1947

Insoluble Residues of Five Sections of the Amsden Formation

Wilmer R. Peterson

INSOLUBLE RESIDUES OF FIVE SECTIONS OF THE AMSDEN FORMATION

BY

WILMER R. PETERSON

A Report

Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

INSOLUBLE RESIDUES OF FIVE SECTIONS OF THE AMSDEN FORMATION

BY

WILMER R. PETERSON

A Report

Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

TABLE OF CONTENTS

	Page
Introduction	I
Value of insoluble residues	2
Location of sampled areas	3
Previous work on Amsden	4
Acknowledgements	4
General Geology	4
Amsden formation of Wyoming	5
Relations and outcrops	5
Rocks	5
Fossils and age	5
Amsden formation in Montana	6
Measured Amsden sections	7
Section at Sappington	7
North Boulder section	I0
South Boulder section	II
Amsden Creek section	I2
Dry Head Creek section	I6
Amsden of sampled areas	I9
Sappington section	I9
North Boulder section	I9
South Boulder section	20
Treatment of samples	20
Study of residues	2I
Photographs	2I
Description of residues	22

Page

Sappington section 22

North Boulder section 26

South Boulder section 27

Amsden Creek section 29

Dry Head Creek section 33

Sappington formation residues 37

North Boulder residues 38

South Boulder residues 38

Amsden Creek residues 38

Dry Head Creek residues 39

Conclusions 40

Bibliography 41

ILLUSTRATIONS

		Following Page
Map and Graphic Representation; Index map of the Sampled area and Diagrammatic Representation of the insoluble residues of the five formations sampled		Back Cover
Plate I	Sappington Section	19
II	Amsden across river from Sappington	20
	Amsden in Jefferson Canyon	20
III	Photographs of Residues	21
Table I	Correlation chart of Amsden	4

INSOLUBLE RESIDUES OF FIVE SECTIONS OF THE AMSDEN FORMATION

BY

WILMER R. PETERSON

INTRODUCTION

The term, "insoluble residue," as used in this report is that portion of the original rock sample remaining after the sample has been digested by a mixture of one part hydrocloric acid and two parts water. The remains or insoluble residue from this acid treatment may vary from nothing to 100 percent. A pure limestone will be completely dissolved while a sandstone, will not be appreciably attacked. Various mixtures of sandstone, limestone, and shale will be dissolved according to their calcareous content.

McQueen (6) made one of the first practical studies of insoluble residues in Missouri, Oklahoma, and Kansas by the correlation and indentification of formations, through the study of residues, in the hope of formation identification in ground water studies. Hamblin (3) started the study of insoluble residues in Montana by studying the Upper Paleozic formations across a strip in central Montana, on outcrops, so residue study could be applied to subsurface oil well problems. He only briefly mentions the Amsden residues and states, "they were recognized by sand grains and aggregates of sand grains." The purpose of this study is to reveal a means of recognizing the Amsden formation when encountered in oil well drilling sludge or cores by comparison to outcrop residues.

VALUE OF INSOLUBLE RESIDUES

Uncorrelated well samples may be identified by insoluble residues as to formation, and this information used to reveal concealed sub-surface stratigraphic structures as folding, faulting, overlap, and unconformites. They reveal also the character of the original rock, types of sediments deposited, and organic matter present. Simple methods are used and elaborate equipment is unnecessary in residue studies. In the field residues can easily be prepared and compared to outcrop samples already studied. Insoluble residues also serve as an aid in working out the source of sediments, and paleography of the subsurface from well logs. It is also valuable in well log work to correlate where the oil accumulated and where certain lenses of sand are distributed.

Ireland (4) states that the use of insoluble residues does not replace lithologic examination, but is a supplement to it. Characteristics of the samples which are obscured by the large volume of the cuttings are liberated, concentrated, and exposed by the solution of the matrix and the diminution of the volume. Types of chert, dolocasts, fossil replacements, igneous fragments, and quartz grains are not commonly seen when embedded or mixed with the general sample. Unconformity structures make oil occurrences possible, and key beds for determining such structures may be limestones or well defined shales. Residue studies facilitate the identification of such limestones or shales. After the correlation of formations is started and something known about them, insoluble residues may answer many problems about the formations. He also states, every stratified bed is deposited

under a definite sedimentary environment, and one task of the geologist is to learn of such environments. A change in source of detritus causes a change in the residues. They tend to show the small changes after the obscuring matrix is removed. The use of insoluble residues is limited to calcareous beds.

LOCATION OF SAMPLED AREAS

The typical Amsden section sampled was three miles northwest of Sappington, Montana (Plate 1 & 2) where 47 samples were collected at five-foot intervals on fresh rock after the weathered surface was pounded away. Total thickness of the Amsden outcrop is 507 feet. Measurement of section and sample cuts were perpendicular to the dip of the formation. The same procedure of sampling was followed at the North Boulder Section, nine miles north of Cardwell, and the South Boulder section, three miles south of Cardwell on South Boulder Creek.

Blackstone, Bradish, and Seager of the Carter Oil Company sampled the Amsden Creek section May 9, 1939, and the Dry Head Creek section May 5, 1939. Their sampling ranges from six inches to twenty-six feet between samples, and this differs somewhat from the five-foot interval of sampling on prominent outcrops.

PREVIOUS WORK ON AMSDEN

In general, literature and work on the Amsden formation is lacking due to its unimportance as a reservoir rock. The great bulk of literature is on the Madison formation which is an oil producing horizon. Perry (7) stated in 1937 that the Amsden is too impervious to serve as a reservoir rock, not known to be

petroliferous, and it is not likely a source rock, but later described the occurrence of oil in the Amsden in the Gage field (8) as follows: "In fact oil accumulation at Gage may result from conditions of porosity as much as, or more than, conditions of structure." In certain cases it might be important to know when the Amsden formation has been encountered, or where it is missing in the field, and residue study of the sludge or cores by comparison to outcrop samples might answer these questions.

ACKNOWLEDGEMENTS

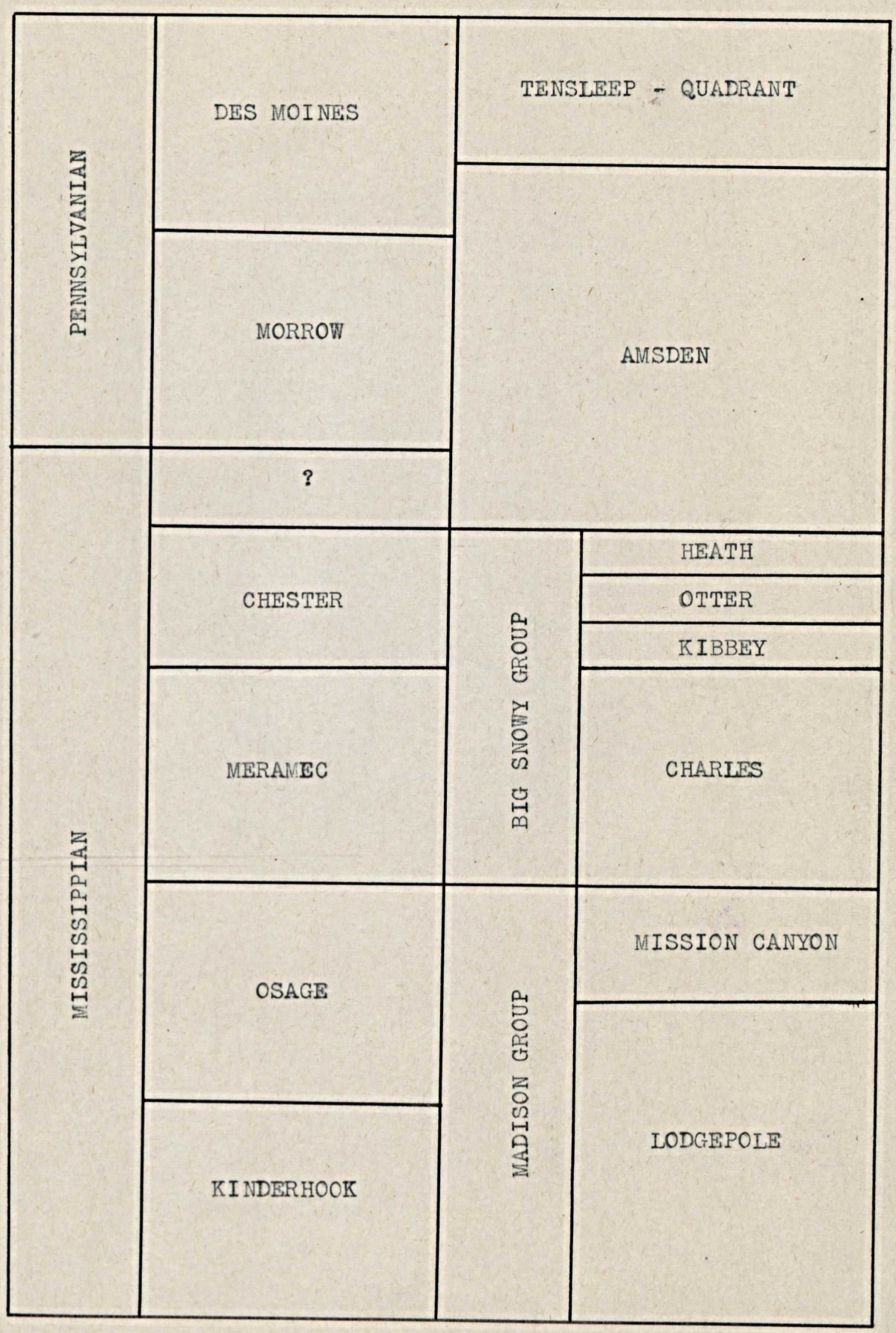
The author gratefully acknowledges the valuable aid by Dr. E. S. Perry and Dr. L. L. Sloss in obtaining information, photography, and constructive criticism of this report. Also acknowledgement is made of the use of the two sampled sections of the Amsden formation which Dr. Sloss obtained from the Carter Oil Company.

