A PETROLOGIC STUDY OF SOME JURASSIC (?) SEDIMENTS LOCATED AT NORTH CREEK, CUSTER AND PUEBLO COUNTIES, COLORADO

by

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INTRODUCTION

General Statement

This thesis describes the results of field and laboratory studies of the lower Morrison and other Jurassic (?) sediments of the North Creek area, Custer and Pueblo Counties, Colorado. The field study involved correlations, measuring sections, megascopic identification, sedimentary structures, and sampling the units for laboratory studies. The laboratory study consisted of three separate investigations; these being bulk mineralogical composition, heavy and light mineral studies, and clay mineralogy.

Purpose of Investigation

The location was chosen because of the need of establishing a boundary between the Morrison and the Jurassic (?) sediments below. It is hoped that a petrologic correlation can be established between the Jurassic (?) sediments and similar rocks in East-central Colorado.

Any divergence or similarity in average bulk mineralogical composition between like units over a lateral extent will aid in field correlation and possibly give an insight as to the source and the direction from which the present sediments were derived.

The processes of weathering, abrasion, and intrastratal solutions tend to destroy the minerals of the parent rock from which a sediment is derived. However, a small percentage of stable minerals persist in the later developed sediment. Among these are the heavy minerals (specific gravity greater than bromoform, 2.85), which represents the very stable minor accessory minerals present in the source rock. It is thought that a comparison of heavy and light minerals of the lower Morrison and the Jurassic (?) rocks might give evidence as to where the boundary should be placed between them.

The clay minerals present in a sediment should show physical and chemical characteristics which can be traced back to the minerals from which they were derived. The validity of this theory is questionable in the case of sandstones. The reason for the doubt is their unusually high porosity and permeability. This allows vast amounts of water and other interstratal solutions to pass through the rocks and react chemically with the mineral constituents, notably the clay minerals. It is anticipated that local correlations may be possible on the basis of the clay minerals present.

Area of Investigation

The North Creek area is located near the northern end of the Wet Mountains in eastern Custer and western Pueblo Counties, East-central Colorado (Fig. 1). The thesis area lies about 25 miles west of Pueblo, Colorado, and can be reached via Colorado State Highway 76 and 214. Beulah, the nearest town, is located eight miles south of the area studied.

REVIEW OF LITERATURE

The geology of the North Creek area was first discussed by Gilbert in 1893, when part of the area was included in the Pueblo

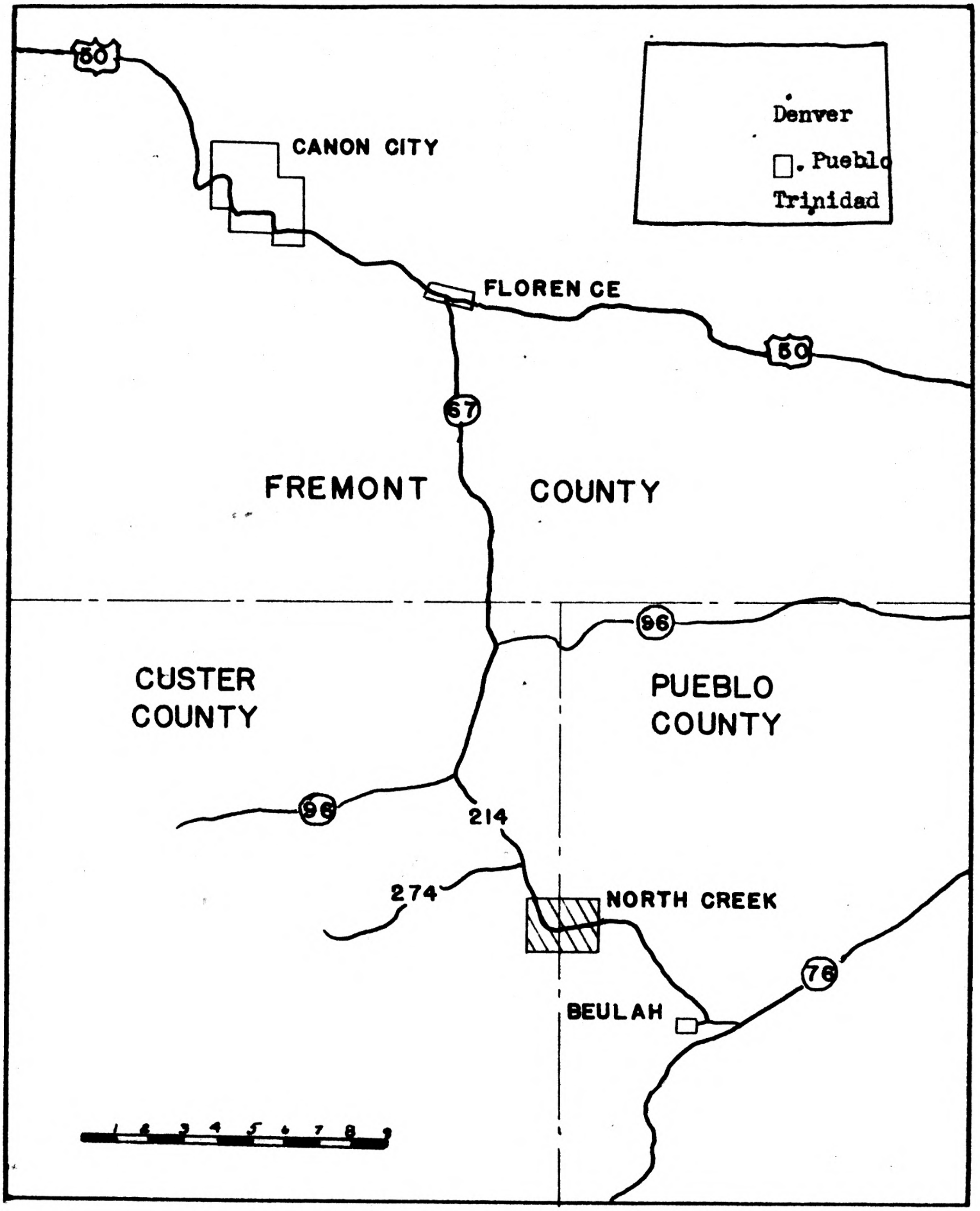


Fig. 1. Index map of Colorado showing the location of the North Creek area.

Folio of the United States Geological Survey.

Heaton (1939) has done considerable work on the Jurassic stratigraphy of the Front Range, southern Colorado, and northern New Mexico. He recognized, at North Creek, the interval between the Morrison and Fountain formations as being Lykins. Heaton placed the base of the Morrison at North Creek as a greenish white even bedded sandstone. At Beulah, eight miles south of North Creek, he encounters the Entrada formation which he says, "The massive, crossbedded sandstone again appears between the Morrison and Lykins formations after being absent as far north as Jarr Canyon, a distance of more than 90 miles." The Entrada Heaton found at Beulah had a thickness of 50 feet.

Heaton further stated that 60 feet of Lykins occurred at North Creek. Within the Lykins there is a limestone which resembles the "crinkled limestone" of the Lykins found along the Front Range.

Later Heaton (1950) evidently discarded his earlier idea about the Lykins being present at Beulah and North Creek. He describes a series of evaporite limestone, gypsum, and shales which were deposited as a marginal phase of a marine basin during Upper Jurassic. These have usually been included in the basal Morrison. The marginal marine phase lies directly below the basal Morrison and above the Entrada when it is present. Heaton correlates the marginal marine phase with the Ralston formation in the vicinity of Golden, Colorado, (LeRoy, 1946) and also with the Todilto formation of northern New Mexico.

