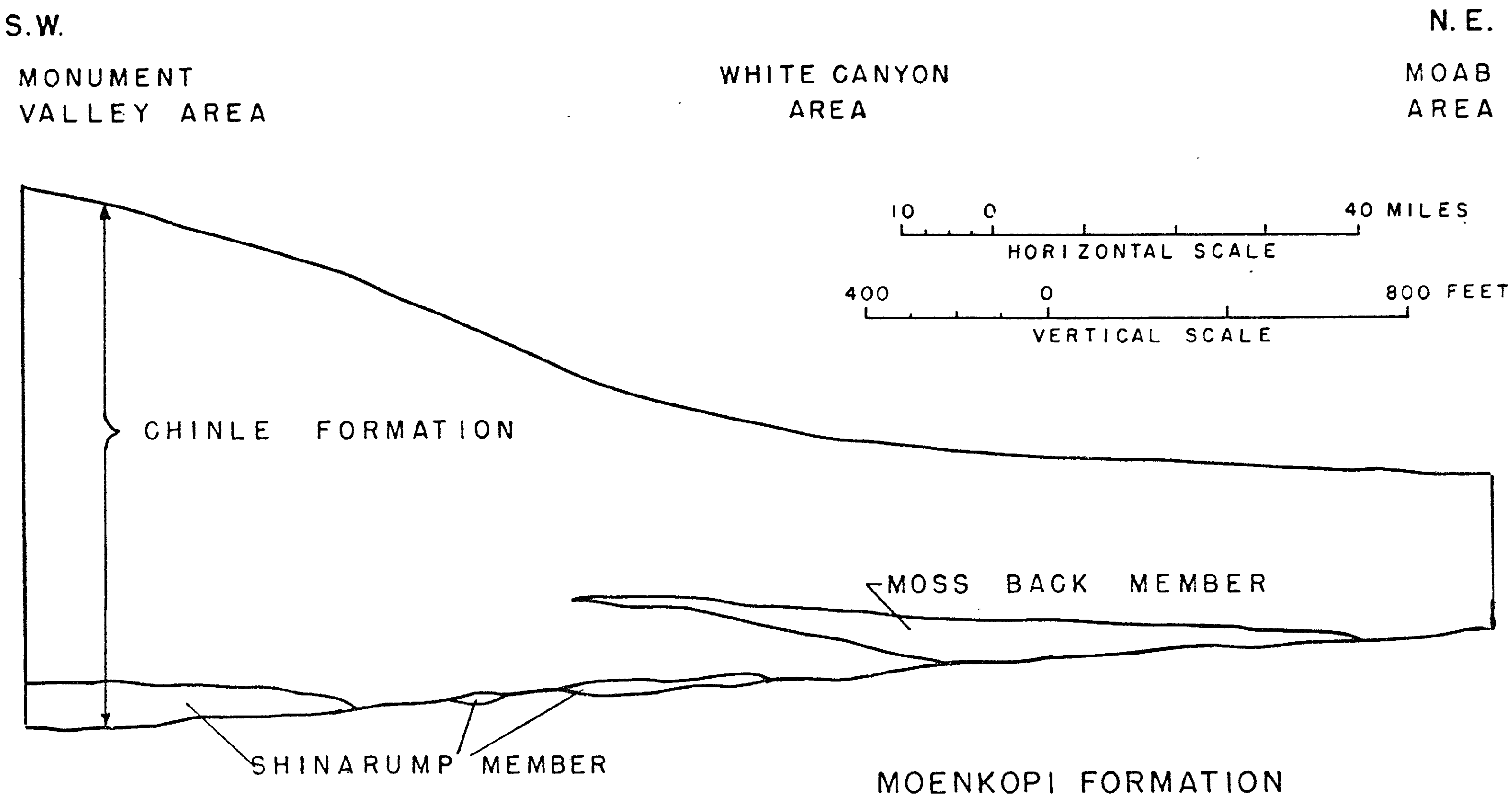

FIGURE 2.--GENERALIZED STRATIGRAPHIC RELATIONSHIP OF THE SHINARUMP AND MOSS BACK MEMBERS OF THE CHINLE FORMATION (MODIFIED AFTER STEWART AND OTHERS, 1956).

Pebbles in the Shinarump member of the Chinle formation

Pebble samples were taken in the Shinarump, where exposures permitted, from the Kanab area, Utah, to the White Canyon area, Utah. The quartz:quartzite:chert ratio in the Shinarump, which is about 11:46:43 in the Kanab area, changes to about 82:16:2 in the White Canyon area. (See table 3.)