GENERAL GEOLOGY

This paper is primarily concerned with the Amsden formation residues from the five sampled outcrops.

Three of these outcrops were sampled within a radius of 12 miles; Sappington, North Boulder, and South Boulder. The Dry Head Creek section in South Central Montana and the Amsden Creek section in northern Wyoming were sampled by Carter Oil Company employees. The index map under the back cover shows the location of the sampled areas. The stratigraphic column showing relation of the Amsden to other time equivalents is shown on the following page.

CORRELATION CHART OF AMSDEN



(11)

Amsden Formation in Wyoming

Relations and outcrops: Overlying the Madison limestone is a somewhat variable series of red shales, limestone, sandstone, and cherty beds which has been designated the Amsden formation. The average thickness is 200 feet. Its outcrops extend along both sides of the mountains, usually flanking the limestone slopes. On the east slope of the uplift the Amsden formation crops out along the higher outer slopes of the front ridge, with thickness gradually increasing from 150 feet in the north to 350 feet in the south.

Rocks; The lower member of the Amsden formation consists of a mass of bright-red sandy shales, abruptly overlying the top member of the Madison limestone, which is in many places stained red from the shale. This basal red shale ranges in thickness from 50 feet to 100 feet, and is often parted by ten feet or more of hard, fine-grained, flesh-colored limestone resembling lithographic stone. Next above are slabby limestones, in part containing extensive deposits of chert, which weather out, and in some places accumulate in large amount on the surfaces.

Fossils and Age; Very few traces of organic remains occur in the Amsden formations in this region, and there is some uncertainty as to its age. A few fragments of Spirifer and Zaphrentis were obtained from the lower limestone bed, and also a Menophyllum excavatum, a Mississippian form. From the upper cherty beds there are Pennsylvanian species. These were determined by G. H. Girty. This evidence indicates that, while the

upper part of the formation is Pennsylvanian, the lower beds belong to the earlier Carboniferous division. The succession is apparently continuous.

Amsden Formation in Montana

Scott (8) states, in northwest Yellowstone Park the Amsden underlies the Quadrant and is above the Madison. In central Montana the limestone, lying below rocks of Jurassic age and above the Big Snowy group, is a northward extension of the Amsden.

Lithological characteristics of the Amsden grade from dominantly red shaly sandstone overlain by a thin gray-blue limestone in south-central Montana to thinly bedded limestones that weather pink and are arenaceous in the basal part in central Montana.

Perry (7) states that throughout southern Montana the formation consists of 150 to 200 feet of buff- to cream-colored, fine-grained limestone underlain by 20 to 30 feet of purple, red, and buff-colored sandy and calcareous shale. The shale member upon weathering in outcrop develops deep red soils which commonly streak the underlying white Madison with red stains.

Branson (2) states, the contact between Amsden and Tensleep is one of disconformity with a clear-cut wavy line of demarcation. The contact between Madison and Amsden is disconformable.

The following is a description of the measured Amsden formations as sampled;

MEASURED AMSDEN SECTIONS

Section at Sappington

Height from base in feet	
	Quadrant quartzite
507	white, chalky limestone containing light-tan chert; seams grade into Quadrant as solution-channel filling
487	light-tan, chalky limestone
477	yellow, sandy limestone
467	white, tan, platy limestone; appears sandy
457	brown, light-blue, white limestone
447	blocky, massive, dark-blue limestone
422	dark-blue, massive, blocky limestone; solution brecciated with chert
	No outcrop between samples
382	light limestone with white stringers
372	blocky, black, dense limestone
362	white and blue limestone
	No outcrop between samples
325	blue, blocky limestone contains fossil brachipods; an easily eroded zone between samples; rocks below stained
280	dark-blue limestone; fossil zone of brachipods (two inches thick)
260	dark, dense limestone
250	blue, dense limestone; brachipods
240	black, dense, blocky limestone; two chert bands seven feet below sample of dark to black chert
230	light-colored, blocky limestone; black crystals, white stringers
220	blue, fine-grained limestone; white stringers
215	blue, fine-grained limestone

210	limestone, light-colored, speckled like salt and pepper
205	dense, fine-grained, black limestone; one-half inch band of dark chert
200	blue, gray, fine-grained limestone
195	tan, gray, limestone
190	bright-colored, fine-grained limestone; brown tone
185	light-colored, fine-grained limestone
175	two bands of black chert above sample; first band one-half inch wide; second, two inches wide; blue, fine-grained limestone
170	blue, fine-grained limestone; white stringers
	No outcrop between samples
140	blue limestone; white stringers
130	light to dark colored limestone; white stringers
120	black, dense limestone
110	black, dense, blocky limestone
95	light-tan, fine-grained, sandy limestone
80	light-tan, fine-grained, sandy limestone
70	tan, fine-grained, chalk-like, sandy limestone
65	tan, sandy, fine-grained limestone; white calcite seams
60	white, sandy limestone; chalky appearance
55	tan, brown, sandy limestone; fine-grained
50	brown, fine-grained, sandy limestone
47 1/2	white, fine-grained, sandy limestone; white calcite seams
45	dark-red, narrow-banded, platy shale; some brown bands
40	white, fine-grained, sandy limestone
35	dark-brown, almost pink, fine-grained, sandy limestone

30	shaly, white, platy, calcareous sandstone
25	brown, fine-grained, platy, calcareous sandstone
10	gray, green, fine-grained calcareous sandstone
Base	Contact between Madison and Amsden covered by Madison talus.

North Boulder Section

Height from base in feet	
329	Quadrant quartzite
299	black, blocky limestone; white calcite seams
274	buff, tan, light-colored limestone
249	white, black, blocky limestone with fossil brachipods
234	white, dark-blue limestone; rich in fossil brachipods
174	dark-blue limestone; white calcite seams; very fossiliferous (brachipods)
139	dark-blue, blocky limestone; white calcite seams; brown staining (limonite)
99	faint-pink, lavender, shaly limestone
79	dull-red, platy limestone; shaly
69	faint-pink limestone; very shaly
49	pink, fine-grained limestone with dendrites
24	tan, buff, platy, shaly, fine-grained limestone; appears shaly
8	tan, pinkish, platy limestone; looks shaly
	Base of Amsden - tan, orange, shaly limestone

South Boulder Section

Height from base in feet		
	Quadrant quartzite	
215		black limestone; white calcite seams
210		white, sugary-grained limestone
205		dark-blue, smooth-grained limestone
200		light-blue, dark-gray limestone
195		dark-blue, black limestone; brachipod fossils
190		white, dark-gray, sugary-grained limestone
155		white, buff-colored limestone
145		light-gray, white, fine-grained limestone
135		tan, buff, light-colored limestone
125		white, light-gray, blocky, smooth limestone
120		light-gray, white limestone; brown cavities, fossil brachipods
115		light-gray, dark-blue, chalcedony-like limestone; fossil brachipod fragments
105		white, light-gray, sugary grained limestone; six inch chert band
100		light-gray limestone; calcite seams
90		base of steep bluff; dark-gray, blocky limestone; two-inch chert band below sample
50		white, gray, sugary grained limestone; white calcite seams; brachipod fossil zone
40		dark-gray, lavender, smooth limestone
30		dark-gray, sugary grained limestone
25		gray, tan, buff-colored limestone
15		blocky, dark-gray, smooth texture limestone
10		faint-gray, very light colored limestone; some limonite seams
Base of Amsden		dark-gray, blocky, fine-grained limestone