Kim (1951) divided the interval between the Fountain and

Morrison into a bottom unit A and an upper unit B. He based the divisions on unconformities found within the interval. He further correlated the units with the Lyons and Lykins formations respectively.

Malek-Aslani (1952) reported that the Lyons and Lykins formations are absent in the Beulah area, but he also said that the upper part of the Fountain is probably the time equivalent of the Lyons of the Front Range. He presumed that the Lykins was deposited but is now absent due to pre-Morrison erosion.

Franks (1956) recognized units A and B as being present in the North Creek area. He indicated that an unconformity is present within the interval between the Fountain and Morrison and so divided the interval into Units A and B. He also recognized unconformities between the Fountain and Unit A and between Unit B and the basal Morrison. He has simply referred to this series of arkosic conglomerates, breccia, sandstone and limestone as "Undifferentiated Jurassic" and made no attempt to correlate them with other rock units.

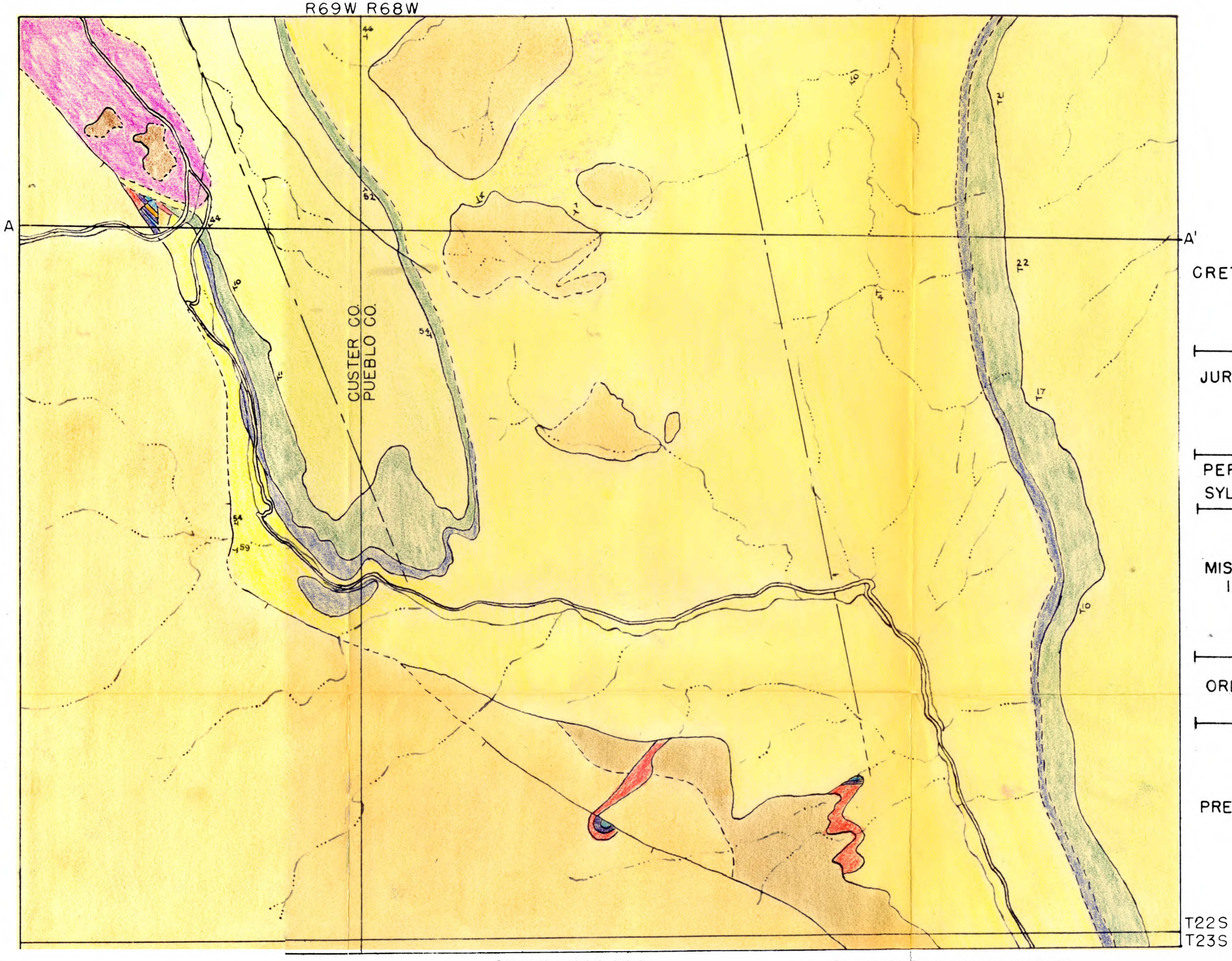
METHODS OF INVESTIGATION

Field Methods

Field mapping was done on U. S. Department of Agriculture Aerial Photographs (1955) at a scale of 1:20,000. Geologic data was transferred to a base map prepared from planimetric maps of the United States Department of Agriculture Soil Conservation Service (Fig. 2).

Fig. 2 Geologic Map of the North Creek Area

GEOLOGIC MAP
NORTH CREEK PASS AREA, COLORADO



SCALE- 1:40,000

PLANIMETRY FROM AERIAL PHOTOS TAKEN IN 1955

True North

LEGEND

IMPROVED DIRT ROADS — CONTACT LINES

INTERMITTENT STREAMS — FAULTS

PERENNIAL STREAMS — FOLD AXIS

STRIKE AND DIP OF BEDS

SEDIMENTARY ROCK

CRETACEOUS	GREENHORN LIMESTONE
	GRANEROS SHALE & SILTSTONE
	DAKOTA SANDSTONE
JURASSIC	MORRISON SHALE
	JURASSIC UNDIVIDED
PERMO-PENN-SYLVANIAN	FOUNTAIN ARKOSIC SANDSTONE & CONGLOMERATE
MISS-ISSIPPIAN	BEULAH LIMESTONE
	HARDSCRBBLE LIMESTONE
	WILLIAMS CANYON LIMESTONE
ORDOVICIAN	HARDING SANDSTONE
	METAMORPHIC ROCKS
(Early)	IDAHO SPRINGS SCHIST & GNEISS
PRE-CAMBRIAN	IGNEOUS ROCKS
	PIKES PEAK GRANITE

Stratigraphic sections were measured with Brunton Compass, tape and Abney hand level. Spot samples were collected from each unit for detailed laboratory studies (Fig. 1). A section was measured and sampled at the Skyline Drive, Canon City, Colorado, for correlation purposes.

Laboratory Methods

The initial phase of the laboratory study was a detailed megascopic study of all samples collected. On the basis of this preliminary examination samples were selected for thin section study, mechanical analysis, mineralogical analysis, and x-ray analysis.

<u>Thin Section Analysis</u>. Twenty-five thin sections were prepared from various samples for detailed petrographic study. Mineralogical composition, texture, and frequency distribution were determined.

<u>Mechanical Analysis</u>. The samples selected for mechanical analysis were subjected to a preliminary disaggregation by a jaw crusher until the largest fragments were of "pea" size. The crushed sample was then split using a Jones sample splitter until a 200 gram test sample was obtained. The test sample was then immersed in water for several days to prepare it for final disaggregation. After air drying the sample was completely disaggregated by hand and gentle pounding with a pestle.

