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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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AEC - 741/4

Dr. Phillip L. Merritt, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
P.O. Box 30, Ansonia Station
New York 23, New York

Dear Phil:

Transmitted herewith are six copies of TEI-341, "Lithofacies of the Salt Wash member of the Morrison formation," by Thomas E. Mullens and Val L. Freeman, February 1954.

We are asking Mr. Hosted to approve our plan to submit this report for publication in the Bulletin of the Geological Society of America.

Sincerely yours,

for Dwight M. Lemmon
W. H. Bradley
Chief Geologist

(200)
+67 R

Geology and Mineralogy

This document consists of 38 pages.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

LITHOFACIES OF THE SALT WASH MEMBER OF THE MORRISON FORMATION*

By

Thomas E. Mullens and Val L. Freeman

February 1954

Trace Elements Investigations Report 341

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

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

USGS - TEI-341

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LITHOFACIES OF THE SALT WASH MEMBER OF THE MORRISON FORMATION

by Thomas E. Mullens and Val L. Freeman

ABSTRACT

The Salt Wash is the basal member of the Upper Jurassic Morrison formation in parts of Utah, Colorado, Arizona, and New Mexico. The Salt Wash member, deposited by an aggrading fluviatile system, comprises lenticular cross-laminated sandstone irregularly interbedded with siltstone, claystone, and horizontally laminated sandstone.

Lithofacies, as used in this paper, denotes the lithologic aspect of the Salt Wash member. The specific lithofacies at a given locality is determined by the thickness, the relative proportion, and the relative continuity of the sedimentary types that comprise the Salt Wash member. For the purpose of accurate interpretations of paleodrainage patterns of the fluviatile system that deposited the Salt Wash member, the sedimentary units in the Salt Wash member are classified as stream deposits and floodplain deposits. Stream deposits include all rocks interpreted as deposited from moving water, and the floodplain deposits include all rocks interpreted as deposited from slack water. Thus, the lithofacies of the Salt Wash member is determined by the thickness, relative proportion, and continuity of the stream and floodplain deposits.

Regional differences in Salt Wash lithofacies show that the Salt Wash member is a fan-shaped wedge of sediments with the apex of the fan in south-central Utah. Except in the Four Corners area and west-central Colorado, the total thickness of the Salt Wash member and the thickness, proportion, and continuity of the contained stream deposits decrease relatively uniformly to the northeast from the apex of the fan.

Interpretation of the regional differences in lithofacies indicates the Salt Wash member was deposited by a distributary stream system that radiated outward from south-central Utah and spread sediments to the north, east, and southeast over a nearly flat plain. The regional variations can best be explained by considering the Salt Wash member as an immense alluvial fan. The symmetry of the

Salt Wash "alluvial fan" was interrupted by irregularities in the surface of deposition in the Four Corners area and in west-central Colorado.

Most uranium-vanadium ore deposits in the Salt Wash member occur in a medial lithofacies. This may be a genetic relation and can be explained as a function of transmissibility of the particular lithofacies. However, the ore deposits are not distributed uniformly through the zone of medial lithofacies; instead the ore deposits are concentrated in a relatively small area in the zone. Because local geologic features such as structure or igneous intrusions might control the localization of ore deposits in the small area, the high degree of correlation of ore deposits and a certain lithofacies may be coincidental.

INTRODUCTION

A lithofacies study of the Salt Wash member of the Morrison formation was made as a part of a detailed stratigraphic study of the Upper Jurassic Morrison formation of the Colorado Plateau and adjoining regions. The detailed stratigraphic study was made by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The use of the term "lithofacies" in this paper denotes the total aspect of inorganic elements which furnish record of the depositional environment of a stratigraphic unit. This usage of "lithofacies" follows Krumbein (1948, p. 1923), and Kay (1947, p. 165). This usage of the term "lithofacies" differs from usage proposed by Moore (1949, p. 16) in that Moore would use the term "physiofacies" (Moore, op. cit., p. 17) to denote the inorganic elements in a sedimentary rock and would retain the term "lithofacies" to denote both inorganic and organic elements which furnish record of the depositional environment of a rock regardless of stratigraphic classification.

Specifically, "lithofacies", as used here, denotes the lithologic aspect of the Salt Wash member of the Morrison formation. Lithofacies is controlled by the thickness, the relative proportions, and the continuity of the two sedimentary types that comprise the Salt Wash member.

The purpose of this study was to determine the regional variation in Salt Wash lithofacies with the ultimate goals of: 1) determining some aspects of the depositional environment of the Salt Wash member, and 2) determining relations between lithofacies and uranium-vanadium deposits found in the Salt Wash member.

The lithofacies study was restricted to the Salt Wash member because it is the smallest unit that has regional stratigraphic continuity and contains within its limits most of the uranium-vanadium ore deposits found in the Morrison formation. The Salt Wash member is composed mainly of interstratified sandstone, claystone, and siltstone. Quantitative data on the lithologic aspect are easily obtained by measuring sections.

MORRISON FORMATION

The Morrison formation, defined originally by Cross (1894, p. 2), is present in most of the western interior of the United States. In the Colorado Plateau region the Morrison has been divided into several members; the Salt Wash, defined by Lupton (1914, p. 127), and by Gilluly and Reeside (1928, p. 82); the Bluff sandstone, Recapture, Westwater Canyon, and Brushy Basin defined by Gregory (1938, p. 58-59). A February 1954 decision by the Geologic Names Committee of the U. S. Geological Survey removed the Bluff sandstone from the Morrison formation and made it a separate formation. This decision was based on detailed work on the Morrison formation by members of the U. S. Geological Survey (Craig, and others, in preparation; Harshbarger, and others, in preparation; and Strobell, in preparation).

Salt Wash member

The Salt Wash, where present, is the basal member of the Morrison formation. It is best developed in southeastern Utah and in southwestern Colorado, but as a recognizable unit the Salt Wash member extends a short distance into northeastern Arizona and northwestern New Mexico where it disappears along an east-west line by depositional pinch-out and intertonguing and intergrading with the Bluff sandstone below, and the Recapture member of the Morrison above. Southwest of a line trending northwest through Lee's Ferry, Ariz., the Salt Wash member has been removed by pre-Dakota erosion. The western limit of Salt Wash is buried by younger sediments under the Wasatch Plateau. The northern and eastern limits of recognizable Salt Wash are exposed in outcrops near Vernal, Utah, and Glenwood Springs and Gunnison, Colo. The extent of the Salt Wash member as here considered is the limit of a sandstone-bearing portion at the base of the Morrison formation. Where this sandstone-bearing portion is absent, as in northeastern Utah and northwestern and central Colorado, the Morrison formation is not divided into members. However, beds equivalent to Salt Wash are probably present in the lower part of the undifferentiated Morrison formation (Craig, and others, in preparation). Figure 1 shows the outcrop pattern of the Morrison formation in parts of Utah, Colorado, Arizona, and New Mexico and the areal extent of the Salt Wash member.