Amsden Creek Section

Height from base in feet	
	Base of Tensleep
294	Top of Amsden - limestone, purplish-gray, very dense, hard, sandy; two inches yellowish green shale at top
292 1/2	sandstone, purple, calcareous, thinly bedded, hard
291	shale, purple, sandy thinly-bedded, hard
290	shale, red, sandy, thinly-bedded, fissile
287 1/2	sandstone, purple, dolomitic, thinly-bedded
286 1/2	sandstone, gray, dolomitic, thinly-bedded
285 1/2	shale, yellow, marly, grades up to purple, flakey shale
283	sandstone, white, soft
276 1/2	cotton rock; dolomite and angular weathered chert
275 1/2	shale, marly and limestone, argillaceous, buff, purple mottling
272	sandstone, gray, dolomitic, hard
269	Covered - purple shale at bottom
243	limestone, light-gray, finely granular, sandy? streaks of chert
240	shale, green, marly
239	Covered - possibly purple shale with nodular limestone
232	shale, purple, blocky to fissile and flakey, green eyes
228	limestone, purple, earthy, very argillaceous; streaks of chert at base
225	shale, green
224	shale, purple, fissile and flakey
222	limestone, purple, lithographic

220	shale, purple, paper thin, flakey; imbedded purple, dense nodular limestone
213	shale, green, paper thin, flakey (two inches)
213	limestone, gray, dense, smooth wavy surface at top
212	shale, purple, with imbedded nodular limestone
211	limestone, gray, dense, purple streaks at top; thin seams purple shale, wavy bedding
209	shale, reddish purple, fissile, green eyes
202	shale and marl, nodular, purple mottled
197	limestone, gray, dense, stringers red chert
196	limestone, gray, finely granular
195	shale, dark-purple, hard, sandy at bottom
194 1/2	shale, dark-red, and limestone, gray, purple spots, finely granular
194	sandstone, buff to yellow, dolomitic, medium pink at top
190 1/2	dolomite, light-gray, granular, hard, yellow streaks; bedded dark chert
183	shale, purple; green at top (half foot)
178	limestone, light pinkish buff, pink spots, dense
177	limestone, light-gray, granular to finely crystalline, some yellow chert
175	sandstone, dark-red, dolomitic, hard
171	limestone, light-gray, dense (two inches)
171	shale, green, fissile, flakey, hard
170 1/2	dolomite, light-gray, some pink, granular to finely crystalline, trace chert at top
166 1/2	limestone, light-gray, dense; very hard, some angular chert at top
164 1/2	clay, bright red, mostly covered
152 1/2	limestone, pinkish-gray, finely granular, with dense streaks; becomes porous at top

148	limestone, medium, gray; finely granular, hard
145	limestone, pinkish gray, dense to finely granular, hard
142	limestone, purple, earthy,argillaceous
128	shale, maroon to purple, mostly covered
126	limestone, purple, dense to earthy, hard, mottled
125 1/2	limestone, light-gray, coarsely crystalline, hard, sub-oolitic?
124 1/2	limestone, gray, dense, nodules and stringers of chert and quartzite
123 1/2	limestone, gray, and purple, earthy argillaceous, mottled
121	shale, dark red, soft, with imbedded nodular red argillaceous limestone
120 1/2	limestone, light-gray, very dense, very hard, fossiliferous; Crinoids, Composita
119	clay, dark-red, maroon, green clay eyes, soft
118 1/2	limestone, gray, finely granular, very hard, calcite veining; wavy bedding
116 1/2	shale, dark maroon, soft, thinly-bedded
116	limestone, gray and light purple, mottled, dense, imbedded crystals
115	limestone, bluish gray to light bluish - purple, dense
111 1/2	clay, shale, bright red, soft; partially covered
96 1/2	shale, dark red, hematitic, blocky, hard, green eyes; calcite veining and nodules
93 1/2	shale, ditto
70 1/2	shale, dark red and purple, some yellow and green mottling, blocky, hard, becomes more red at top
58 1/2	shale, dark reddish brown, blocky, few green eyes

56	shale, dark-red, hematitic, blocky, hard
52 1/2	sandstone, red and white, mottled, argillaceous
46 1/2	shale, red, hematitic, blocky, very hard
31 1/2	sandstone, white to pink, medium, thin purple shale streaks, weathers red; quartzitic at bottom; slightly conglomeratic at top with angular chert
14 1/2	shale, red, hard, few green sandy eyes

Unconformity

Madison - limestone, light-gray, dense, few streaks of chert

Dry Head Creek Section

Height from base in feet	
390	Minnekahta - limestone, white to pink, granular, porous, punky, becomes gray and dense at top; small purple shale break in middle
384	Opeche- shale, red, sandy
359	Tensleep
259	Top of Amsden- shale, gray, sandy, marly, very fossiliferous
257 1/2	limestone, white, very dense, chert
256 1/2	sandstone, purple, very dolomitic, hard, porous, streaks shale in middle
252 1/2	shale, bright-red, flakey
250	sandstone, red, dolomitic, very highly cross-bedded; streaks quartzite
247 1/2	shale, purple, blocky, calcareous?
243	sandstone, purple, soft streaks quartzite
242	shale, bluish purple
237 1/2	limestone, gray, very dense, hard
236 1/2	limestone, gray, earthy, porous
235 1/2	sandstone, conglomerate, dolomitic, purple with black shale pebbles
225 1/2	sandstone, purple, dolomitic, gypsum, shaly
224 1/2	conglomerate, grayish purple, sand matrix, angular quartz pebbles
223 1/2	shale, purple, green eyes
220	shale, green, flakey, at base
220	shale, dark bluish purple, paper thin, flakey, few green eyes, imbedded nodular quartzite
197 1/2	cotton rock, angular, chert, very porous
192 1/2	limestone, light-gray, dense, gnarly, nodular chert, red and yellow
181 1/2	shale, purple, green eyes

178 1/2	limestone, purple, green and gray, mottled; very dense, fossiliferous, little cotton rock in middle
174	shale, dark-red
173	gypsum, interbedded red and purple shale
164	sandstone, gray, soft, nodules and streaks gypsum
160	gypsum, Note - becomes limestone to west
158	Covered - possible red and purple shale
152 1/2	dolomite, purple, earthy, sandy
151 1/2	shale, red, streaks of gypsum
145	gypsum, trace nodular limestone
142 1/2	limestone, purple and red mottled, hard, dense; interbedded with gypsum
140 1/2	shale, dark-gray, hard, slightly sandy, very blocky
139 1/2	dolomite, light-gray to purple, finely granular, imbedded anhydrite, hard
137 1/2	gypsum (weathered anhydrite), streaks purple and gray dolomite
131 1/2	dolomite, light-purple, granular, argillaceous, green eyes
130 1/2	limestone, white, dense
126 1/2	gypsum?
125 1/2	dolomite, light-purple, earthy, imbedded mud balls
124 1/2	shale, dark-purple, mottled, with maroon and green
120 1/2	limestone, light-gray, dense to lithographic, light purple streaks, fossiliferous at top
118	talus slope; possible purple shale and gypsum
110	sandstone, light-red, dolomitic, green eyes
106	anhydrite, interbedded red shale
97	shale, dark-red, blocky, green eyes
85	dolomite, pale-green, sandy

84 1/2	sandstone, red, argillaceous, thinly-bedded; cross-bedded
81	siltstone, pale-green, sandy
80	shale, deep-red, splinter, fissile, flakey, white eyes
76 1/2	shale, yellow to yellowish-green, fissile, splintery, flakey
74	shale, yellow, some red mottling, hard, blocky, yellow nodular limestone zone at top; Gastropods
65	shale, dark-red, some purple, yellow eyes and mottling
63	shale, dark-purple, hard, blocky, light-green eyes
62	shale, purple, some red, and yellowish green mottling, blocky
51	shale, red, some purple mottling, hard, blocky
46	shale, red, fissile, flakey, hard, streaks dark purple and yellow at top
34	shale, dark-red, fissile, hard
28	sandstone, dark-red, fine, very argillaceous, hard green eyes
26	Covered-possibly red sandy shale
16	clay, red and yellow, nodular yellow limestone
14	sandstone, gray, purple streaks, calcareous, hard, thin-bedded
13	Covered- possibly red shale
10	limestone, greenish gray, purple spots, very dense
8	limestone, gray, finely crystalline, oolitic, very fossiliferous, styolitic
6	limestone, gray, finely crystalline
2	Covered - possibly red shale