The test sample was then placed in a 1000 milliliter beaker and a 50 percent solution of hydrochloric acid was added to remove all carbonates and iron oxides. When the initial frothing had subsided the sample was boiled until chemical action between the acid and the carbonates had ceased. The sample was then filtered, washed, and allowed to dry. The dried sample was weighed to determine the amount of carbonates and iron oxides removed.

The mechanical analysis was to be run only on the sand size and larger fraction; therefore, it was necessary to remove the silt and clay sized particles. A sodium silicate solution (1 gram of Na_2SiO_3 per 40 milliliters of deionized water) was used to disperse the clays. The dispersed sample was then wet sieved and all material passing through the 230 sieve was discarded.[1] The sand size and larger material retained on the sieve was then dried and weighed to determine the amount of silt and clay removed.

Considerable controversy has arisen over the use of hydrochloric acid rather than a less active one. However, the effectiveness of using hydrochloric acid for removal of carbonates and iron oxide stains cannot be contested. The main objection to the use of this acid is that certain minerals, notably apatite and gypsum, may go into solution. Whether these minerals, which might have played an important part in the overall mineral assemblage, have been completely destroyed is questionable. However, it appears that if a mineral is to be used as a reliable index of the mineral assemblage involved, it should possess stability in the laboratory as well as in the field.

Numbers 5, 10, 18, 35, 60, 120 and 230 sieves were placed

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[1]All sieve numbers are those of the U. S. Standard Sieve Series.

in a nest and were sieved for 10 minutes on a mechanical shaker. The weight retained on each sieve was then recorded and the results analyzed.

Mineralogical Analysis. The sand fraction that remained on the 230 sieve was resieved onto a 170 sieve for the purpose of collecting material for mineralogical analysis. The sand fraction retained on the 170 sieve is ideal for preparation of detrital sections and gives a representative mineralogical sample.

To facilitate the mineralogical analysis a heavy liquid separation was performed using bromoform ($CHBr_3$) as a separating medium. After the heavy minerals had settled to the bottom of a separatory funnel, they were tapped off, washed, dried, and then mounted in Permount on glass slides (refractive index-1.54). The same procedure was then carried out for the light minerals.

One to two hundred mineral grains were chosen at random for the mineralogical identification on each slide. The results of frequency distribution studies made on the light and heavy minerals are shown in Tables 1, 2, 3 and 4.

X-ray Analysis. The first consideration given to preparation of the material for clay analysis was that of carbonate removal. The effect of hydrochloric acid on certain clay minerals has been studied quite extensively. Grim (1953) found that certain montmorillonites and chlorites were either altered or completely destroyed by the use of hydrochloric acid to remove carbonates from the samples, hence acid treatment was not used on the sample prepared for x-ray analysis.

Each sample was crushed and sieved through a No. 120 sieve.

They were further disaggregated by adding one gram of dry sodium silicate per 300 milliliters of deionized water and agitated in a Waring blender for 15 minutes. The sample was then wet sieved through a No. 270 sieve, agitated again, and placed into a sedimentation tube with enough deionized water to make a total volume of 1000 milliliters. Twelve hours is required for each 10 centimeters of settling distance. After 36 hours the upper 30 centimeters of liquid was decanted. The portion left in the bottom of the sedimentation tube was then agitated again, placed back into the sedimentation tube with enough water to make a volume of 1000 milliliters. The above procedure was followed for a second and third separation with the exception that 24 and 12 hours sedimentation time was used respectively. The material that had been decanted was considered to be a representative sample of the clay minerals present.

Slides for x-ray analysis were prepared from an aliquot of the decanted sample with the clays still in liquid suspension. An eyedropper was used to transfer a small amount of the sample to a clean glass microscope slide. The sample was then air dried to allow the clay particles to form an orientated slide for easier x-ray diffraction analysis.

Identification of the clay minerals present in the samples was done by x-ray diffraction using a North American Phillips diffraction unit. Nickel filtered copper radiation was used with a one degree slit system, scale factor of 400, time constant of four seconds at 20 milliamps and 40 kilovolts. The scanning speed was one-fourth degree two theta per minute. The orientated slides

Table 1. Mineral analysis of the heavy and light fractions of the "Undifferentiated Jurassic" samples collected at the Skyline Drive, Canon City, Colorado. All numbers are percentages.

	Samples							
Minerals	1A	2A	3A	5A	6A	7A	12A	13A
				Light Fraction				
Quartz	55	51	58	48	49	53	51	53
Orthoclase	6	9	4	7	6	4	8	7
Microcline	21	19	22	23	26	20	31	28
Plagioclase	6	8	7	12	4	9	2	7
Chalcedony	6	4	3	4	8	5	2	2
Volcanic Ash	1	2	3	2	3	0	0	1
Coated grains and opaques	5	7	3	4	4	9	6	2
				Heavy Fraction				
Magnetite	47	60	51	49	53	47	41	39
Ilmenite	4	27	10	9	10	23	4	8
Leucoxene	1	5	7	4	9	5	12	20
Tourmaline	21	3	21	17	12	18	14	15
Chlorite	9	1	7	7	6	4	12	9
Zircon	4	1	0	7	5	0	6	5
Stilpnomelane	2	2	1	4	1	1	9	4
Muscovite	9	1	3	3	3	2	2	0

Table 2. Mineral analysis of the heavy and light fractions of the "Undifferentiated Jurassic" samples collected three miles north of Beulah, Colorado. All numbers are percentages.

	Samples						
Minerals	1B	2B	3B	4B	6B	7B	12B
				Light Fraction			
Quartz	62	48	53	57	51	46	54
Orthoclase	5	3	6	2	8	4	3
Microcline	18	26	21	19	25	32	26
Plagioclase	4	3	6	8	5	4	6
Chalcedony	3	5	5	4	3	5	4
Volcanic ash	2	5	2	3	1	3	2
Coated grains and opaques	6	10	7	7	9	6	5
				Heavy Fraction			
Magnetite	59	39	65	38	76	37	30
Ilmenite	12	12	16	15	8	4	10
Chlorite	5	6	3	2	4	13	2
Leucoxene	7	18	5	25	4	12	35
Tourmaline	8	11	6	14	5	28	17
Zircon	5	2	3	4	1	4	0
Stilpnomelane	0	3	1	0	0	1	5
Muscovite	4	9	1	2	2	1	1

Table 3. Mineral analysis of the heavy and light fractions of the "Undifferentiated Jurassic" samples collected at the North Creek Campground. All numbers are percentages.

	Samples							
Minerals	1C	2C	4C	5C	6C	7C	9C	13C
				Light Fraction				
Quartz	65	58	54	56	49	53	47	58
Orthoclase	4	6	8	77	8	5	9	3
Microcline	18	23	24	21	28	22	19	22
Plagioclase	5	7	4	6	3	9	11	6
Chalcedony	3	2	5	3	2	2	3	2
Volcanic ash	1	1	2	1	3	4	2	4
Coated grains and opaques	5	3	3	6	7	5	9	5
				Heavy Fraction				
Magnetite	49	48	56	54	50	60	56	57
Ilmenite	14	18	12	15	14	21	18	25
Chlorite	2	2	6	4	7	4	3	5
Leucoxene	16	12	17	21	12	8	9	5
Tourmaline	2	8	6	3	6	1	6	2
Zircon	3	5	4	1	4	3	5	1
Stilpnomelane	0	2	2	0	3	2	0	3
Muscovite	14	5	7	2	4	1	3	2

Table 4. Mineral analysis of the heavy and light fractions of the "Undifferentiated Jurassic" samples collected one mile south of the North Creek Campground. All numbers are percentages.