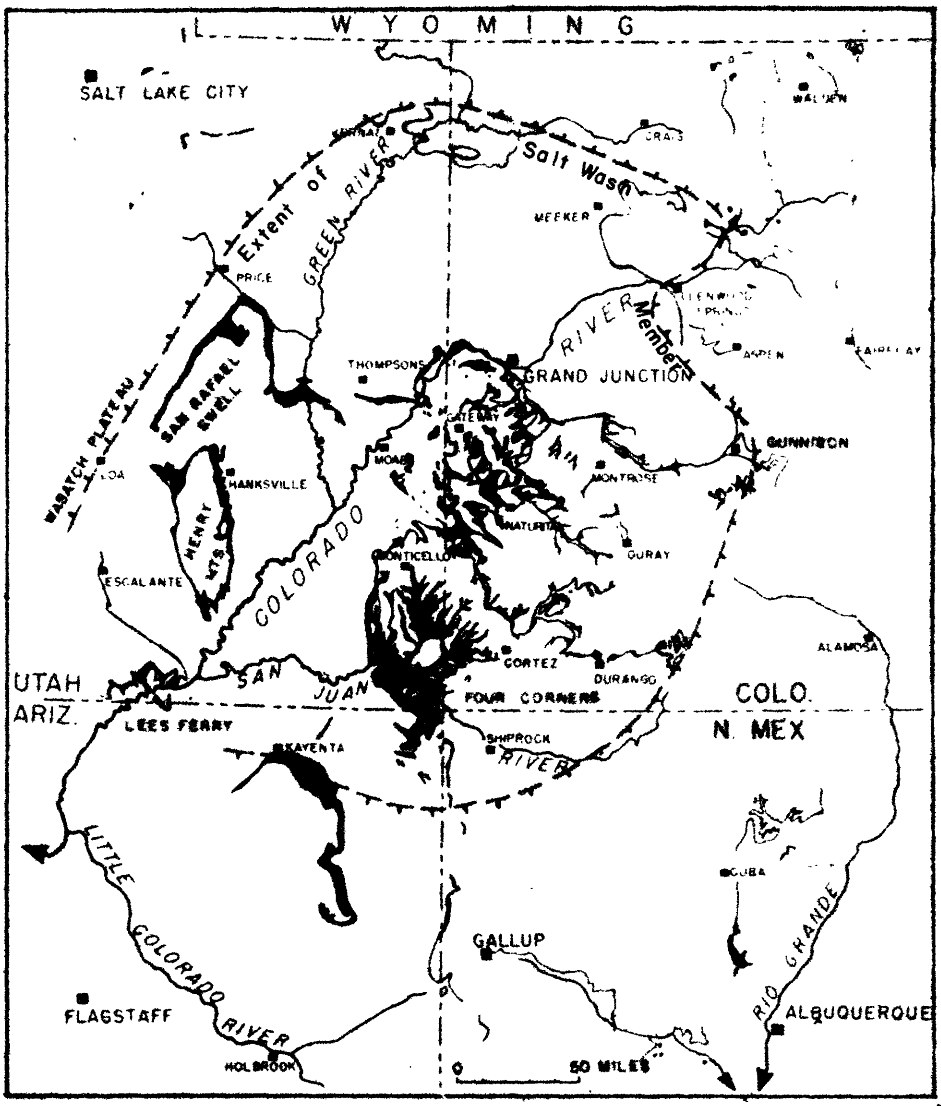
The Salt Wash member consists mainly of lenticular cross-laminated sandstone and conglomeratic sandstone interstratified with claystone, siltstone, and structureless to horizontally laminated sandstone. Some thin beds of limestone, locally containing fresh water fossils, occur near the base of the Salt Wash in east-central Utah and west-central Colorado.

The cross-laminated sandstone is generally light colored and ranges from fine- and medium-grained in Colorado to coarsely conglomeratic with common lenses of cobble conglomerate in south-central Utah. The cross-laminated sandstone may occur as a single lensing unit from 2 to 20 feet thick that extends less than 300 feet along strike; or many cross-laminated sandstone units may combine and make up a composite unit. The composite units are more abundant and generally much thicker than the single bed units in the Salt Wash; some composite units form lenses that are over 80 feet thick and extend several miles along strike. All cross-laminated units have a gently undulatory to well-defined scour surfaces at the base.

The claystone, siltstone, and structureless to horizontally laminated sandstone are mainly reddish brown. All gradations and mixtures of grain size between that of very fine-grained sandstone and that of pure claystone is common among these rock types. Bedding structures in these rocks range from horizontal to gently lensing types; fissility is rare.

The irregular assemblage of sandstone, siltstone, and claystone, scour surfaces, and other sedimentary structures in the cross-laminated sandstone indicates that the Salt Wash member was deposited by an aggrading fluviatile system.

The Salt Wash member is characterized by a steep ledgy outcrop. The cross-laminated sandstone forms steep-faced ledges; the finer grained units form rubble-covered slopes between the ledges.



EXPLANATION

OUTCROP OF MORRISON FORMATION

AREAL EXTENT OF SALT WASH MEMBER

Figure 1. MAP OF PARTS OF UTAH, COLORADO, ARIZONA, AND NEW MEXICO, SHOWING THE OUTCROP PATTERN OF THE MORRISON FORMATION AND AREAL EXTENT OF SALT WASH MEMBER

Stratigraphic relations of the Salt Wash member

Over most of its extent the basal contact of the Salt Wash member is the base of the fluviatile deposits above the marine and marginal marine deposits of the Curtis and Summerville formations. The contact represents a change in depositional environment and the contact is conformable in most places. In the San Rafael Swell and Henry Mountains area in Utah, however, contorted beds in the Summerville formation are locally bevelled by Salt Wash sediments, and over the crests of the salt anticlines in western Colorado the Salt Wash bevels older formations. Near Gunnison, Colo., the Salt Wash rests on pre-Cambrian rocks. The Salt Wash rests on the dominantly eolian Bluff sandstone in Arizona and New Mexico and in parts of Colorado and Utah near the Four Corners. This contact is a scour surface in the Bluff sandstone in most places, but locally fluviatile and eolian deposits intertongue.

In the Four Corners area most of the upper part of the Salt Wash grades laterally into the Recapture member of the Morrison formation. In other places the top contact of the Salt Wash represents a change from a dominantly fluviatile environment to the dominantly lacustrine environment of the Brushy Basin member of the Morrison formation. This change in environment is transitional and in many places the basal deposits of the Brushy Basin are fluviatile; however, a distinct composition and textural change between Salt Wash and Brushy Basin sediments is noted in most places where the basal Brushy Basin is fluviatile.

METHOD OF STUDY

Classification of sedimentary units

Although the Salt Wash member consists mainly of clastic sediments, the sandstone-shale classification of sedimentary units used in other lithofacies studies (Dapples, and others, 1948; Read and Wood, 1947; and Sloss, and others, 1949) was not followed in this study. Instead, a genetic classification based on types of deposits found in a fluviatile system was used.

Genetically the rocks found in a fluviatile environment may be separated into stream deposits and floodplain deposits. The stream deposits consist of rocks whose collective characters indicate that the rocks were deposited in areas where sedimentation was noticeably influenced by water currents. In a fluviatile system these areas are restricted to channels and areas closely bordering the channels. The floodplain deposits consist of rocks whose collective characters indicate the rocks were deposited from water in areas not noticeably influenced by current action. These areas are the relatively flat surfaces adjacent to stream channels where sedimentation from slack water occurs during and after floods.

The distinction in the field between stream and floodplain deposits is clear in most cases. In this study a unit was considered a stream deposit if it was cross-laminated, had a basal scour surface, was composed of fine or larger sized grains, and was free of clay matrix. A unit was considered a floodplain deposit if it was structureless or horizontally laminated and was composed of very fine-grained sand or smaller particles. Limestone, a minor rock type in the Salt Wash member, probably was deposited in shallow bodies of water on the floodplain and was included with the floodplain deposits. The transitional rock in the stream-floodplain deposits classification is very fine-grained well-sorted sandstone with poorly defined sedimentary structures. During the course of field work most sandstone beds over 2 feet thick were identified on the basis of the criteria given above as stream deposits and thinner sandstone beds were identified as floodplain deposits. Consequently, lacking other criteria, sandstone beds 2 feet or less in thickness were considered floodplain deposits and sandstone beds over 2 feet thick were considered stream deposits.