Madison - limestone, gray, finely granular, slightly oolitic, bands of chert; becomes finely crystalline at top

AMSDEN OF SAMPLED AREAS

Sappington Section

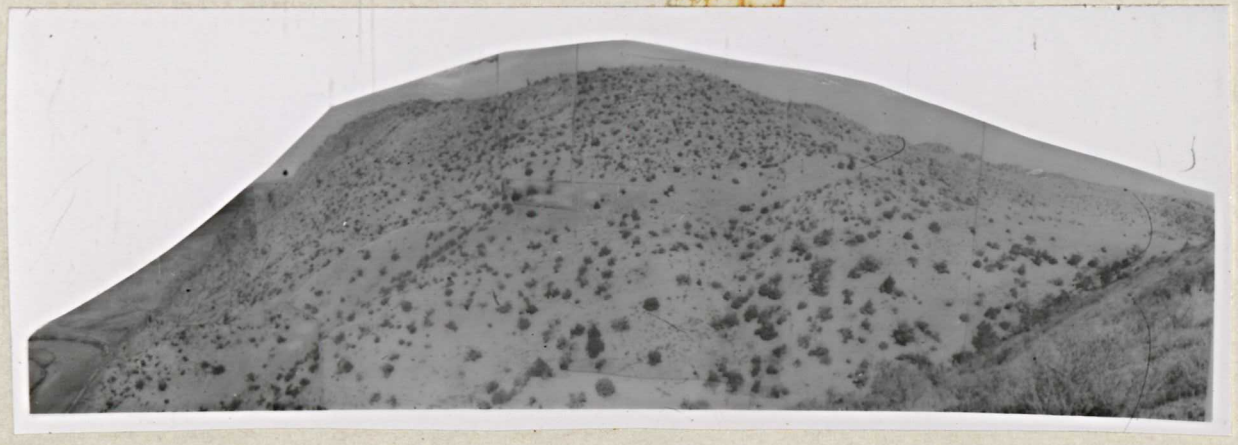
At Sappington, the Amsden beds are well exposed, although they have been highly eroded on the Madison contact which is obscured by Madison talus and cedar trees. (Plate 1) This exposed section is 507 feet thick with a dip 40 degrees north. The first outcrops are thin shaly limestones very highly colored in deep reds, purples, tan, and buff. These weather out and stain the rocks a bright red. The shaly limestones get lighter in color and thicker in bedding, and grade into blocky limestones with black chert seams. The limestone has several zones that are highly fossiliferous with brachipods. The Quadrant quartzite lies conformable on the Amsden. The formation is entirely marine as determined by fossil recognition.

North Boulder Section

The Amsden formation consistsof highly weathered shaly limestones of deep red, 1/4 inch to 1 inch thick at the base. It grades into a dark blue and tan highly fossiliferous limestone. The Quadrant contact and upper part of the Amsden formation is obscured by Quadrant talus and faulting. The lower contact of Madison beneath Amsden is obscured by erosion, and the first bed sampled was the first outcrop which is designated the base of this section. Faulting and solution breccia of the Madison also tend to obscure the Amsden.

The upper 229 feet of this formation has several prominent outcrops of a dark blue and tan highly fossiliferous limestone, and most of this part of the formation is obscure as there are no prominent outcrops to sample.

PLATE II



SAPPINGTON SECTION

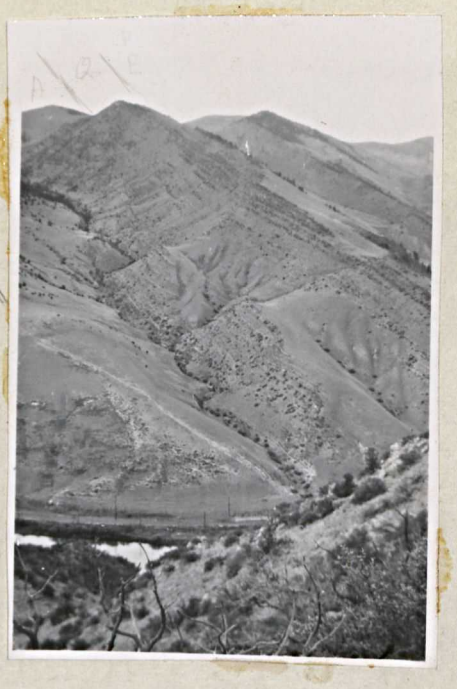
Deep gulley at the right is eroded basal Amsden resting on the Madison limestone. The Quadrant quartzite outcrops near the top of the ridge and the Ellis chert overlies the Quadrant at the extreme top of the ridge.

South Boulder Section

The base is occupied by red beds in a narrow gulley that is easily eroded. Above the red beds are rather thin-bedded white, gray, and buff limestones. Some of this limestone is sugary grained with black specks and a slight pinkish color. The steep bluff above consists of dark gray limestones with calcite seams and black chert bands which are characteristic also at Sappington.

TREATMENT OF SAMPLES

Samples were crushed by a small gyratory crusher (1/2 inch maximum size) which was carefully cleaned after each sample was crushed. They were then screened to get rid of the coarse and fine material. Screening also served to split the sample. Oversize and under size was stored for future use. The screening operations give uniform size for acid treatment and microscopic examinations. Accurate weighing is not necessary as a representative of the sample as a residue for examination is all that is required. The sample is measured out to 30 cubic centimeters in a graduated cylinder and then the dilute acid is added. They are next heated in groups on an asbestos pad by a hotplate until there is no further reaction with acid. After thorough digestion the acid is decanted with the clay and silt fractions, and the residue is washed, dried, and the volume of residue is compared with the original sample volume.



AMSDEN ACROSS RIVER FROM SAPPINGTON

AMSDEN IN JEFFERSON CANYON

STUDY OF RESIDUES

The residues are put in test tubes or vials, corked, labeled, and subsequently examined, described, and interpreted with a five power microscope in ordinary light. The residues can be viewed through the glass of the test tubes when fitted with a cork. Residues can be examined faster in this manner and contamination or mixing of samples is impossible. Each section was now plotted to scale and the types of residues found was noted opposite each sample.

Chert is the predominant insoluble material and there are many distinct types and variations with many varying colors. Sand grains are common in the Amsden residues and they range from extremely fine, angular, well cemented grains to coarser, rounded, and frosted grains. Shale residues are generally large in volume, bright colored, angular, irregular, and dense. The clay and silt fractions were decanted and are of no importance in this study. Heavy minerals as pyrite, hematite, limonite, and sphalerite are not present in Amsden residues which is probably diagnostic when compared to Madison residues.

PHOTOGRAPHS

The photographs of the residues were taken with a Reflex-Korelle camera. A spotlamp was used for illumination with a black background. All residues were photographed natural size. Photographs of typical Amsden residues are shown on Plate III.