Minerals	Samples 1D	2D	4D	5D	7D	9D	10D	11D	13D	14D	15D	17D	18D
Light Fraction													
Quartz	64	55	51	57	53	48	56	52	49	54	51	62	53
Orthoclase	6	3	7	4	2	8	5	7	9	3	6	4	7
Microcline	21	26	24	19	23	25	22	17	24	21	23	22	26
Plagioclase	5	7	4	6	9	11	8	6	4	11	7	5	8
Chalcedony	1	3	3	4	3	4	2	7	5	4	3	4	1
Volcanic ash	1	2	4	1	4	1	2	4	4	3	2	1	2
Coated grains and opaques	2	4	7	9	6	3	5	7	5	4	8	2	3
Heavy Fraction													
Magnetite	35	42	71	61	19	68	54	58	37	57	45	57	44
Ilmenite	15	9	9	12	12	11	16	12	14	10	19	20	26
Chlorite	3	12	3	2	12	2	3	3	6	2	4	6	3
Leucoxene	31	9	8	12	40	10	12	17	18	10	15	14	13
Tourmaline	12	5	7	8	14	3	13	8	21	18	11	3	11
Zircon	1	3	0	1	0	4	0	0	2	0	0	0	3
Stilpnomelane	4	3	2	0	3	0	2	0	2	0	1	0	0
Muscovite	0	17	0	4	0	2	0	2	0	3	5	0	1

were examined from 35 degrees two theta to 3 degrees two theta.

Table 5. Average mineral composition of the five different rock types as determined by thin section studies.

Minerals	Rock Types: Arkosic Conglomerate and Arkosic Sandstones with Pebbles	Medium to fine grained Arkosic sandstones	Arkosic Siltstones	Dense Arkosic Dolomitic Limestone
		Detritals		
Quartz	41	46	13	11
Microcline	28	24	03	04
Plagioclase	07	04	02	00
Orthoclase	00	00	02	00
Ilmenite and magnetite	01	01	00	00
Biotite	01-	01-	00	00
Muscovite	00	02	00	00
Clay minerals	09	05	15	01-
Others	01-	01	00	01
		Non-detritals		
Calcite and dolomite	11	13	60	84
Limonite	02	03	05	00
Chalcedony	01-	00	00	00

After being examined through this angular distance the orientated slide was treated with ethylene glycol. Ethylene glycol forms an organic complex which will expand the basal spacings of montmorillonite from 14 to 17 angstroms. After the glycol treatment the diffraction pattern was scanned from 15 degrees two theta to three degrees two theta. This range will allow the (001) of kaolinite, illite, and montmorillonite in its expanded position to be recorded. The 15 to 3 degree range also includes the (001) and (002) reflections of chlorite and vermiculite.

The diffraction patterns were recorded on a strip chart calibrated in degrees two theta. The two theta measurements were then converted to angstrom spacings using, <u>Tables for Conversion</u>

of X-ray Diffraction Angles to Interplanar Spacings, published by the National Bureau of Standards. The angstrom spacings were then compared to known and theoretical spacings of minerals that occur in the clay-size range.

RESULTS AND CONCLUSIONS

The mechanical analysis of the samples studied showed the sediments to be very poorly sorted. This was especially evident when the sorting was determined for all size ranges occurring within a particular sediment. A separate determination of sorting was figured for the sand size fraction which showed a marked increase in the coefficient of sorting. The sorting of the bulk sediments ranged from 3.5 to 4.6. The analysis of the sand fraction ranged only from 1.5 to 2.5. According to Trask (1932), well sorted sediments have a sorting coefficient of less than 2.5, moderately well sorted sediments range from 2.5 to 4.0, and poorly sorted sediments have values larger than 4.0.

A comparison of the sorting coefficients for each collecting site showed that the degree of sorting is higher south of the North Creek area and also at Canon City. Here the sorting coefficients were 3.5 and 3.9 respectively. The average sorting coefficient found at North Creek was 4.3. This indicates a lateral variation in dispersion of the sediments was in effect. The variation suggests either a channel or a deltaic type deposit.

The grains found in the sand size range (2 millimeters to 1/16 millimeters) were generally much better rounded than the grains and rock fragments found in the fraction larger than two

EXPLANATION OF PLATE I

Fig. 1. Large angular grains of microcline surrounded by calcite. Note the roundness of quartz grains compared to the microcline. 25X Arkosic conglomerate.

Fig. 2. Arkosic siltstone showing stratification. Detrital grains are quartz and feldspar. Solution channel is filled with secondary calcite. Matrix is also calcite. 25X.

PLATE I

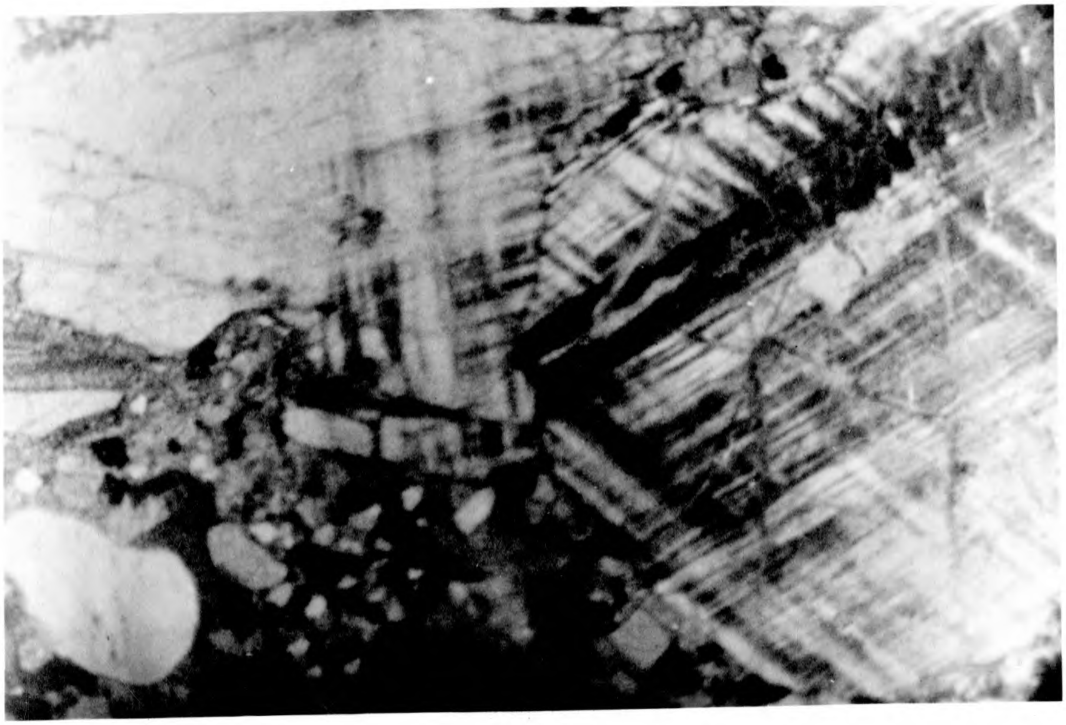

Fig. 1.