In a lithofacies study of the Salt Wash member of the Morrison formation the stream-floodplain classification of sedimentary units had two distinct advantages over a sandstone-shale classification. The first advantage is in reconstructing paleodrainage patterns. Sandstone is not an indicator to areas of stream current action, for sandstone occurs in both stream and floodplain deposits. The stream-floodplain classification shows the relations between areas of current action and areas of no current action; paleodrainage patterns based on stream deposits and floodplain deposits should be more accurate than those based on sandstone and shale. The second advantage of the genetic classification is a standardization of units measured. Complete gradation between claystone and sandstone is common and sandy claystone or clayey sandstone is encountered in every measured section of the Salt Wash member. These units commonly form poorly exposed slopes between ledges of cross-laminated sandstone and the relative amount of sandstone in the poorly exposed interval is difficult to determine. The difficult problem of measuring the amount of sandstone in the clayey sandstone and sandy claystone was avoided by using a genetic classification, for these rock types were included in the floodplain deposits.

Collection of data

Sampling technique

To determine the regional variations in the lithofacies--regional variations in thickness, relative proportions, and continuity of the stream and floodplain deposits--a sampling technique that gave quantitative data was developed. This sampling techinque consisted of measuring several sections through the Salt Wash member of the Morrison formation at each of a number of selected localities. Several sections at each locality were measured in order to calculate average thickness figures of the lenticular fluviatile deposits at each locality. Average thickness figures at each locality are necessary as a single section may not be representative for the locality; a section measured through the fluviatile deposits can be considerably different in total thickness of stream deposits and proportion of stream deposits from one measured only 200 feet away. Five sections evenly spaced over about 1,200 feet of outcrop were measured at most localities. This number of sections spaced over this length of outcrop is thought to give a valid representation of the total lithologic aspect at each locality. Exposures and topography did not permit measuring five sections at all localities; however, all lithofacies localities represent at least three measured sections. In addition to average thickness values, the relative continuity of the sedimentary units at each locality can be computed by measuring several sections at each locality.

For each locality the average total thickness of the Salt Wash member, the average total thickness of contained stream deposits, the average total thickness of the contained floodplain deposits, the average percentage of contained stream deposits in the Salt Wash, and the relative continuity of the stream deposits were computed from the sections measured at that locality.

Sections were measured by Abney level and tape. The thickness and lithologic description of the units were recorded and each unit classified as either stream or floodplain deposits as the section was measured.

Field work

The area of study includes the southeastern quarter of Utah, the southwestern quarter of Colorado, and small parts of northwestern New Mexico and northeastern Arizona. Most of the Salt Wash member of the Morrison formation is within the area outlined, but no lithofacies measurements were made in the Salt Wash member in northwestern Colorado and northeastern Utah, where poor exposures prohibited lithofacies measurements by the sampling technique used.

Field work was begun by L. C. Craig and others in 1948. Field techniques were developed and lithofacies measurements were made at five localities that year. In 1949, lithofacies measurements were made at 19 more localities by J. D. Ryan and the authors. The authors made lithofacies measurements at 39 additional localities in 1950 and 1951.

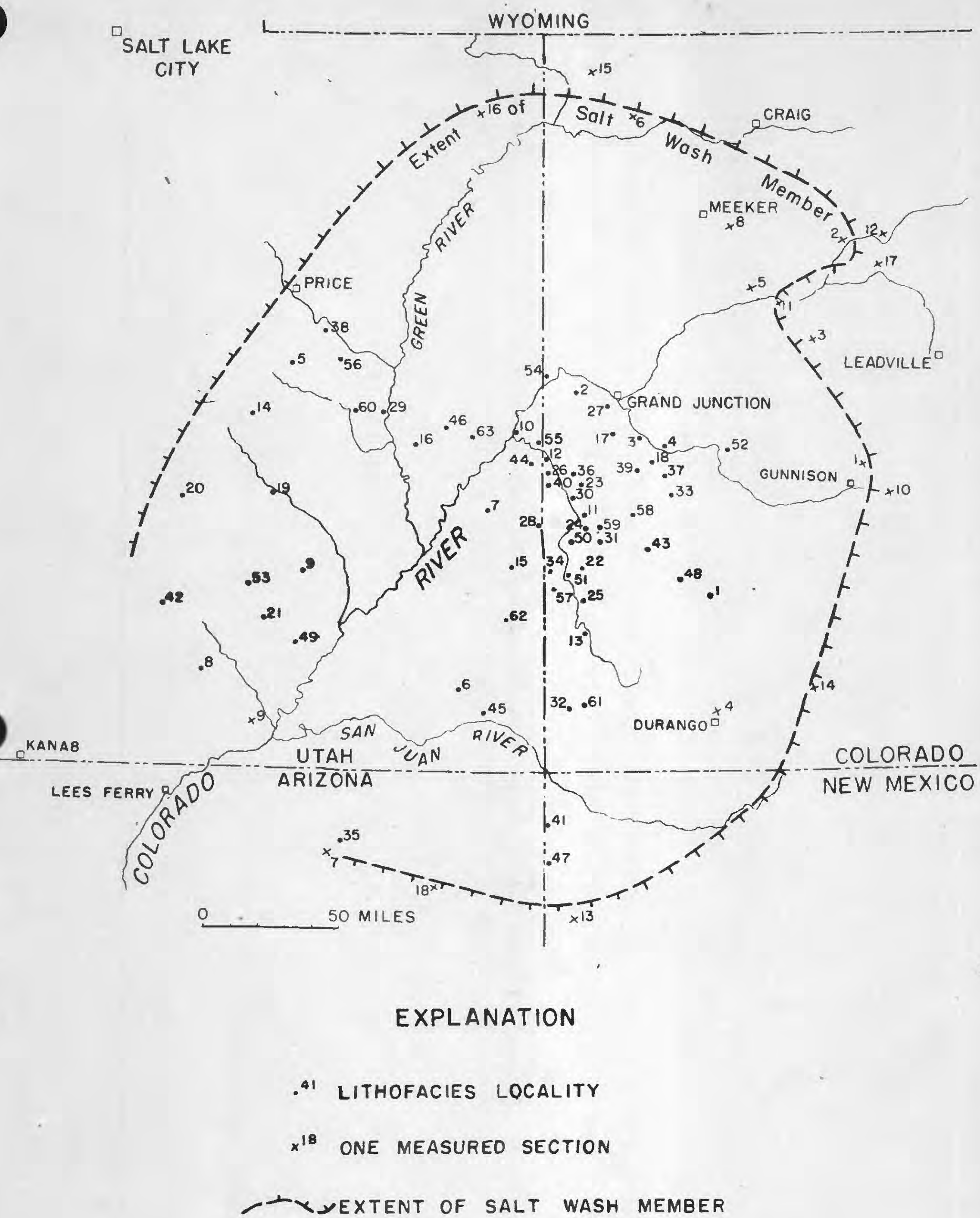
Field work started in western Colorado and was extended radially outward from this area with a decrease in concentration of lithofacies localities away from western Colorado. Figure 2 shows the name and location of the lithofacies localities.