The colors of quartz, quartzite, and chert differ markedly among the areas sampled. In general in the Kanab area, 10 to 30 percent of the pebbles in the Shinarump have bright colors such as red, pink, or orange. In the White Canyon area, however, over 90 percent of the pebbles are mostly of light colors such as white, gray, and tan.

The maximum length of pebbles, determined by measurements of the long axes, varies regionally (table 1). The maximum length decreases from about 113 mm. in the Kanab area to about 38 mm in the Circle Cliffs area, and decreases from about 125 mm in the southeastern part to about 40 mm in the northwestern part of the White Canyon area.

The mean size of the pebbles, determined by measurements of the intermediate axes, reflects a decrease in size over the same area as the maximum size pebbles--that is, a general decrease in size from south to north (table 1). The mean size decreases from 23 mm in the Kanab area to 13 mm in the Circle Cliffs area and from 25 mm in the southeastern part to 12 mm in the northwestern part of the White Canyon area.

The pebbles in the White Canyon area have the highest average index of sphericity, (0.77) and are composed mainly of quartz. The pebbles in the Circle Cliffs area are composed largely of quartz and quartzite and the

Table 1.--Location of sample sites and the composition, size, roundness, and sphericity of pebbles from each site.

Location	Sample No.	Composition (Percent) Quartz	Quartzite	Chert	Maximum Length (mm)	Mean Size (mm)	Roundness	Sphericity
			Moss Back member of the Chinle formation					
Elk Ridge area								
Deer Flat	HA- 40	9	48	43	70	17	0.62	0.74
The Notch	HA-134	20	46	34	83	22	0.62	0.76
Bridger Jack	HA-132	6	18	76	80	19	0.58	0.75
Average		12	37	51	78	19	0.61	0.75
Green River Desert area								
Poison Springs Box Canyon	HA- 61	9	28	63	70	20	0.61	0.74
Junction Butte	HA-102	12	28	60	75	22	0.63	0.75
"C" group mines	HA-129	8	33	59	95	21	0.58	0.74
Bighorn Mesa	HA-128	9	49	42	58	23	0.60	0.73
Middle Trail	HA-120	13	48	39	75	20	0.58	0.74
Average		10	37	53	75	21	0.60	0.74
San Rafael area								
Muddy River	HA-46	13	26	63	60	17	0.57	0.75
Chute Canyon	HA-57	9	31	60	58	18	0.61	0.76
Straight Wash	HA-79	21	61	18	85	16	0.61	0.74
Buckhorn Wash	HA-91	16	65	19	100	23	0.62	0.74
Average		15	46	40	76	19	0.60	0.74
			Shinarump member of the Chinle formation					
Kanab area								
Canaan Gap	HA-2	18	34	48	113	20	0.61	0.69
Pipe Springs	HA-3	5	39	56	93	22	0.59	0.70
Fredonia	HA-1	6	49	45	113	23	0.55	0.74
Pioneer Gap	HA-4	15	60	24	93	22	0.61	0.73
Average		11	46	43	103	22	0.59	0.72
Circle Cliffs area								
Colt Mesa	HA- 5	45	24	31	45	16	0.57	0.74
The Peaks	HA- 6	79	12	9	58	15	0.49	0.79
Lampstand	HA- 7	40	18	42	63	15	0.54	0.74
Bicknell	HA- 8	30	54	16	45	14	0.65	0.74
Twin Rocks	HA-17	67	18	15	38	13	0.64	0.75
Average		52	25	23	50	15	0.58	0.75
White Canyon area								
Happy Jack	HA-13	79	17	4	40	12	0.59	0.79
Soldiers Grave	HA-21	92	6	2	63	19	0.60	0.75
Frey Canyon	HA-14	96	4	0	80	26	0.65	0.79
Dillon mine	HA-42	79	21	0	97	25	0.63	0.76
Posey mine	HA-10	60	34	5	85	19	0.63	0.78
Red House Spring	HA-11	86	9	5	125	25	0.62	0.77
Clay Hills Pass	HA-12	71	28	1	58	22	0.63	0.76
Deer Flat	HA-38	90	10	0	85	24	0.62	0.75
Average		82	16	2	79	22	0.62	0.77

average index of sphericity is about 0.75. In the Kanab area the pebbles are composed largely of chert and quartzite and the average index of sphericity is lowest--about 0.72.

The average roundness of the pebbles is highest--about 0.62--in the White Canyon area. The average roundness is 0.59 in the Kanab area and 0.58 in the Circle Cliffs area.