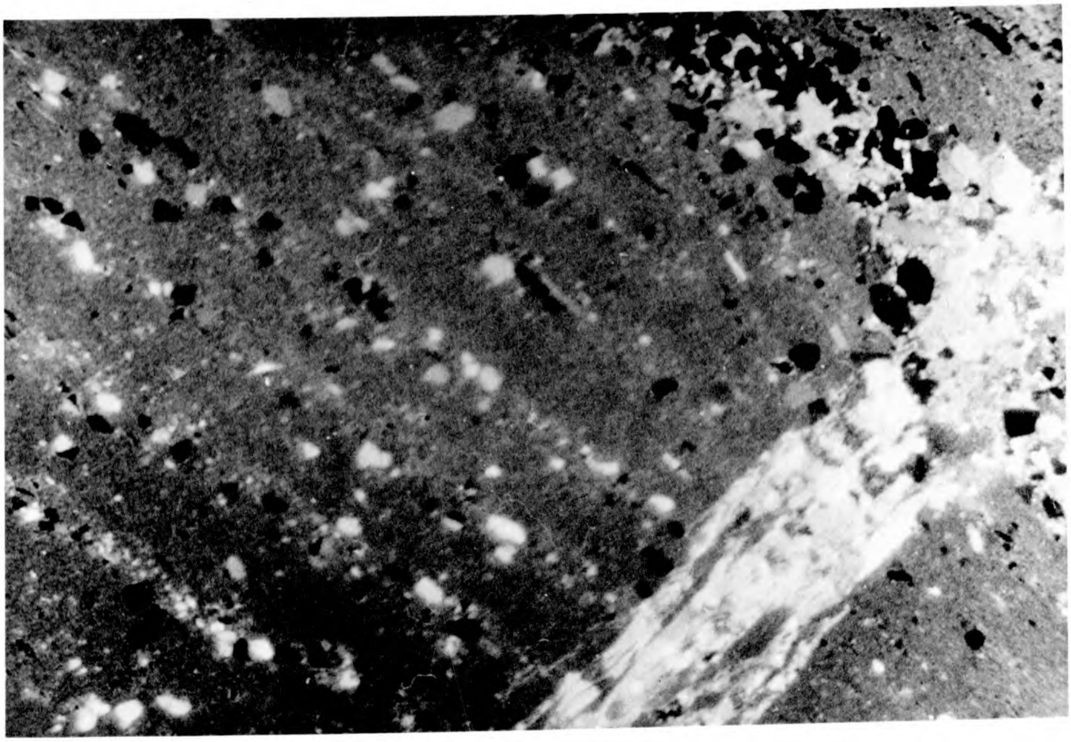

Fig. 2.

EXPLANATION OF PLATE II

Fig. 1. Various orientations of calcite and dolomite found within a fossil. 80X Arkosic Dolomitic Limestone.

Fig. 2. Angular to sub-angular grains of microcline and quartz. Matrix and cement is chalcedony. 80X Arkosic Sandstone.

PLATE II

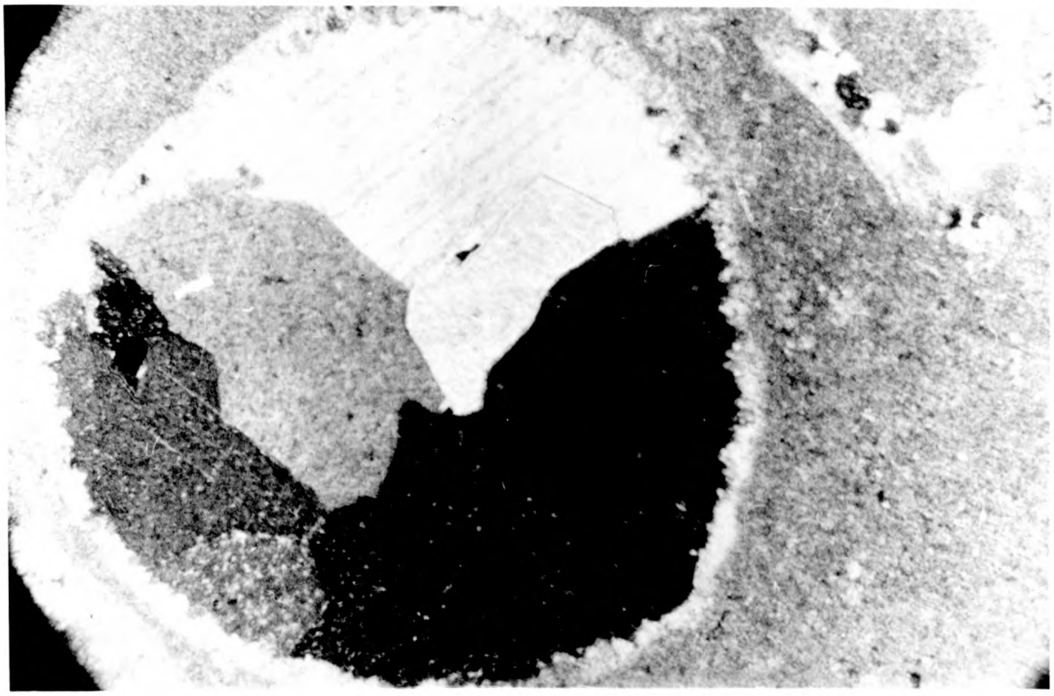

Fig. 1.

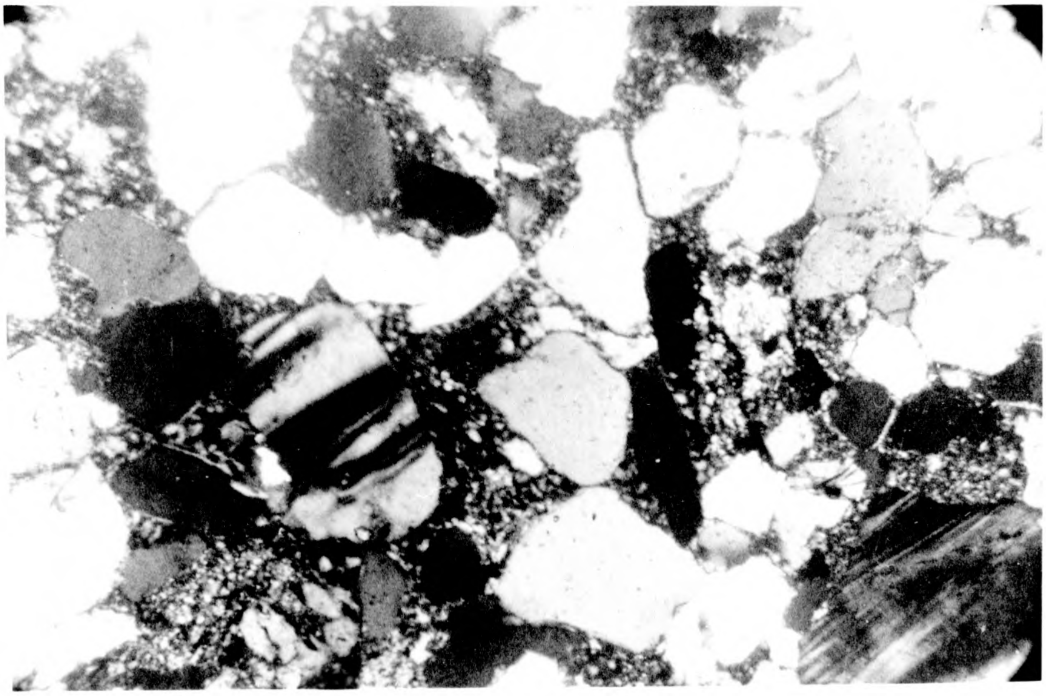

Fig. 2.

EXPLANATION OF PLATE III

Fig. 1. Grain of microcline being replaced by quartz. The gray to dark minerals are quartz grains that are oriented. 80X Arkosic Siltstone.