Conversion of data

Three isopach maps (figs. 3, 4, 5) and two isolith maps (figs. 6, 7) were constructed from the data collected in the field. The isopach maps show: (1) total thickness of the Salt Wash, (2) total thickness of contained stream deposits in the Salt Wash, and (3) total thickness of contained floodplain deposits in the Salt Wash. The isolith maps show: (1) percentage of stream deposits in the Salt Wash, and (2) relative continuity of the stream deposits in the Salt Wash as measured by the percentage mean deviation in thickness. In general, the method of converting the data to isopach and isolith maps follow methods of regional stratigraphic analysis proposed by Krumbein (1948).

Except for use of single measured sections to delineate areal extent of the Salt Wash, all data used in preparing the isopach and isolith maps were averages of measurements obtained from the several sections at each locality.

Table 1 summarizes the data collected in the lithofacies study.



LOCALITIES

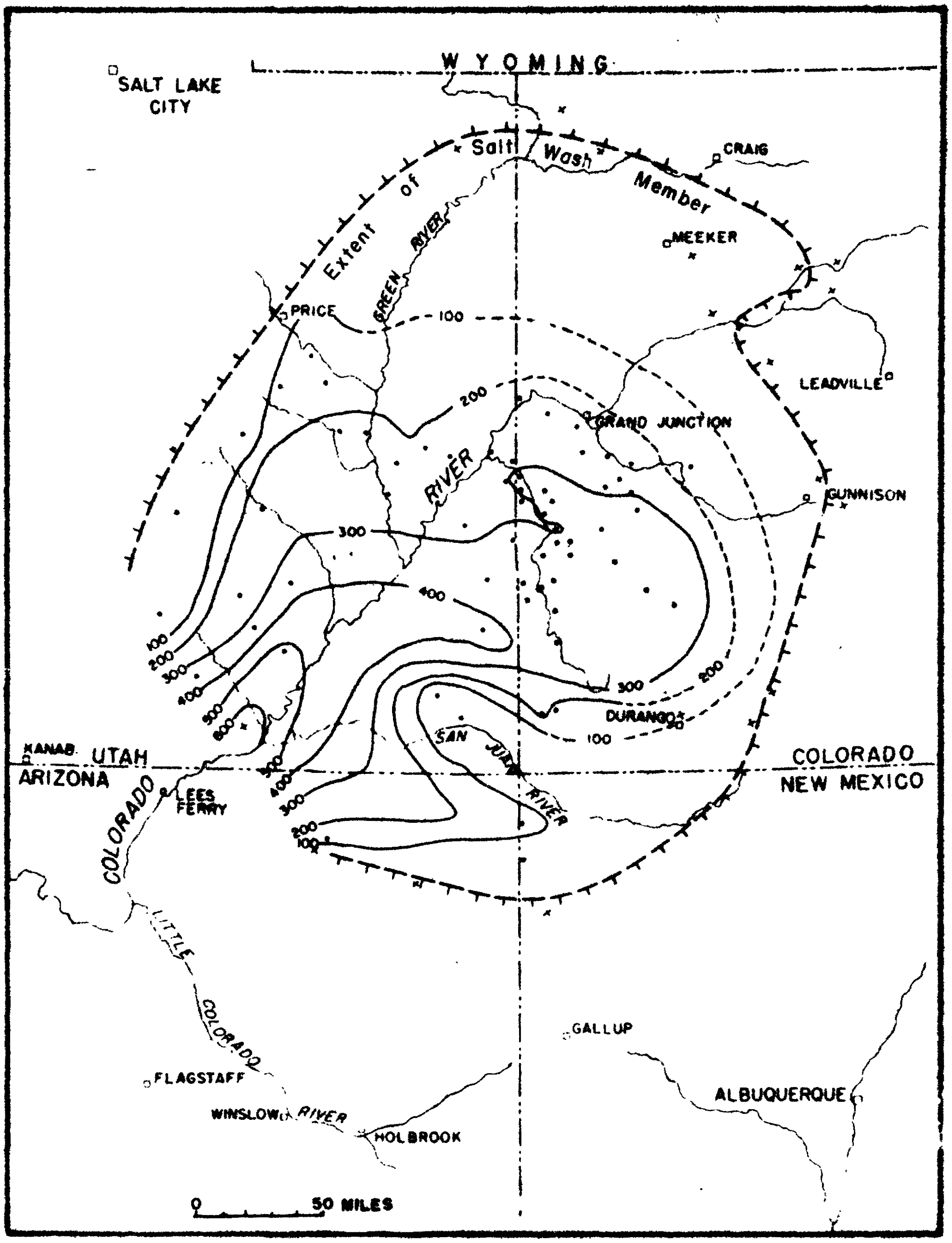
LITHOFACIES

1 BILK CREEK
2 BLACK RIDGE
3 BRIDGEPORT
4 BROUGHTON
5 BUCKHORN FLAT
6 BUTLER WASH
7 CANE SPRING
8 COLLETTE CREEK
9 CRESCENT CREEK
10 DEWEY
11 DOLORES GROUP
12 DOLORES POINT
13 DOVE SPRING
14 DRUNK MAN'S POINT
15 DRY VALLEY
16 DUMA POINT
17 EAST UNAWEEP
18 ESCALANTE FORKS
19 FACTORY BUTTE
20 GARDEN RANCH
21 HALL CREEK
22 HAMM SPRING
23 HEAD OF BLUE CANYON
24 HIEROGLYPHIC CANYON
25 HORSESHOE GROUP
26 JOHN BROWN CANYON
27 LADDER CANYON
28 LA SAL CREEK
29 LITTLE GRAND FAULT
30 LONE TREE MESA
31 LONG PARK
32 LOWER MC ELMO CANYON
33 LOWER ROBIDEAU
34 MC INTYRE CANYON
35 MARSH PASS
36 MAVERICK CANYON
37 MONITOR CREEK
38 MOUNDS
39 NORTH ESCALANTE CREEK
40 NORTH SINBAD VALLEY
41 OAK CREEK
42 PINE CREEK
43 PINON
44 POLAR MESA
45 RECAPTURE CREEK
46 SALT VALLEY
47 SANASTEE WASH
48 SAN MIGUEL CANYON
49 SHOOTERING POINT
50 SKEIN MESA
51 SLICK ROCK
52 SMITH FORK
53 SPRING CANYON
54 STATE LINE
55 STEAMBOAT MESA
56 SUMMERVILLE DRAW
57 SUMMIT POINT
58 TABEGUACHE
59 THIRD PARK
60 TIDWELL RANCH
61 UPPER MC ELMO CANYON
62 UPPER MONTEZUMA CANYON
63 YELLOW CAT

SINGLE MEASURED SECTIONS

1 ALMONT
2 BURNS
3 CARBONDALE
4 DURANGO
5 ELK CREEK
6 LITTLE SNAKE RIVER
7 LONG HOUSE VALLEY
8 MEEKER
9 NAVAJO POINT
10 PARLIN
11 SOUTH CANYON
12 STATE BRIDGE
13 TOADLEND
14 UPPER PIEDRA RIVER
15 VERMILION CREEK
16 VERNAL
17 WOLCOTT
18 YALE POINT

Figure 2. MAP OF PARTS OF UTAH, COLORADO, ARIZONA, AND NEW MEXICO SHOWING AREAL EXTENT OF THE SALT WASH MEMBER OF THE MORRISON FORMATION, LOCATION OF LITHOFACIES LOCALITIES, AND SINGLE MEASURED SECTIONS