EXPLANATION OF PLATE III

A. Earthy, dark gray, chalky, soft, rounded pieces of chert

B. Crinoid and brachipod fragments of platy chert; other meshlike fossil fragments

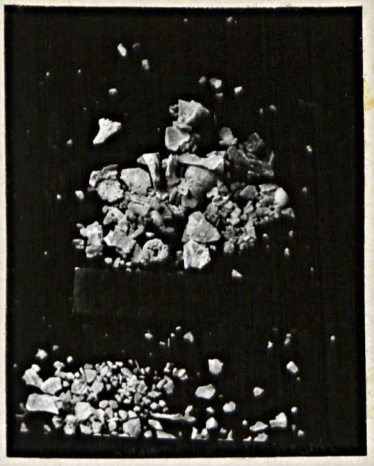
C. Black, irregular, pieces of chert with crinoids; cavity quartz crystals; brachipod and other fossils in white chert

D. Shaly, angular, red fragments of chert; white oolites on chert

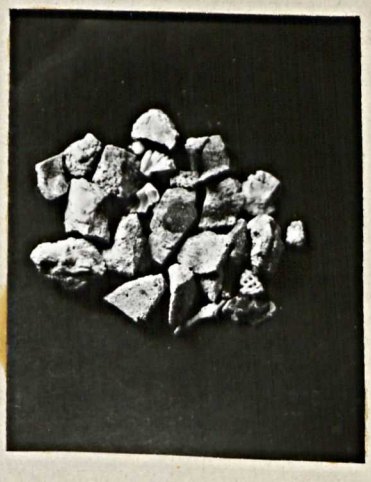
E. Snow white pieces of gypsum, some red tinged

Plate III

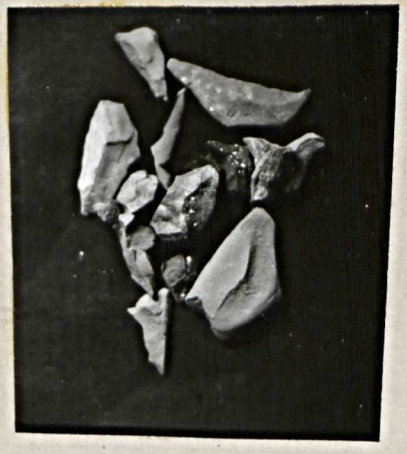
A



B



C



D

E

DESCRIPTION OF RESIDUES

Sappington Section

Height from base in feet	Amount of Residue (Percentage)	
		Quadrant quartzite
507	1/4	fissure fillings of clusters of chert; earthy appearance; some limonite staining
487	1/4	spongy pieces of chert; gray and tan; few small grains and clusters of quartz crystals
477	12	rounded balls composed of cemented quartz grains; small, well sorted, quartz grains in large amount
467	8	small, well sorted, quartz grains; pieces of quartzite composed of quartz grains cemented by earthy chert
457	1	angular, irregular, and rounded pieces of chalcedony; limonite staining; well sorted quartz crystals
447	1/2	grayish, partially rounded, pieces of chert; red stains on quartz crystal clusters
422	2	angular, coarse, pieces of tan chert; one with a brachipod mold
382	1/2	small fragments of tan chert; cavity quartz crystal clusters
372	1	gray, angular, fragments of earthy chert; in spongelike masses
362	1/8	brownish, small, fragments of earthy chert in spongelike masses
325	1/2	gray, lavender, irregular, fragments of sponge-like, earthy chert
280	2	angular flat pieces of chalcedony; hematite stained; earthy clusters of limonite; stained quartz clusters; brachipod fragment, crinoid
260	1	earthy, lavender, sponge-like, pieces of chert; quartz crystal clusters; limonite staining

250	4	irregular fissure fillings of limonite stained chalcedony; gray, sponge-like, earthy, pieces of chert
240	10	black, irregular, pieces of chert with crinoids; cavity quartz crystals; brachipod and other fossils in white chert
230	1/2	concentric quartz grains; cavity quartz crystals
220	1	dark gray, sponge-like, pieces of chert; brachipod replacement in chert; fossil fragments of green silicate; concentric chalcedony
215	1	replaced crinoid stems, brachipod fragments; few angular fragments of chert and asbestos; sugary grained fissure fillings of chert and chalcedony
210	2	angular, meshlike, pieces of fragmental fossil in chalcedony; crinoid and asbestos fragments
205	10	black, angular, pieces of chert; few gray, platy, pieces of chert; some as fossil fragments
200	4	platy, concentric, opalized, fossil fragments of brachipods
195	30	rounded, angular balls of clusters composed of clear rounded quartz grains with a lavender and lemon color
190	2	crinoid and brachipod fragments of chert; quartz grain clusters as fissure filling with red spots; fragment of hematite
185	4	crinoid and brachipod fragments of platy chert; other meshlike fossil fragments
175	1/4	meshlike fossil fragments of crinoids and brachipods in chert; limonite, hematite present; stains the residue; few quartz grains, quartz crystals
170	1/4	Sample yields oil on digestion; some crinoids; other fossil fragments in chert; one piece limonite; clusters of quartz crystals

140	1/4	Sample yields oil on digestion; greasy, dirty appearing chert fragments; crinoids, brachipod, fragments; some limonite; quartz crystal clusters
130	2	earthy, gray, soft, pieces of chert; fissure filling fossil fragments of chalcedony; quartz crystal clusters
120	8	Sample yields oil on digestion; earthy, dark gray, chalkly, soft, rounded, pieces of chert
110	4	green silicate mineral in angular pieces; dark grey, earthy, chalky chert; one fossil fragment in platy chert
95	1/2	pure white aggregates of fine quartz crystals loosely cemented together in irregular shapes; some porous chert; hematite, limonite fragments
80	50	greenish gray, angular, irregular, pieces of chert
70	30	greenish gray, angular, irregular pieces of chert
65	30	white, light green, angular, irregular, pieces of chert
60	25	angular, irregular, pieces of gray chert
55	25	angular, irregular pieces of lavender chert; rounded clusters of quartz grains loosely cemented together; hematite grains; hematite, limonite staining
50	30	gray, yellow, irregular, angular, fragments of chert
47 1/2	30	white, light gray, angular, pieces of quartzite composed of small quartz grains; fragments of hematite; hematite staining
45	15	rounded, angular, clusters of clear, quartz grains; loosely cemented; appears as sand; pink, black, grains
35	25	brownish, earthy, angular, pieces of chert

30	30	white, gray, angular, pieces of chert
25	15	brownish, rounded, pieces of chert; pink, yellow stains yield the color
20	30	angular, irregular, pieces of white, gray chert
10	15	angular, irregular, pieces of white gray chert and green silicate
5	10	pink, white, yellow, angular, irregular, fragments of chert; few quartz crystals and grains
Base of Amsden	5	angular white chert and silicate; quartz grains and crystals

North Boulder Section

Height from base in feet	Amount of Residue (Percentage)	
329		Quadrant quartzite
299	1	small, rounded, quartz grains; irregular, porous clusters of chert with lavender tone; irregular green pieces of chert
274	2	small, rounded, quartz grains; irregular, porous clusters of chert; clusters of quartz grains
249	1	rounded, angular, quartz grains; limonite stains on quartz cavity crystals; pieces of white chert; residue silt in size
234	1/2	rounded quartz grains; irregular white pieces of chert; dark, silt in size
174	1/2	porous, tan, black, lavender-tone, clusters of chert; limonite stains; limonite, hematite present; silt in size; rounded quartz grains
139	1/2	angular chert fragment; rounded quartz grains; spongy clusters of chert; partially rounded fragments of white stained quartzite; limonite stains; lavender-tone; mostly silt in size
99	30	large angular pieces of shaly, colored, chert; limonite stained
79	30	large, coarse, angular fragments of shaly chert; limonite stained
69	35	large, angular, pieces of shaly, colored chert
49	35	large, coarse, angular fragments of shaly chert; hematite stained
24	35	large, coarse, angular fragments of shaly chert; hematite stained
8	35	large, coarse, angular fragments of shaly chert; hematite stained
Base of Amsden	35	large, coarse, angular fragments tan, shaly, chert

South Boulder Section

Height from base in feet	Amount of Residue (Percentage)	
		Quadrant quartzite
215	2	sticky looking pieces of chert; abundant, small, well rounded quartz crystals; clusters missing
210	25	limonite stained, coarse, angular, fragments of chert; faint lavender tinge
205	1/4	pure white fissure fillings of pumice-like chert; few well rounded, clear quartz crystals, weakly limonite stained; angular, red stained chert
200	1/10	few red pieces of hematite; clear, limonite stained, quartz crystals; some well rounded; dark blue quartz crystals
195	5	fissure fillings of quartz crystals cemented together into irregular shapes, dirty, limonite stained; large, angular, pieces of chert composed of fine quartz grains; pieces limonite and hematite
190	1/3	very fine quartz crystals as fissure filling; not cemented in clusters
155	25	large pieces chalky, or pumice-like chert in angular fragments; light gray, faint yellow, lavender in color
145	1	gray chert in broken and angular fragments; clear white pieces of quartz-ite
125	5	fissure filling of chert in thin clear pieces; some stained red; fissure filling of irregular, cemented, quartz grains
120		No Residue
115	27	angular pieces of quartzite composed of fine grained, well cemented, quartz crystals