Fig. 2. Angular grains of microcline that are being replaced by calcite and dolomite. 25X Arkosic Conglomerate.

PLATE III

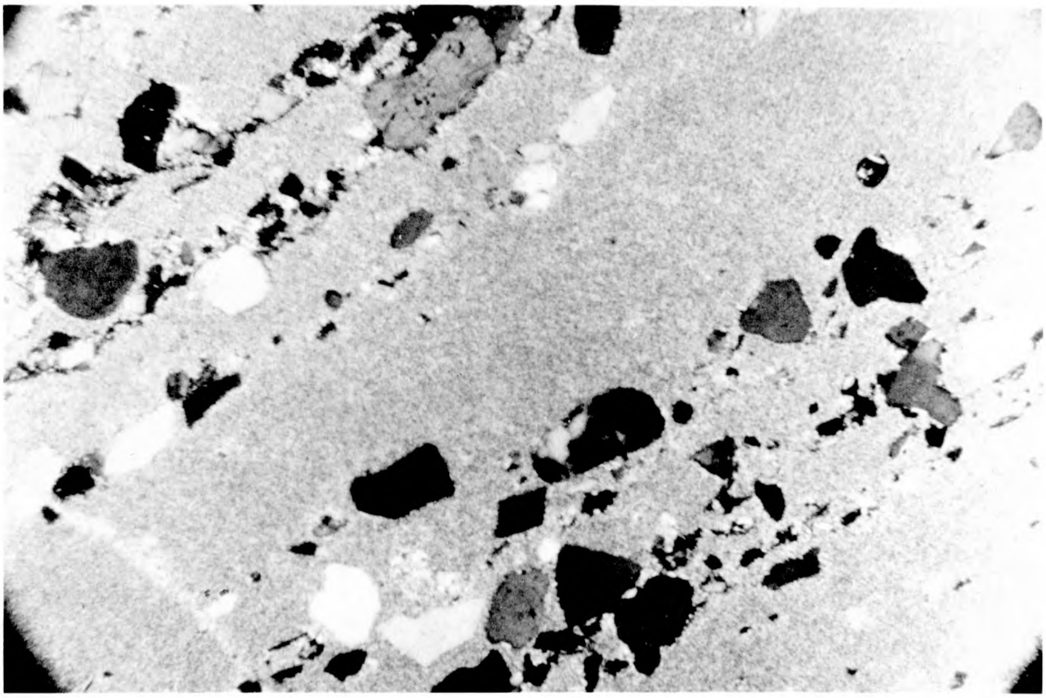

Fig. 1 .

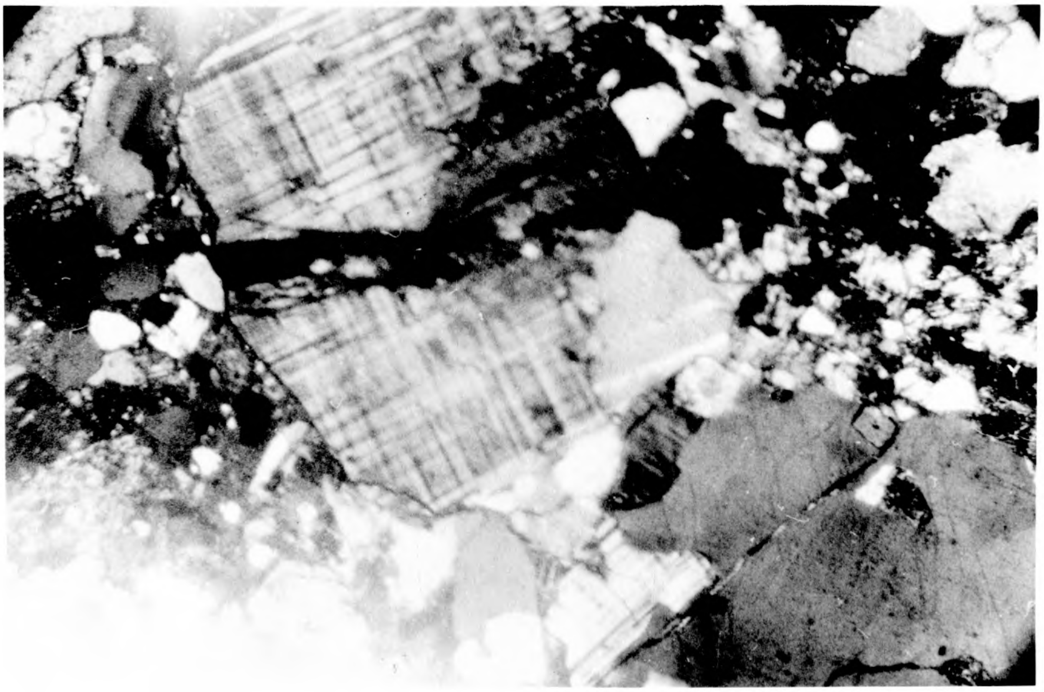

Fig. 2.

millimeters. The larger fraction was primarily composed of feldspar and rock fragments. They probably owe their angularity to a combination of shorter transport distance and cleavage. Any mineral that has cleavage will tend to be more angular than a mineral that lacks cleavage.

The thin section study showed a definite orientation of quartz grains within the rocks studied. The orientation of the c-axis of the quartz grains was parallel or roughly parallel to the bedding in about 35 percent of the rocks studied. The writer believes that the orientation of the c-axis is also parallel to the direction of transport; however, this cannot be proved in this study since oriented samples were not collected in the field.

Rock Types

The mechanical analysis, megascopic analysis, and petrographic analysis, showed that the sediments found between the Fountain formation and the Morrison formations consist of arkosic conglomerates, arkosic sandstones with included pebbles of feldspar and rock fragments, medium to fine grained arkosic sandstones, arkosic siltstones, and dense arenaceous arkosic limestones.

<u>Arkosic Conglomerates and Arkosic Sandstones with Included Pebbles</u>. (Plates I & III). Microscopic studies revealed that the arkosic conglomerates and the arkosic sandstones with included pebbles of feldspar and rock fragments to be of essentially the same composition and texture.

The grains in these sediments are angular to subrounded with detrital grains ranging from a fraction of a millimeter in the matrix to those whose long dimension exceeds a centimeter. The hand specimens have grains which sometimes are five centimeters in length.

The matrix is composed of fine to medium grained angular and rounded detrital grains of quartz, feldspars, ilmenite, magnetite and occassionally a grain of biotite. Clay, limonite, calcite, and cryptocrystalline quartz occur between the detrital grains. The calcite is seen to be replacing the detrital grains of quartz, feldspar, and cryptocrystalline quartz.

The larger grains of the rock are generally angular and quite fresh and are composed of quartz, microcline, and lesser amounts of plagioclase. As is to be expected in the area, the quartz shows undulatory extinction. An average composition for this rock is shown in Table 5.

Medium to Fine Grained Arkosic Sandstones. (Plate II). This rock is light gray to light red in color, arkosic, medium to fine grained, and has a calcareous cement. The grain size ranges from a fraction of a millimeter in the matrix to 0.5 millimeters in the detrital grains other than those in the matrix. The larger grains are sub-angular to sub-rounded and consist of quartz, microcline, plagioclase, muscovite, magnetite, and small amounts of biotite. The cement is calcite and limonite.

The larger grains of microcline and plagioclase have been partially altered to clay minerals. The quartz is both of igneous and metamorphic origin and often contains inclusions of zircon.