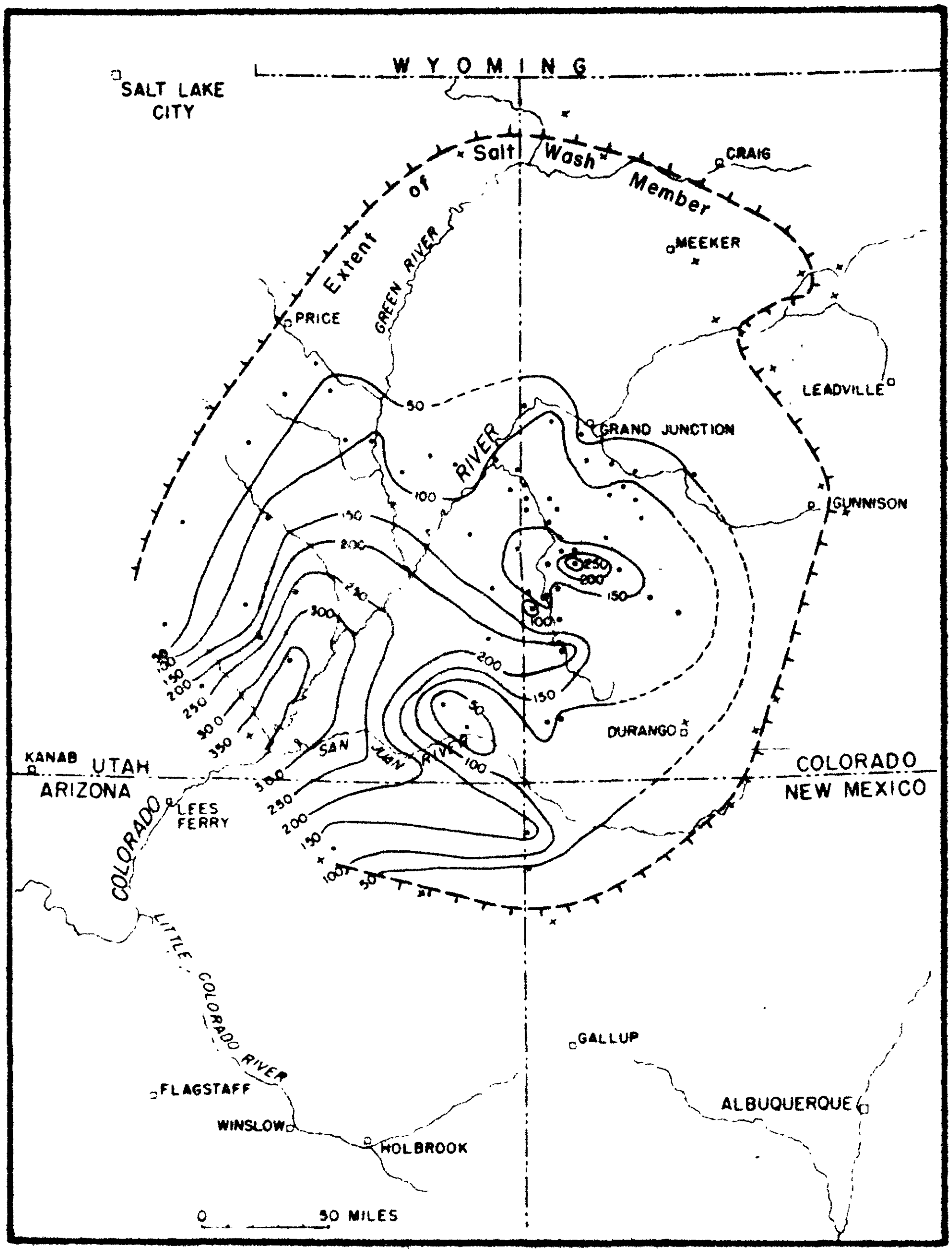
EXPLANATION

. LITHOFACIES LOCALITY — 100 — - - - ISOPACH LINE, DASHED WHERE INFERRED

× ONE MEASURED SECTION EXTENT OF SALT WASH MEMBER

ISOPACH INTERVAL 100 FEET

Figure 3. ISOPACH MAP OF THE SALT WASH MEMBER OF THE MORRISON FORMATION



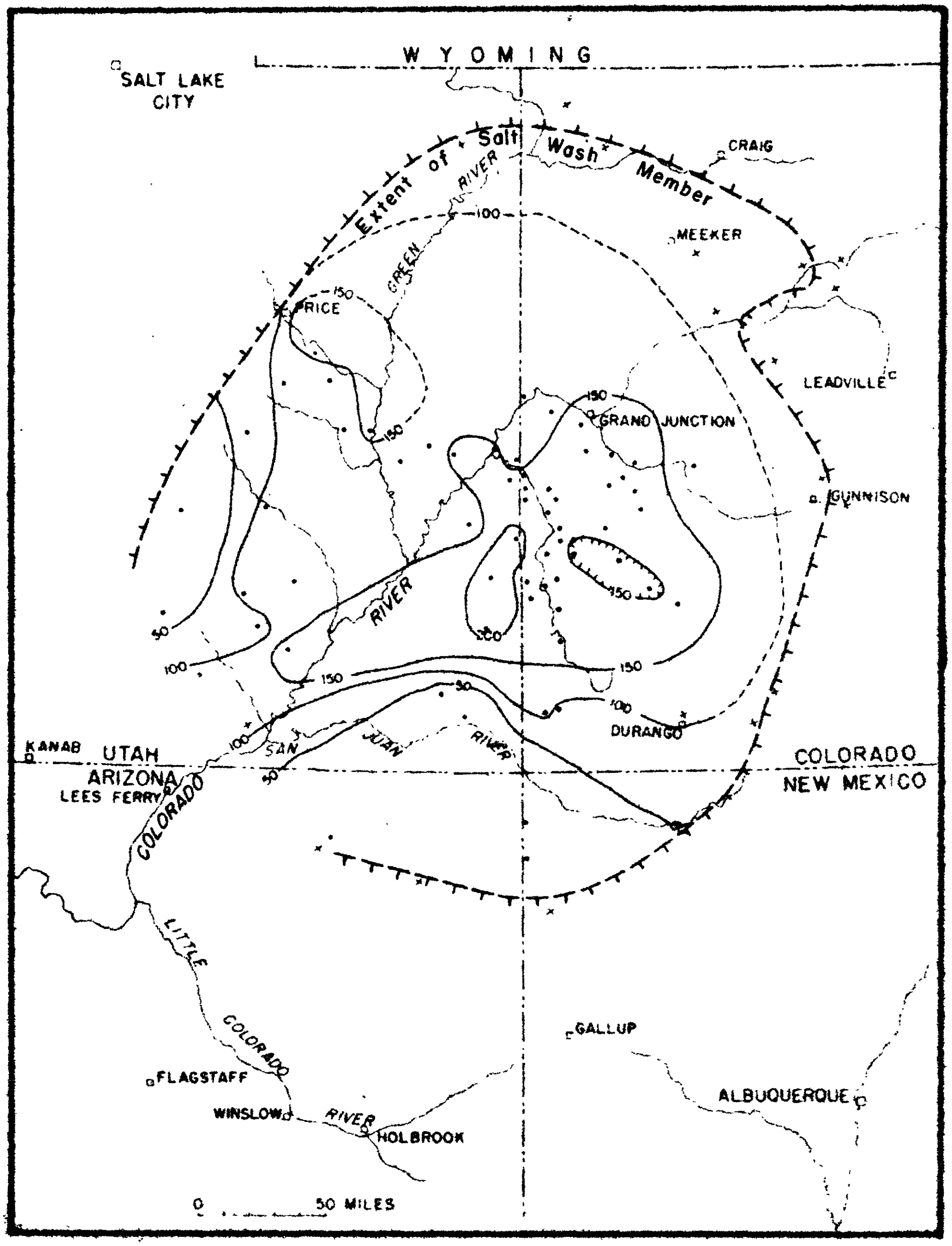
EXPLANATION

· LITHOFACIES LOCALITY — 50 — ISOPACH LINE, DASHED WHERE INFERRED

× ONE MEASURED SECTION — EXTENT OF SALT WASH MEMBER

ISOPACH INTERVAL 50 FEET

Figure 4. ISOPACH MAP OF THE STREAM DEPOSITS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION



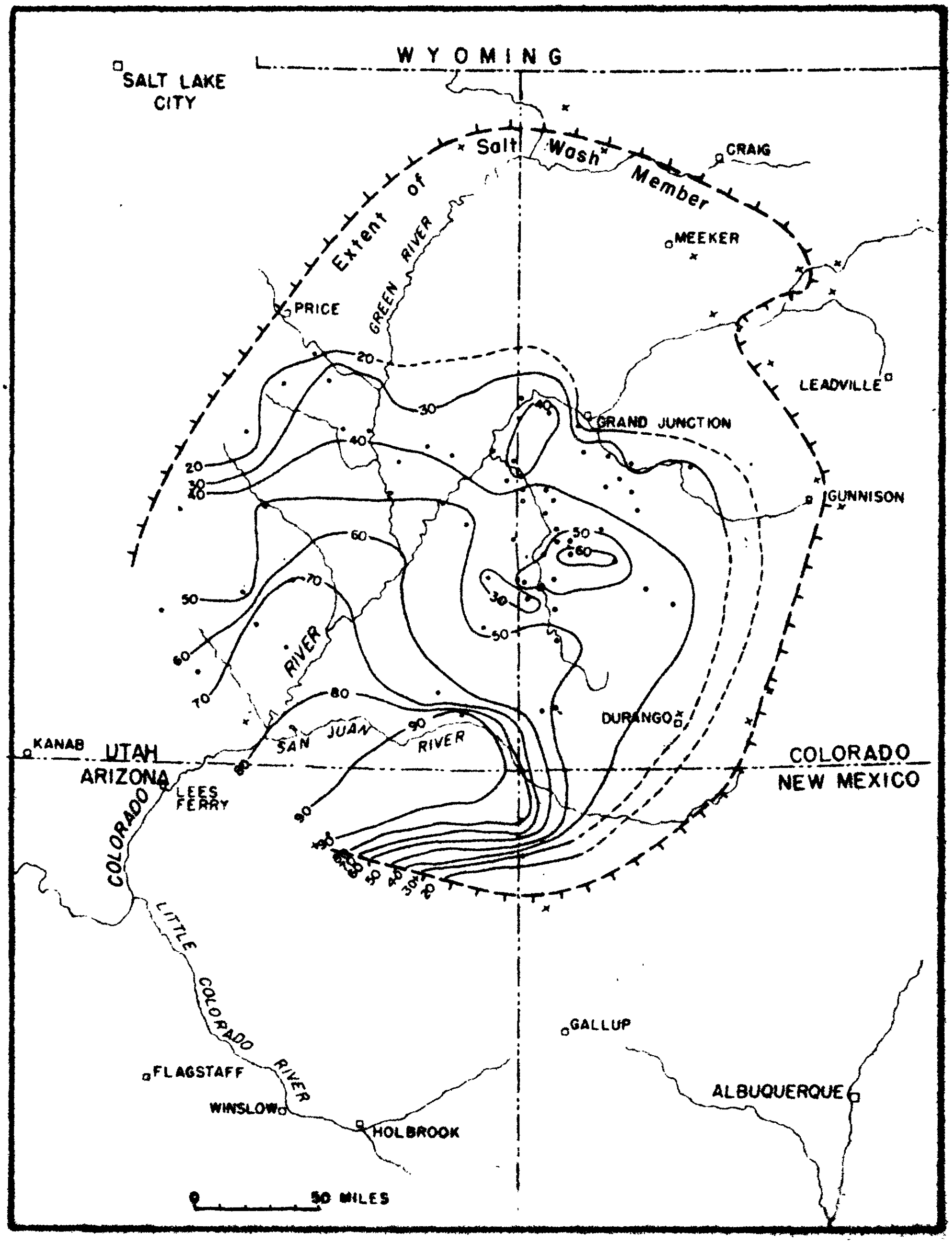
EXPLANATION

· LITHOFACIES LOCALITY — 50 - - ISOPACH LINE, DASHED WHERE INFERRED

× ONE MEASURED SECTION — — — EXTENT OF SALT WASH MEMBER

ISOPACH INTERVAL 50 FEET

Figure 5. ISOPACH MAP OF THE FLOODPLAIN DEPOSITS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION



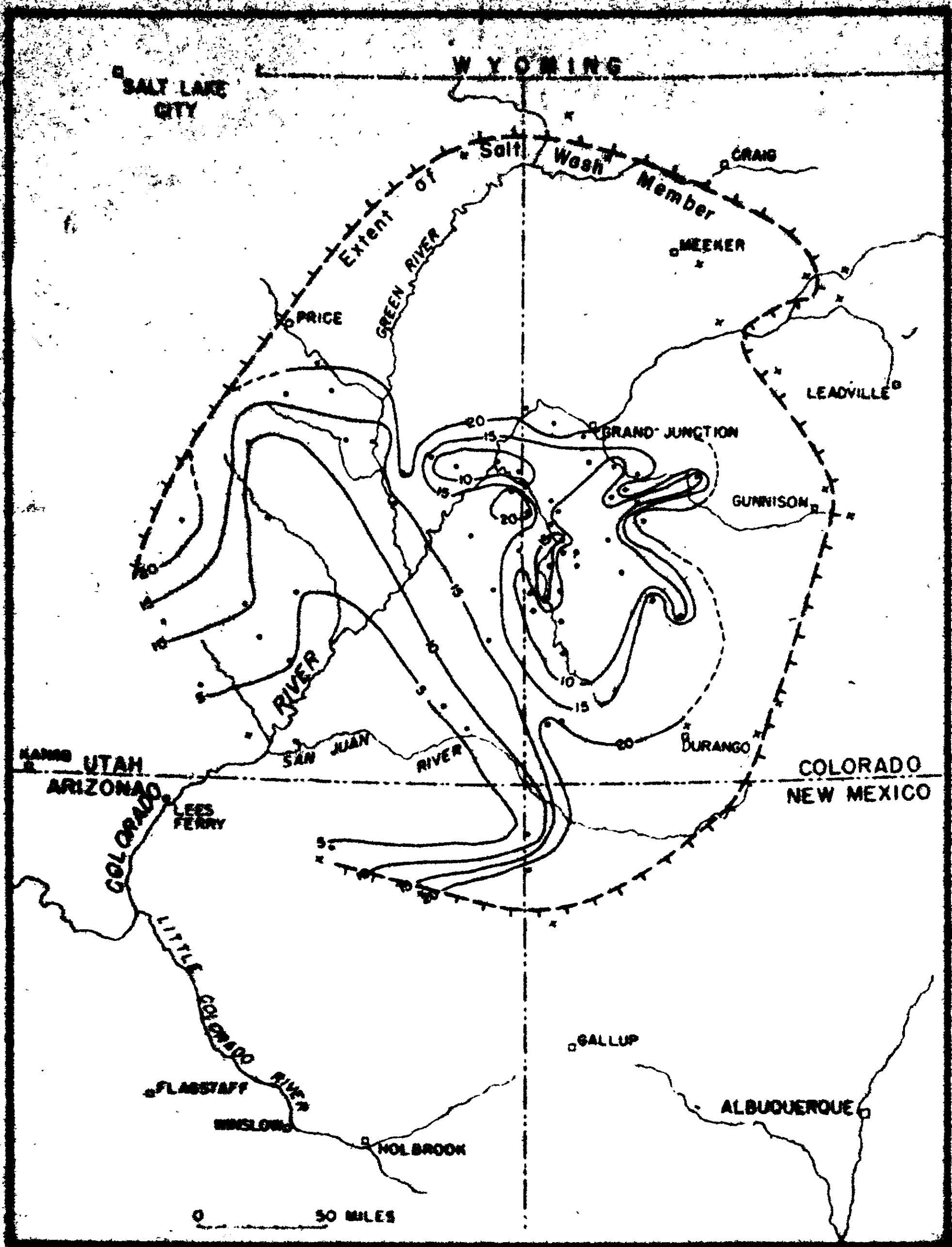
EXPLANATION

· LITHOFACIES LOCALITY —20—-- ISOLITH LINE, DASHED WHERE INFERRED

× ONE MEASURED SECTION EXTENT OF SALT WASH MEMBER

ISOLITH INTERVAL, 10 PERCENT

Figure 6. ISOLITH MAP OF THE PERCENTAGE STREAM DEPOSITS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION



EXPLANATION

· LITHOFACIES LOCALITY	ISOLITH LINE, DASHED WHERE INFERRED
× ONE MEASURED SECTION	EXTENT OF SALT WASH MEMBER

ISOLITH INTERVAL 5 PERCENT

Figure 7. ISOLITH MAP OF THE PERCENTAGE MEAN DEVIATION IN THE THICKNESS OF STREAM DEPOSITS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION

Table 1. Lithofacies data sheet for the Salt Wash member of the Morrison formation

Lithofacies locality No.	Name	No. of sections at locality	Average thickness of stream deposits (feet)	Average thickness of flood-plain deposits (feet)	Average total thickness (feet)	Average percentage of stream deposits	Percentage mean deviation of the thickness of stream deposits
1	Bilk Creek	3	140	197	337	42	5
2	Black Ridge	5	108	129	237	46	26
3	Bridgeport	4	78	167	245	32	9
4	Broughton	5	66	179	245	27	13
5	Buckhorn Flat	5	37	103	141	27	18
6	Butler Wash	5	42	27	68	64	9
7	Cane Spring	5	138	132	270	51	17
50	Skein Mesa	5	162	161	323	50	15
51	Slick Rock	5	165	161	329	50	16
52	Smith Fork	4	48	104	151	32	9
53	Spring Canyon	4	114	124	237	48	11
54	State Line	5	84	132	216	39	22
55	Steamboat Mesa	4	109	132	241	45	8
56	Summerville Draw	5	71	107	178	40	18
57	Summit Point	5	89	199	288	31	9
58	Tabeguache	4	148	154	302	49	3
59	Third Park	5	178	150	340	54	18
60	Tidwell Ranch	4	93	146	239	39	13
61	Upper McElmo Canyon	5	86	93	179	48	17
62	Upper Montezuma Canyon	5	200	220	420	49	15
63	Yellow Cat	3	97	153	250	39	7

The maps (figs. 3-7) were drawn to represent conditions existing at the end of deposition of the Salt Wash member. The reconstruction involved drawing lines across areas with no control points because the Salt Wash member either has been removed by erosion or is covered by younger rocks; however, the subjective element in drawing the isolith and isopach lines was lessened by plotting the lines at proportional intervals between control points. Isopach and isolith lines are not connected on the southwestern side of the maps, because in this area the Salt Wash member was removed by early Cretaceous erosion, and control points were not obtainable.

DESCRIPTION OF DATA

Isopach map of Salt Wash member

The areal distribution and thickness of the Salt Wash member of the Morrison formation is shown on figure 3. This isopach map of the Salt Wash member of the Morrison formation was constructed from data gathered at lithofacies localities, and the thickness figure for each locality is an average of the sections measured at that locality. However, some single sections are used to delineate the areal extent of the Salt Wash.

The map shows that the Salt Wash member is restricted to a nearly circular area. On the southwest side the Salt Wash has been removed by pre-Dakota erosion. The remainder of the area is bounded by a line "extent of Salt Wash member" which extends, counter-clockwise, from northeastern Arizona through northwestern New Mexico, western Colorado, and then through eastern Utah to a point about 140 miles northwest of the starting point.

The line marked "extent of Salt Wash member" in part represents a true depositional pinch-out and in part a grading of Salt Wash into other units. In Colorado and northeastern Utah some Salt Wash equivalents are probably represented in the basal part of the undifferentiated Morrison formation (Craig, and others, in preparation).

In Arizona, New Mexico, and the extreme southeastern part of Utah and Salt Wash grades and intertongues into the Recapture member of the Morrison formation and the Bluff sandstone.

Isopach lines show that the Salt Wash member was deposited as a fan-shaped wedge of sediments. The apex of the fan, the area of thickest sediments, is in south-central Utah. Isopach lines, which are crudely concentric outward to the north and east from the apex, are split into two distinct lobes by an area of thin Salt Wash in extreme southeastern Utah.

The southern lobe of the Salt Wash member is narrow and trends slightly south of east through northeastern Arizona and into New Mexico. Thickness of Salt Wash sediments in this lobe thins uniformly towards the limit of the Salt Wash member in New Mexico.

The northern lobe of the Salt Wash member is more extensive than the southern one. Isopach lines in the northern lobe form an asymmetric fan with an axis that curves eastward from the apex. Except in western Colorado, thinning in the northern lobe is rather uniform with a greater thinning per unit distance in areas close to the apex of the fan than in areas far removed from the apex. Anomalous thicknesses, over 400 feet at the Long Park locality and less than 300 feet at the Summit Point, Dolores group, and North Sinbad Valley localities, destroy the symmetry of the isopach lines in western Colorado. Isopach lines in the area of thin Salt Wash that separates the lobes of thicker Salt Wash form an oval-shape and the long axis of the oval trends northwest through the Four Corners. In this area the Salt Wash overlies the thicker part of the Bluff sandstone, a dominantly wind-blown deposit. If the isopach lines were connected through this area of thin Salt Wash, the isopach lines would have a nearly perfect fan-shape.

Isopach map of stream deposits

The areal distribution of thickness of stream deposits in the Salt Wash member is shown on figure 4. The data for this map are averages of the thickness of the stream deposits in the several sections measured at each locality.

The isopach map of the stream deposits is similar to the total thickness isopach map but shows more detail due to a smaller isopach interval. Greater thickness of stream deposits is near the apex of the fan in south-central Utah. Like the total isopach map, the isopach lines are divided into two lobes by an area of thin stream deposits in southern Utah. These lobes correspond in general with the lobes shown on the total thickness isopach map. The southern lobe is narrow and trends slightly south of east into New Mexico; the northern lobe is more extensive and isopach lines show a crude asymmetric fan with an axis that curves eastward from the apex. In western Colorado isopach lines reveal two areas of anomalous thickness of stream deposits. Both areas are enclosed by isopach lines; however, the lines around the northwestern anomaly, the Long Park locality, indicate an increase in stream deposits thickness, and the line around the southwestern anomaly, the Summit Point locality, shows a decrease in stream deposit thickness.