105	25	dark, angular fragments, of brittle, coarse, fine grained chert
100	1	chalcedony in small, irregular pieces as lattice-like fissure filling; well rounded quartz grains; lemon and lavender pieces of chert; (fossil Bryoza)
90	2	numerous, clear, white, fine, rounded quartz grains; lavender pieces of chert as fissure filling; fragments of limonite
50	1/4	irregular, angular fragments, of white, brittle silicate; fissure fillings of chert
40	1	soft, very brittle, earthy, porous talc residue with a pink tone; some hematite fragments
30	1/5	fine residue of cavity clear quartz crystals; sharp, angular, yellow, chalcedony fragments
25	1	pitted quartz, angular silicates; fissure fillings of chert and chalcedony; grayish, weakly limonite stained
15	No Residue	
10	1/4	angular chert fragments; fissure fillings of lavender stained quartz grains; some limonite stains
Base of Amsden	1/20	crystal clear cavity quartz grains; flat blue chalcedony fragments

Amsden Creek Section

Height from base in feet	Amount of Residue (Percentage)	
	25	Base of Tensleep - angular, irregular, pieces of quartzite composed rounded quartz grains; lavender, limonite stained
294	1/5	Top of Amsden - dolocasts of limonite, hematite, and chert; fiberous mineral
292 1/2	20	pink, tan, gray, angular, pieces of quartzite containing mica
285 1/2	30	pink, yellowish, angular, irregular white serpentine-like, pieces of chert
283		Sample missing
276 1/2	10	angular, irregular, rounded, clusters of quartz grains containing hematite; limonite stains; well cemented
275 1/2	1/4	few quartz grains; limonite, specular hematite; irregular, iron stained; flakes of chert
272	25	pink, white, rounded, quartzite; composed of rounded quartz grains; some limonite staining; not well cemented
243	25	acid stained chert; composed of rounded quartz grains; some white quartzite; lavender tone
240	60	gray, irregular, angular, pieces of chert
232	5	rounded quartz grains; red flakes, irregular, angular, red pieces of chert; some feldspar; green silicate
228	30	acid and limonite stained quartzite; composed of quartz grains; rounded quartz grains
225	100	white, thin, shale fragments
224	60	white, thin, shale fragments; some muscovite

222	5	dull, earthy, sponge - like chert dolocasts; some quartz grains, crystals
220	15	irregular, angular, pieces of acid stained chert
213 1/6	25	thin, white, shale fragments
213	5	angular, irregular, fissure fillings of chert; some replaced brachipod fragments
209	50	pale green shale fragments
202	20	acid stained, angular fragments of chert; appears soft and greasy
197	30	pink, gray, dolocasts of chert; some with limonite; pink chalcedony
196	4	red (pink) dolocasts of spongy looking chert; white round balls (oolites)
195 1/2	30	acid stained, white, angular, pieces of chert
194 1/2	4	red, pink, gray, dolocasts of spongy chert; breaks up easily
194	10	pink, white, green,coarse, spongy, pieces of chert; some limonite, hematite present
190 1/2	8	coarse, angular, pieces of chalcedony; fine, spongy, powdery, chert dolocasts
183	30	angular, irregular, pieces of coarse chert in white and pink; some green also
178	1	white balls present (oolites); angular, irregular, pieces of white, pink, red, spongy chert; few rounded quartz grains
177	30	angular, irregular chalcedony; yellow, spongy, chert dolocasts
175	8	pink, white, spongy, dolocasts of chert; looks like honeycomb
171 1/6	1/4	white balls present (oolites); dolocasts pure white in color

171		Sample missing
170 1/2	2	pink, red, white, lattice-like, spongy, dolocasts of chert
166 1/2	1/10	few rounded quartz grains; conchoidal quartz fragments
164 1/2	10	red, pink, angular, irregular, pieces of chert; few pieces white chert
152 1/2	1/5	white balls (oolites); few quartz grains; angular chert fragments
148	1/10	small, rounded, quartz grains; flakes of chert and limonite; white balls (oolites)
145	1/2	white, spongy, dolocasts of chert; quartz grains and crystals; white balls (oolites); hematite and apatite?
142	5	light purple, various pinks, red, white, gray pieces of fine grained chert (shaly appearance)
128	1	light pink, white, spongy, dolocasts of chert; oolites; fossil fragments (brachipods)
126	2	irregular, angular, white, spongy, dolocasts of chert; oolites; fossil fragments
125 1/2	5	oolites; lattice-like, sponge-like dolocasts of pure white quartz crystals
124 1/2	1/4	dolocasts of white chert; quartzite; spines, crinoids; gastropod fossil in clear quartz; crystals of clear quartz
123 1/2	1/10	dolocasts of spongy pink and white chert; rounded quartz grains; specular hematite?
121	2	red, shaly, pieces of chert; fissure fill pink, white quartzite; crinoids, greenish shale, mica
120 1/2	3	fossil pieces of brachipods; crinoids in chert and quartzite

119	5	spongy dolocasts of quartzite (pink and white); shaly faint green tone; earthy, gray, angular and rounded, pieces of chert
118 1/2	1	Sample yields oil on digestion; fossil sponge? in platy chert; angular, gray, white chert pieces; rounded quartz grains
116 1/2	20	faint green, white, shaly appearing, pieces of chert
115	2	white, gray, platy, fissure fillings of chert; crinoid, brachipod fragments in chert
115	1/4	bright clear muscovite; spongy dolocasts of pink chert; angular, red, pieces quartzite; specular hematite?
96 1/2	15	pink angular quartzite; some white fissure filling; quartz grains
93 1/2	100	dark-red, angular, fragments of shaly chert
70 1/2	80	white, red, pink, mixed colored quartzite and chert in angular, irregular fragments
58 1/2	1/2	pumice-like chert; earthy, dark-gray in color; contains limonite, hematite
56	100	dense, dark-red, angular, and shaly - like quartzite
52 1/2	80	white, orange pieces of quartzite; well cemented grains
46 1/2	100	dense, dark-red, angular, shaly - like quartzite
31 1/2	25	few pieces of pink and white quartzite; very poorly cemented; rounded quartz grains
14 1/2		Sample missing
	Unconformity	
Madison		Sample missing

Dry Head Creek Section

Height from base in feet	Amount of Residue (percentage)	
390	25	Minnekahta - chert pieces with red meshwork of hematite and limonite, spongelike in appearance; rounded quartz crystals
384	25	Opeche - brick red, tan, chert and quartzite with rounded grains protruding
359		Tensleep - No sample
259	15	Top Amsden - black and dark gray, porous, sponge-like chert; brachipods
257 1/2	20	faint blue chert with protruding quartzite grains in irregular and angular fragments
256 1/2	20	light purple quartzite in rounded and angular pieces; few quartz grains, rounded
252 1/2	20	smooth, dull-red, fine grained, shaly, angular, and irregular pieces of chert
250	70	white, dark-gray, angular and irregular pieces quartzite; gray pieces of fine grained chert
247 1/2	1	purple cherty platy residue; contains mica, gastropods; some white chert and rounded quartz grains
243	15	pink and white pieces chert; rounded quartz crystals well cemented
242	1	crystal clear vein type quartz crystals
237 1/2	25	white, very porous, pieces of chert or quartzite; some well cemented
235 1/2	10	pink and tan chert; angular and irregular white quartzite; rounded quartz grains
225 1/2	15	angular, irregular, yellow, limonite stained, pink chert with mica; white quartzite; rounded quartz grains

224 1/2	10	irregular, angular, pink, white, hard dense, quartzite; rounded quartz grains
223 1/2	30	pink and white flaky or platy pieces of chert; some mica on pink chert; gray, hard,dense, angular, irregular, pieces of chert
220	25	irregular, angular, pink, lavender, red, yellow, chert
197 1/2	20	pink, gray, tan, orange, angular, irregular, pieces of chert and chalcedony
192 1/2	20	hard, dense, irregular, angular, lavender, pink, yellow, white, chert
181 1/2	20	white, yellow, soft, irregular, angular pieces of chert
178 1/2	20	hard, dense, light-pink, white, chert in angular, irregular pieces
174		Samples missing
173		Samples missing
164		Samples missing
160	20	snow white pieces of gypsum
158	2	pink, gray, spongy, chert; red,shaly, irregular, angular pieces of chert
152 1/2	1/2	very fine quartz grains,well rounded; clusters hematite; generally powder-like
151 1/2	20	snow white pieces of gypsum; red tinged
145	20	snow white pieces of gypsum
142 1/2	1/4	two angular flakes chert (pinkish); rounded, fine, quartz grains and clusters
140 1/2	20	dark, purple, dark green, pieces of chert
139 1/2	5	white, clear, fissure filling quartzite; brachipod fragments; irregular, angular, white, pink, spongy chert