The largest average indices of both sphericity and roundness are in the White Canyon area where the pebbles are composed mainly of quartz. It is not known if the high quartz-pebble content is the cause of the high roundness and sphericity figures, but such a correlation does seem possible. Of two samples from the Circle Cliffs area that are high in quartz--one sample has a high average index of roundness; the other has the lowest of all samples taken. Both samples have a high average index of sphericity, and of these, the one that has the highest sphericity has the lowest roundness. Such apparent anomalies indicate that generalizations about differences in sphericity or roundness should be confined to differences between the mean of all samples in an area and the mean of samples from six other areas, and not differences between individual samples. The lithology of a pebble strongly controls its original shape, cleavage or bedding, and durability, and these factors influence the shape of the pebble.

Pebbles in the Moss Back member of the Chinle formation

Conglomerate and conglomeratic sandstone are common in the Moss Back member. The pebbles comprise two lithologic assemblages: 1) quartz, quartzite, and chert; and 2) limestone and siltstone. These assemblages occur together or separately but are commonly present in the same lens along an outcrop. Where the limestone and siltstone pebbles occur with the quartzose pebbles, they generally are 10 to 20 times as numerous as the quartzose pebbles. Where only limestone and siltstone pebbles are present, they may constitute more than 50 percent of the rock by volume.

The limestone and siltstone pebbles are not counted with the quartz quartzite, and chert pebbles, but a visual estimate is made of their quantity. They will not break out of the matrix but are easily identified by the weathered surface characteristic of these rocks.

The average ratio of quartz:quartzite:chert pebbles in the samples from the Moss Back member is 12:40:48. These figures were obtained from a study of 3,000 pebbles collected at 12 localities (table 1). The ratios are not greatly different from locality to locality. At places, the difference may be greater between samples within an area than between samples from different areas.

At all places studied, quartz pebbles constitute a minor part of the conglomerate in the Moss Back member. Quartz pebbles comprise about 12 percent of the total quartzose pebbles in the Elk Ridge area, about 10 percent in the Green River desert area, and about 15 percent in the San Rafael Swell area; quartzite and chert comprise most of the remainder in about equal proportions.

The colors of pebbles are not appreciably different in the areas of outcrop. Some of the chert pebbles have bright colors, but in general, the pebbles are mostly shades of gray to black.

The maximum length of the pebbles ranges from 58 to 100 mm, but this range in maximum length does not show a systematic regional variation. The mean size of the pebbles, which ranges from 16 to 23 mm, is about the same throughout the Moss Back member. This variation, similar to the variation of maximum length, is not systematic regionally; both the maximum and minimum mean sizes obtained were on samples from the San Rafael Swell.

Sphericity and roundness figures vary little over the entire area of outcrop. The sphericity averages about 0.74 and ranges from 0.73 to 0.76. The roundness averages about 0.60 and ranges from 0.57 to 0.62. The differences in sphericity and roundness are small and show no systematic changes in any direction across the area.

Comparison of pebbles in the Shinarump and Moss Back members of the Chinle formation

In the Kanab, Utah, area the quartz:quartzite:chert ratio of the Shinarump is about the same as that of the Moss Back in the areas to the northeast (table 1). This is the only area studied, however, where the Shinarump has such a similarity to the Moss Back in this regard. It is about 100 miles from the nearest Moss Back outcrop.

The quartzose lithologies of the Shinarump and the Moss Back pebbles are similar in that quartz, quartzite, and chert are present in both units. The differences within the quartzose lithologies of the two units are only in the colors and ratios of the three components. In the White Canyon and Elk Ridge areas where the Moss Back and Shinarump members both crop out, the quartz:quartzite:chert ratios are 82:16:2 for the Shinarump and 12:37:51 for the Moss Back. From an average of all the samples studied the ratios are 56:26:18 for the Shinarump and 12:40:48 for the Moss Back. The most obvious difference is the percent of quartz pebbles in each unit. The percent of quartz in the Moss Back is persistently low, whereas it is high in the Shinarump.

A primary difference in the lithologies of the Moss Back and the Shinarump is that the Moss Back contains limestone and siltstone pebbles, whereas the Shinarump does not.

Five hundred pebbles from each unit have been compared with colors in the National Research Council Rock Color Chart (Goddard and others, 1948). The colors of the pebbles from both units fall into the same categories of the color chart. Close observation, however, shows that the ratio of gray to black pebbles is greater in the Moss Back, and this difference is great enough to be seen at the outcrop.

The maximum length and the mean size of pebbles are not significantly different between the two units. Locally the pebble sizes are different, but regionally the sizes are nearly the same.

The means of the indices of sphericity and roundness of the quartz, quartzite, and chert pebbles are essentially the same for each unit, although fewer determinations were made on Moss Back samples. The mean was determined from all quartzose pebbles in the samples.