The average composition of this rock is shown in Table 5.

Arkosic Siltstone. (Plate I & III). This type of rock is very fine-grained, light gray to green in color, arkosic, calcareous and argillaceous. The rock has a varved appearance with alternating bands of green and gray mineral matter. The hand specimen shows the bedding very well as does a thin section. The detrital grains are embedded in a fine calcareous matrix which contains large amounts of clay matter. The long diameters of the detrital grains range from 0.3 millimeters to 0.03 millimeters with the greatest amount being between 0.05 and 0.1 millimeters.

The predominant detrital mineral is quartz, with lesser amounts of microcline, plagioclase, and orthoclase. The detrital minerals make up about 20 percent of the mineral assemblage. The average composition is shown in Table 5.

Dense Arkosic Dolomitic Limestone. (Plate II). The rock is a dense finely crystalline arkosic dolomitic limestone that is dark gray in color. Angular grains of pink feldspar are dispersed randomly through the rock as are small grains of quartz.

Thin sections show the rock to be finely crystalline, arenaceous, and an arenaceous limestone with large enough amounts of clay matter and dolomite to color the rock a dark gray. The long diameter of the grains range from 0.8 millimeters to less than 0.04 millimeters. The detrital grains include quartz, microcline, plagioclase, and very minor amounts of muscovite and magnetite.

Most of the calcite and dolomite is fine-grained but about 10 percent of it has recrystallized into larger grains. All of the detrital minerals other than magnetite show secondary replacement by calcite or dolomite. The average composition is shown in Table 5.

Heavy Mineral Analysis

The study of the heavy minerals present in the sandstones and conglomerates showed that magnetite was by far the most dominant heavy mineral. The magnetite averaged 51 percent of the heavy minerals for all of the samples studied, and it ranged in amounts from 19 to 74 percent.

The next mineral in abundance was ilmenite followed by leucoxene and tourmaline. These minerals were present in all of the samples studied and would serve best as correlation minerals.

The tourmaline that was found was of several types. The most common type was brown and occurred as rounded grains. Other types found were brown with inclusions, colorless, blue, and green. Krynine (1946) explained that brown and green tourmaline in sediments is usually derived as an end phase product within large plutonic igneous bodies. The tourmaline was generally medium sized idiomorphic crystals, frequently having bubbles and inclusions. Blue tourmaline occurs in petmatites and vein rocks as very large crystals. Sediments later derived from this type of igneous body would contain angular fragments due to breakage during erosion. Colorless and green tourmaline is found associated with metamorphosed sedimentary rocks.

The light minerals found were quartz, microcline, orthoclase, plagioclase, chalcedony, and volcanic ash. Quartz comprised about 65 percent of the light minerals. The quartz found was of both igneous and metamorphic origin and commonly had overgrowths of secondary quartz. Some quartz had formed secondary overgrowths on magnetite and ilmenite and was thus found in the heavy mineral fraction.

Chalcedony or cryptocrystalline quartz was found and averaged five percent of the light fraction. The chalcedony occurs as the cement in many of the sandstones, however, part of it is detrital.

Microcline was the most abundant feldspar. It constituted 22 percent of the light minerals. Orthoclase and plagioclase averaged eight percent. Small amounts of volcanic ash were found and these were attributed to falls from the atmosphere; their origin was probably volcanic activity occurring in the western part of the United States.

Source Area of the Jurassic (?) Sediments

Feldspar is not a normal constituent of sandstones. It is absent or nearly absent from mature sands and generally it is found in large amounts in immature sands only. It owes its presence to the retardation of weathering in the source area or to being protected from weatheringat the site of deposition.

Retardation of weathering in the source area may be explained in one of two ways. It is either due to high relief or a rigorous climate which is either extremely cold or arid. It is possible, however, that the climate be humid as long as the relief is sufficiently high and the rate of erosion is fast enough that the feldspar does not decompose.

Arkoses are found as either a thin blanket-line mass that overlies a grainitic terrane or as very thick wedge shaped deposits. Krynine (1948) related arkoses "to the stage of maximum deformation of the diastrophic cycle (orogenic state)" and believed they were formed immediately after that stage. Since they are generally red they are thought to be of continental origin and usually associated with large scale block faulting.

A study of Jurassic paleogeography shows no masses of high altitude occurring in the Colorado region. The areas of high relief in Colorado were the Ancestral Rockies of Pennsylvanian time and the present Rocky Mountains. It is probable that some remnants or "monadnock-like hills" were still present in Jurassic time and had escaped the intensive erosion that took place to form the Fountain formation. These areas were located near to the site of deposition as evidenced by the large amount and the extreme angularity of the large feldspar grains and rock fragments. If this is the case then climate was the controlling factor of formation rather than tectonics. A combination of aridity and torrential rainfall can deposit sediments similar to those found at North Creek.

Another possibility of formation is that the Wet Mountain fault may have been initiated sometime before Laramide time. The fault is located along the front of the Wet Mountains and its location is less than one mile from North Creek (Fig. 2). The length of the fault extends northward past Canon City and southward to the southern tip of the Wet Mountains. An erratic and abrupt movement along this fault would produce a graben like structure which is an ideal depositional site for arkosic sediments. Maher (1953) indicated that the Wet Mountain fault may have been formed after the close of Ordovician time which permitted the removal by erosion of the Cambrian and most of the Ordovician rocks from the area. Maher also thought that the Wet Mountain fault was accentuated during the Morrowian age of Pennsylvanian time. Geologic evidence of pre-Laramide movement of the Wet Mountain fault is not to be found probably because the magnitude of the Laramide faulting was so great that it destroyed all traces it is.

It is thought then that the sediments at North Creek are of Middle to Upper Jurassic in age and were developed from the Pikes Peak granite and the Idaho Springs gneiss and schist. They could have either been the product of climatic conditions on remnants of the Ancestral Rockies or the result of pre-Laramide movement along the Wet Mountain fault. The latter case presumes that a graben type structure would be formed along the face of the fault in which the sediments would be deposited.

The large angular fragments of feldspar and rock fragments are attributed to the closeness of the source area and to pre-Cambrian hills present after Pennsylvanian erosion had taken place.

Clay Analysis

X-ray analysis of the clay minerals show that illite is the most common clay mineral found. Montmorillonite as well as kaolinite and chlorite were present in smaller amounts.

It is felt that a study of the clay minerals will not help appreciably as far as determining source area or correlation is concerned. The porosity and high amounts of ionic solutions that must pass through these rocks is too great and so variable that specific correlations on the basis of clay minerals would be nearly impossible.

Correlation Study

The Jurassic formations other than the Morrison formation that are found in southeastern Colorado are as follows in order of age:

Entrada Sandstone

Wanakah Formation

Ralston Formation

The Entrada sandstone is a light colored sandstone facies characterized by clean rounded quartz grains, by conspicuous color banding of red, pink, and gray, and by large scale cross-bedding (Imlay, 1952).

The Wanakah formation includes a sequence of limestone, gypsum, a sandstone, and shale between the Entrada sandstone and the Morrison formation. It has been described as being present in northern New Mexico, southwestern Colorado, and southeastern Colorado. It is divided into the Pony Express member in south-western Colorado and the same lower unit is called the Todilto limestone in southeastern Colorado. Above this basal unit in southeastern Colorado is a series of sandstones and small amounts of shale.

The Ralston formation is found along the Front Range of Colorado. Fredrickson, et al (1956) has divided the Ralston formation into four separate facies in the Canon City Embayment. He recognized a conglomeratic facies, a sandstone facies, a gypsum-shale facies, and a sand-shale facies. LeRoy (1946) has included the Wanakah formation as part of the Ralston formation where it occurs along the Front Range.