137 1/2	25	snow white pieces of gypsum
131 1/2	3	acid stained, yellow, angular quartzite; two pieces tan chert; rounded quartz grains
130 1/2	1	white chert; platy fissure fillings
126 1/2	1/2	pink, spongy, dolocasts of chert; fine quartz clusters; grains of quartz
124 1/2	25	dark-red, purple, irregular, angular chert; shaly in appearance
120 1/2	1/10	clusters of quartz grains; red hematite; few chert dolocasts
118	60	red, shaly, flaky quartzite; white, platy, chert; brachipod fragments; quartz crystals
110	1/4	pink, lavender, lattice-like, dolocasts of chert; specular hematite crystals; lattice-like quartz crystals in clusters
106	25	snow white pieces of gypsum
97	60	dark-red, shaly, angular, irregular, chert; some white chert
85	25	brown, sandy, hard pieces, irregular, angular quartzite
84 1/2	30	dark-red, irregular, angular, shaly quartzite
81	25	irregular, angular, brown, tan pieces of chert
80	25	Sample yields oil on digestion; dark red, shaly, chert-like jasper
76 1/2	25	acid stained, crumbly, earthy, pieces of chert; some limonite
74	25	Sample yields oil on digestion; red, brown, angular, irregular, chert fragments; purple and white chert
65	25	Sample yields oil on digestion; red, angular, irregular, chert fragments; some brown, purple, and white fragments

63	25	Sample yields oil on digestion; red, purple, brown, irregular, angular, fragments of chert
62	30	Sample yields oil on digestion; red, purple, brown, irregular, angular, fragments of chert
51	30	Sample yields oil on digestion; irregular, angular, pieces of red chert; few brown pieces
46	30	Sample yields oil on digestion; shaly, angular, red fragments of chert; white oolites on chert
34		No sample
26	25	Sample yields oil on digestion; irregular, angular, red chert and quartzite
16	25	mammillary chert, chalcedony, and quartzite; clear quartz grains
14	25	shaly, angular, red pieces of chert; white oolites on chert
13	1/50	Sample yields oil on digestion; porous oolites hematite; two quartz crystals; fibrous mineral; all very small in size
8	1/10	Sample yields oil on digestion; red fissure fillings of chert (dolocasts); very small in size
6	25	Sample yields oil on digestion; red, yellow, large, angular, pieces of chert
2	1/5	Base of Amsden - red, angular, pieces of chert and yellow fissure fillings; very small in size
Madison Limestone	1/10	Sample yields oil on digestion; soft, white, fluffy, dolocasts of chert; fibrous mineral; very small in size

SAPPINGTON FORMATION RESIDUES

The residues of the Amsden in its lower 95 feet consist mainly of light colored chert with quartz crystals and grains. This compares favorable with the other formations in the type of residue, but the color is much lighter. The volume of residue averages about 30 percent for this first 95 feet of section plainly showing that it is the bright red, lower, easily eroded shaly zone which is characteristic of the Amsden.

From 95 feet to 190 feet the residues average about two per cent of the original volume, showing this part of the section to be chiefly limestone. The lower 50 feet of this zone contains porous and colored chert, while the upper part was highly fossiliferous with brachipod and crinoid fragments. A few samples in this part of the section yielded oil on digestion.

From 190 feet to 205 feet the volume of residue increases to 30 per cent of lavender and white chert, back to 4 per cent of opalized fragments of brachipods, and then to 10 per cent of black chert with fossil fragments. Residues from here to the 467 foot part of the section remain low in volume indication high limestone content. They also contain fossil remains as replacements in chert. The remainder of these residues are earthy, porous, dark gray, and black colored cherts.

At the 467-foot measurement the residues change to quartz crystals that are rounded, sorted, and small in size. The cementing material was all dissolved leaving the grains. The last two residues have also chalcedony as fissure filling in the limestone.

NORTH BOUIDER RESIDUES

The residues show that the lower 100 feet of the Amsden consist of calcareous shales or shaly limestones that yield a residue of 30 to 35 per cent of dense, hard, shaly chert, which has hematite and limonite stains coloring the residues from brown to red. The deposition of this first 100 feet seems to be relatively of the same material throughout, and the volume of the residues might have approached 100 per cent, but the smaller shale particles were decanted with the solution. The upper 229 feet averages about three-fourths of one per cent, and are composed of rounded quartz grains, fissure-fill quartz crystals clusters, and white, porous, irregular, clusters of chert.

SOUTH BOULDER RESIDUES

Examination of the residues of the lower 100 feet reveal that this part of the formation is limestone with an average of about one-half of one per cent residue that consists of cavity-quartz crystals and porous, soft, colored chert. The next 55 feet increases in volume and ranges from 5 to 25 per cent of residue, which is composed of light colored and porous chert with some quartz grains. The remainder of this section is composed of quartz crystals and grains with some colored chert. The North Boulder and South Boulder sections are practically void of any fossil remains in the residues.

AMSDEN CREEK RESIDUES

Residues from this section differ notably from the Sappington, North, and South Boulder sections. This is due to the great distance between sections which causes a variation

in sediments, and also due to the close and different type of sampling. The lower 116 feet have large amounts of residue ranging from 15 to 100 per cent. It is largely composed of bright colored, hard, shaly chert and conforms favorably with the Sappington section except for brighter red colors and more shale than the Amsden Creek section.

From 116 to 175 feet the residues decrease in volume to an average of about one per cent, and are composed largely of colored chert and spongy dolocasts, with oolites present in some residues. Therefore the formation is predominately limestone at this section. The 175 to 294 feet zone is generally large in volume of residue, averaging 25 per cent which is composed largely of porous, earthy, platy, and colored chert. Colors and character of the residues at this part of the section are variable in appearance, and the section here is shale while at Sappington it is limestone.

DRY HEAD CREEK RESIDUES

This section in northern Wyoming was sampled similar to the Amsden Creek section by Blackstone, Bradish, and Seager. In general the residues yield a large percentage of residue indicating that this formation has less limestone than at the other localities studied.

Most of the samples in the first 75 feet of section yield oil on digestion, and were composed largely of chert with some quartz grains. In the next 85 feet of section five residues consist of gypsum which is found only in this particular section of the five studied. From 174 to 259 feet the residues consist mainly of highly colored chert from tans to dark reds. There is also some porous chert and chalcedony.

CONCLUSIONS

Conditions of deposition and source of sediments cause variation in the residues of each of the various Amsden localities, and long distance correlation by residues is not practical due to this horizontal variation. In general the Amsden could be recognized from other Paleozic formations by the characteristic types of colored cherts that are present in its residues. Occurrence of quartz does not seem to be of any diagnostic value. Heavy minerals such as pyrite, hematite, limonite, and sphalerite are not present in Amsden residues so as to be of any value in the recognition of the Amsden, except that their absence may be of value. Correlations in Montana by insoluble residues help, but they are not the answer to the problem of the correlation of the Amsden in various localities in Montana. It is easier to recognize the Amsden formation lithologically than through residue study. The Pennsylvanian-Mississippian contact was not distinguishable by Amsden residues, so the deposition of strata is apparently continuous from one period to the next.

BIBLIOGRAPHY

I. Branson, E. B. and Greger, D. K., Amsden formation of the Wind River Mountains of Wyoming and its fauna: Bull. G. S. A., pp. 309 - 326, vol. 29, I9I8.

2. Branson, C. C., Stratigraphy and fauna of the Sacajawea formation, Mississippian, of Wyoming: Jour. of Paleo., vol. II, No. 8, pp. 650 - 660, I937.

3. Hamblin, Ralph H., Stratigraphy and insoluble residues of the Upper Paleozic formations of Montana: Master Thesis, Mont. Sch. of Mines, I938.

4. Ireland, H. A., Use of insoluble residues for correlation in Oklahoma: Bull. Am. Assos. Pet. Geol., vol. 20. No. 8, pp. I086 - II2I, I936.

5. Martin, H. G., Insoluble residues of Mississippian limestones in Indiana: Dept. of Conservation Pub. No. I0I, pp. II, I93I.

6. McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geol. and Mines, Bien, Rept. 56, Appen. I, I93I.

7. Perry. E. S., Natural gas in Montana: Mont. Bureau of Mines and Geology., Memoir No. 3, Dec., I937.

8. Perry. E. S., Montana's newest discovery of particular interest: Oil Weekly, vol. II4, No. 9, July, I944.

9. Scott, H. W., Some carbiferous stratigraphy in Montana and northwestern Wyoming: Jour. of Geol., vol. 43, pp. I0II - I032, I935.