The pebbles in both units have reached "maturity" as defined by Plumley (1948) in his study of sediment transport in the Black Hills region. Three indices of maturity that Plumley cites are: 1) all components quartzose (that is, quartz, quartzite, and chert), 2) high index of roundness, and 3) high index of sphericity.

Pebble-size components in the units studied are not all quartzose; limestone and siltstone pebbles are present in the Moss Back member. The two assemblages of pebbles may be together or separate, and either assemblage may overlie the other. Moreover, the limestone and siltstone pebbles are chemically and mechanically unstable. If they had been introduced into the sediments from the same source area as the quartzose components, a reduction in the ratio of soft rock components to quartzose components would be evident across the sampled area. Such is not the case; regionally, the ratio of soft rock to quartzose components and the size of the soft rock components are about the same.

Plumley's data (1948) suggest that mature indices are reached rather quickly in gravel deposits. From a study on Rapid Creek in the Black Hills, he found that 30 miles of transport resulted in the loss of all but 2 or 3 percent of the limestone and sandstone components that had originally comprised about 25 percent of the gravel.

Krumbein (1941b), in an experiment on the effects of abrasion on the size, shape, and roundness of rock fragments, showed that for limestone fragments, after the equivalent of 20 miles in a tumbling barrel, the roundness appeared to approach an asymptote slightly higher than 0.64 and that sphericity appeared to approach an asymptote slightly higher than 0.77.

The limestone was obtained from a commercial crusher, which assured a high initial angularity in the fragments. The initial average roundness was 0.13 and the initial average sphericity was 0.65. This shows that roundness had increased nearly 400 percent, whereas, sphericity had increased only about 18 percent.

The average sphericity of both the Shinarump and Moss Back pebbles is 0.75 and the average roundness is 0.60. The indices are lower than the end figures in Krumbein's experiment. This may be accounted for by the homogeneity of Krumbein's samples, whereas, the Shinarump and Moss Back samples are composed mainly of three rock types.

The quartzose pebbles of the Shinarump and Moss Back are regarded as having attained maturity. The area across which the pebbles were sampled is well over 100 miles long. In this distance the indices of roundness and sphericity change very little, which indicates an asymptotic value had been approached prior to deposition in the area being studied.

Fossils in the Shinarump and Moss Back pebbles

Some of the fossils found in the Shinarump and Moss Back are indigenous to these units, but most of them are contained in the pebbles. The only fossils indigenous to the Shinarump and Moss Back, found in this study, are wood, plants, and phytosaurian bones.

Most of the fossils found are contained in pebbles of chert. Some of the fossiliferous pebbles in both units apparently were derived from the Kaibab limestone of Permian age or rocks of the same age as the

Kaibab. Others contain fossils that are known to occur in the Rico, Hermosa, and Redwall formations, suggesting these formations as possible sources. One sample contained bryozoans commonly found in the Brazer limestone of Mississippian age and its equivalents. Other samples contained a genus of algae that is known only from the Permian. In western North America this algae has been reported from the Carlsbad limestone, the Capitan limestone, and the Delaware formation of New Mexico and Texas.

From the lists of fossils found in the pebbles it is evident that rocks of several ages and of different areas contributed pebbles. The lists include bryozoans, protozoans, brachiopods, pelecypods, algae, and horn coral. Some of the genera were identified in pebbles that were collected from both the Shinarump and Moss Back. Other forms are known in pebbles only from one unit or the other. Fossils, however, that so far are known in pebbles of only one unit cannot be considered indicative of that unit. Inadequate sampling could account for finding an assemblage of fossils in one unit but not in the other.

SUMMARY

Differences in the pebbles of the Shinarump and the Moss Back members can be used to distinguish the units. These differences are mainly: 1) limestone and siltstone pebbles abundant in the Moss Back and essentially absent in the Shinarump, 2) a large percentage of quartz pebbles in the Shinarump and a low percentage in the Moss Back, and 3) the ratio of gray to black pebbles is greater in the Moss Back than in the Shinarump.

Sphericity and roundness vary only slightly and are about the same for each unit, suggesting that the pebbles are mature. The average indices of sphericity and roundness are respectively about 0.75 and 0.60.

The fossils contained in the pebbles can not now be used to identify either the Shinarump member or Moss Back member. With further work, however, it is hoped that fossils will aid in locating source rocks.

The differences between the pebbles of the Moss Back and Shinarump are significant. Each probably received major contributions from different source areas. Part of the Shinarump member probably received a major contribution from a granitic area, as evidenced by the high quartz-pebble content, that did not contribute or was only a minor contributor to the Moss Back member. The Moss Back member, on the other hand, has a high content of limestone and siltstone pebbles that must have been locally derived, probably from the underlying sediments.

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