The Entrada Sandstone is present at Beulah and can be traced southward into New Mexico. It is found for a short distance north of Beulah but it is thought that post-Entrada erosion has removed it from the North Creek area.

The interval of sediments found at North Creek that lie between the Morrison and Fountain formations has been divided into two units on the basis of unconformities. The lower unit consists of brownish to light colored arkosic sandstones and conglomerates. Locally a lenticular crinkly limestone is found to occur within this unit. The lenticular limestone is not found at North Creek but it is found a few miles north and also east of the North Creek area. The writer correlates the basal member with the Todilto limestone member of the Wanakah formation (Fig. 3).

The upper part of the section found at North Creek is then correlated with the Upper Wanakah. This also consists of light colored arkosic conglomerates and sandstones and is found throughout the area.

It is thought that as the Wanakah sediments are traced into the Canon City Embayment that they become thinner and constitute the conglomerate and the sandstone facies as described by Fredrickson.

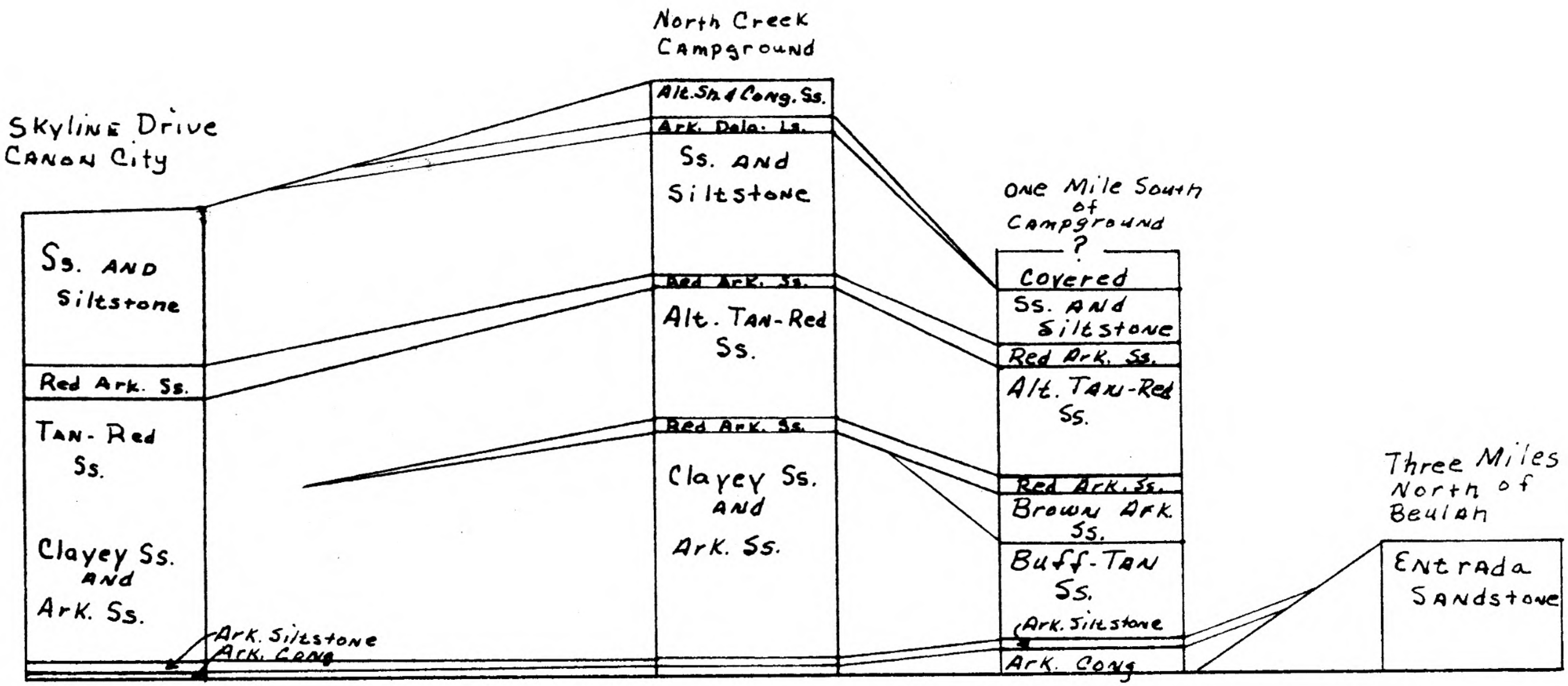

Fig. 3. Correlation samples based on petrographic study.

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A PETROLOGIC STUDY OF SOME JURASSIC (?) SEDIMENTS LOCATED AT NORTH CREEK, CUSTER AND PUEBLO COUNTIES, COLORADO

by

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The sediments found at North Creek that lie between the Morrison formation and the Fountain formation present an interesting problem in petrology and stratigraphy. The rocks consist of coarse conglomeratic sandstones, arkosic sandstones, and siltstones. Often pebbles of feldspar, quartz, and rock fragments up to five centimeters in diameter are included within the sandstones and conglomerates.

The purpose of this thesis is to determine the source area of these sediments, describe their depositional environment, and to establish correlations between these rocks and similar rocks found in southeastern Colorado.

The methods used to determine the various properties of the sediments were field descriptions and measurements, mechanical analysis, thin section analysis, heavy liquid separations, and clay mineral analysis.

The mechanical analysis indicated that the sediments were poorly sorted, but that sorting increased both north and south of the North Creek Area. This indicates a deltaic or channel type deposit.

Five distinct rock types were recognized by the use of petrographic thin sections. These were arkosic conglomerates; arkosic sandstones with and without included pebbles of feldspar, quartz, and rock fragments; arkosic siltstones; and arkosic dolomitic limestones.

Heavy liquid studies revealed that magnetite composed over 50 percent of the heavy minerals. Ilmenite, leucoxene, and tourmaline were found in all of the samples studied and could be used for petrographic correlations.

Illite was the most common clay mineral found. Kaolinite, montmorillonite, and chlorite were found in lesser amounts. It is not felt that the clay minerals can be used for correlation because of the vast amount of solutions that pass through the rocks which cause varied degrees of ion exchange.

The source area for the sediments at North Creek was a nearby slightly elevated landmass lying to the west. Two possibilities are considered for the development of the sediments. The area to the west was either a low landmass that had retained elevated remnants of the Ancestral Rockies or it was an uplifted area that was the result of pre-Laramide movement along the Wet Mountain fault. If the source was the remnants of the Ancestral Rockies, deposition was probably controlled by climatic conditions rather than by tectonics. Evidence for pre-Laramide movement of the Wet Mountain fault is inconclusive due to the magnitude of the faulting that took place during the Laramide Revolution. If pre-Laramide movement had occurred it would necessitate postulating a graben or trough structure along the face of the Wet Mountains. The North Creek Area could be a part of such a feature.

The stratigraphic interval of sediments found at North Creek has been divided into two units on the basis of unconformities. The lower unit commonly contains a crinkled limestone which is absent at North Creek but is present both east and north of the area. The lower unit has been correlated with the Todilto limestone member of the Wanakah formation and the upper unit with the upper Wanakah. These units are found in southeastern Colorado and northern New Mexico. It is thought that as these units are traced northward into the Canon City Embayment that they become thinner and compose the conglomerate and the sandstone facies of the Ralston formation.