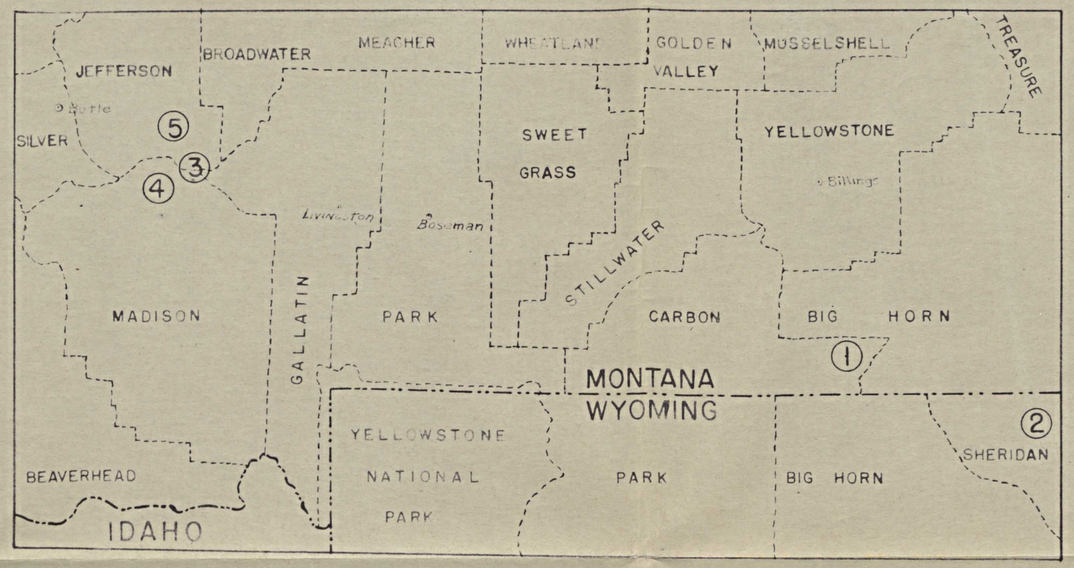
I0. Twenhofel, W. H. and Tyler, S. A., Methods of study of sediments: Textbook.

II. Sloss, L. L. and Hamblin, Ralph H., Stratigraphy and insoluble residues of Madison group (Mississippian) of Montana: A. A. P. G. Bull., vol. 26, No. 3, March, I942.

I2. Geologic atlas of the U. S. Ball Mountain: Dayton Folio, No. I4I, Wyo. U. S. G. S., I906.

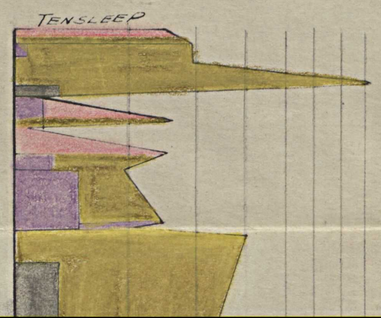
EXPLANATION

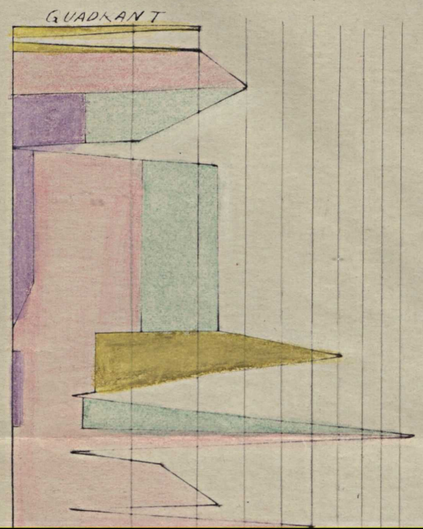
- Quartz crystals and quartz grains
- Quartzite
- Earthy, shaly, and colored chert
- Porous chert
- Black chert and chalcedony
- Gypsum

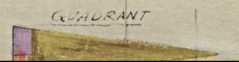


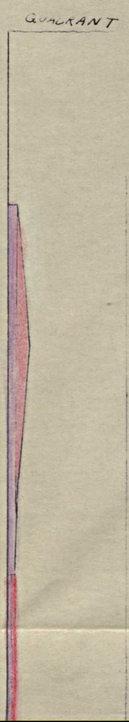
MAP OF PART OF SOUTHERN MONTANA AND NORTHERN WYOMING

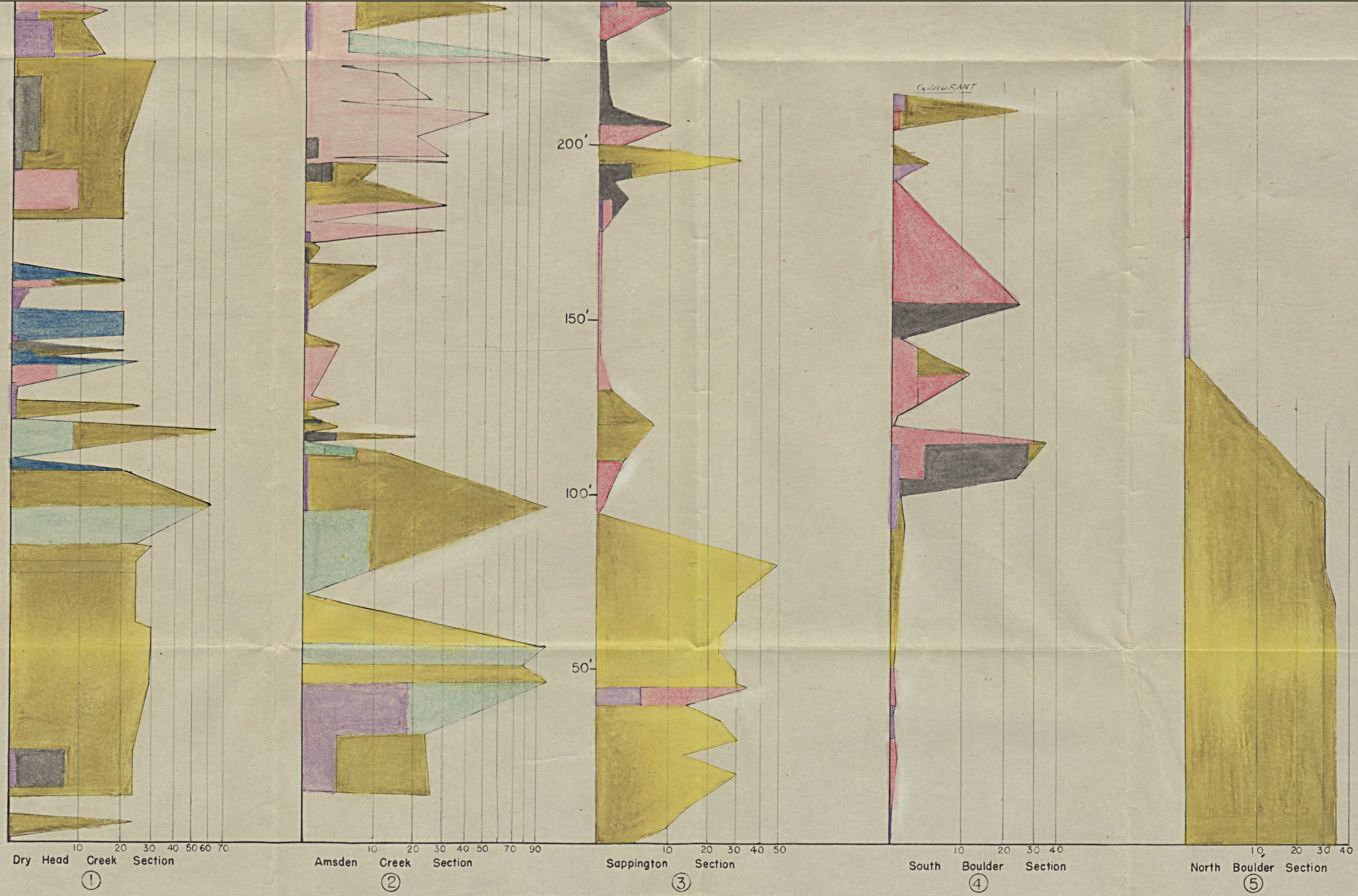
SHOWING LOCATION OF AMSDEN AREAS SAMPLED











PERCENT OF UNDIGESTED SAMPLE

DIAGRAMMATIC REPRESENTATION

OF

INSOLUBLE RESIDUES OF AMSDEN FORMATION