The area of thin stream deposits in southeastern Utah overlies the greatest thickness of the Bluff sandstone.

Isopach map of floodplain deposits

The areal distribution of the thickness of floodplain deposits in the Salt Wash member is shown on figure 5. Data for this map are the averages of the thickness of floodplain deposits in the several sections measured at each locality.

The map shows that the area of thickest floodplain deposits is near the center of the area of Salt Wash deposition. In general, isopach lines are roughly concentric about the area of thickest floodplain deposits, but the spreading of isopach lines from south-central Utah indicates a fan-like shape for the distribution of the floodplain deposits.

The floodplain deposits generally thin away from the center of the area, but two notable irregularities exist. One area, controlled by the Mounds and Little Grand Fault localities in east-central Utah, has anomalously thick floodplain deposits, and another area, controlled by the Long Park, Pinon, and San Miguel Canyon localities in southwestern Colorado, has anomalously thin floodplain deposits. The pattern of the isopach lines around the area of thickest floodplain deposits is not symmetrical. The isopach lines show the Salt Wash member contains less floodplain deposits in the Four Corners area than at the Little Grand Fault, Duma Point, and Salt Valley localities. These localities are about the same distance north and west of the axis of the fan as the Butler Wash, Recapture Creek, and Oak Creek localities in the Four Corners area are south and east of the axis.

The 50 foot isopach line is not extended completely around the area of deposition because of the difficulty in distinguishing Salt Wash deposits on the north and east sides of the Salt Wash area of deposition.

Isolith map of percentage of stream deposits in the Salt Wash member

The areal distribution of the relative amount of stream deposits in the Salt Wash member is shown by figure 6. Data for this map were prepared by computing the percentage of stream deposits in the total thickness of the Salt Wash member in each section measured at a locality and then averaging the percentages to obtain a value for the locality.

In general, the isolith lines form irregular concentric arcs outward from southeastern Utah. These arcs roughly parallel the line marking the extent of the Salt Wash member except on the southern side. On the southern side of the Salt Wash basin of deposition the isolith lines butt into the line marking the extent of the Salt Wash member.

The map shows the area of highest percentage of contained stream deposits is in southeastern Utah and northeastern Arizona. North of this area the percentage of contained stream deposits decreases rather gradually. Northeast the percentage decreases, but decrease in this direction is not progressive as several localities in western Colorado have relatively high percentages of stream deposits, and two, Summit Point and Dry Valley, have anomalously low percentages. South and southeast of the area of highest percentage of contained stream deposits the percentage stream deposits decreases uniformly and in a relatively short distance.

Isolith map of percentage mean deviation of thickness of stream deposits in the Salt Wash member

The areal distribution of the relative continuity of the stream deposits in the Salt Wash member is shown by figure 7. This map is based on the percentage mean deviation of the thickness of stream deposits at each locality. Quantitative data are computed in this manner: (1) the average of the thickness of stream deposits in all sections measured at the locality is determined; (2) the amount in feet that each section differs from the average of the locality is determined; (3) the deviations are added and divided by the number of sections measured at the locality (this figure is the mean deviation); (4) the figure determined in step 3 is divided by the average thickness of contained stream deposits at the locality; and (5) the figure determined in step 4 is converted to percent by multiplying by 100.

The percentage mean deviation of thickness of contained stream deposits is a relative index of continuity. The relative index is desirable because it enables continuity between localities with different thicknesses of contained stream deposits to be compared. In general, a low percentage deviation indicates high continuity between stream deposits, and a high percentage deviation indicates low continuity.

The mean deviation in thickness (step 3 of the calculations) is also an index of continuity between stream deposits; however, the mean deviation cannot be used to compare continuity between localities with different thicknesses of contained stream deposits.

The index of continuity used in this study applies to the total Salt Wash member and is not an index for individual lenses of stream deposits in the Salt Wash. Conditions could conceivably occur where the index would indicate a high continuity, but in actuality there would be little or no continuity. This condition would arise if sections of Salt Wash had the same total thickness of stream deposits, but the stream deposits were not continuous between the sections. Possibilities that such conditions are reflected in the data are decreased by measuring several relatively closely spaced sections at each locality.

Figure 7 shows two areas of relatively high continuity of stream deposits. One area is in southeastern Utah and northeastern Arizona, the other is in western Colorado and east-central Utah. Both areas are enclosed by higher value isolith lines that indicate a relatively low continuity of stream deposits away from the center of both areas. Isolith lines around the southern Utah and northeastern Arizona area of high continuity form roughly concentric arcs that are elongated northwestward. Continuity of stream deposits progressively decreases away from southeastern Utah except northeastward. Isolith lines around the Colorado and east-central Utah area of high continuity form a closed irregularly lobate pattern.

INTERPRETATION OF DATA

The maps (figs. 3 to 7) are shown separately and described separately for clarity, but no single map shows the lithofacies of the Salt Wash member. To present the lithofacies of the Salt Wash on a single map requires a composite map of the three isopach and two isolith maps. Such a composite map would be difficult to read and for this reason no composite map is shown. However, all interpretations are made on the basis of a composite map.

The data presented can determine the lithologic aspect of the Salt Wash only in terms of thickness, proportion, and continuity of the stream and floodplain deposits. Other factors pertinent to the total lithologic aspect, such as grain size distribution and heavy minerals distribution are not included in this study.

Depositional environment

The first goal of this lithofacies study was to determine aspects of the depositional environments of the Salt Wash member. The Salt Wash member has long been considered a product of an aggrading fluviatile system, (Mook, 1916; Stokes, 1944; and Craig, and others, in preparation) but little was known about the pattern of the streams that deposited the Salt Wash. Some new interpretations of the Salt Wash stream pattern and depositional environment can be made from data gathered in this study.

The lithofacies maps show the Salt Wash member to be a fan-shaped wedge of sediments with an overall decrease both in the relative proportion and continuity of stream deposits outward from the apex of the fan.

An aggrading distributary stream system, if the system discharges on a flat surface, produces a fan-shaped pattern of sediments called an alluvial fan. Within the alluvial fan the lithologic aspect, as determined by stream and floodplain deposits, is a function of division of water and sediments by the distributary streams. Divisions of water and sediment by the distributary streams causes a decrease in total volume of water and sediments per unit area as the distance from the apex of the alluvial fan is increased. This decrease of water and sediment per unit area results in: (1) an overall decrease in total thickness, and (2) a decrease in concentration and continuity of stream channels outward from the apex of the system. The decrease in concentration and continuity of stream channels results in a decrease in amount and continuity of stream channel sediments per unit area as the distance from the apex is increased.

Thus, by analogy with an alluvial fan, the regional variations in Salt Wash lithofacies can best be explained as resulting from a distributary drainage system. The possibility that the distributary system existed as a delta is precluded by field relations; no intertonguing of Salt Wash rocks and marine rocks is known. On the other hand, an alluvial fan concept of the Salt Wash member is supported by sedimentary features and fossils that indicate a terrestial environment. Therefore, the Salt Wash member is here considered as an immense alluvial fan.

The surface on which the Salt Wash member was deposited has been described by several writers (Craig, and others, in preparation; Stokes, op. cit.; and Baker, and others, 1936). In general, the surface was the plain formed by northward retreat of the Curtis Sea which was floored by marine and marginal marine deposits. Relief on the plain was low. Sand dunes in the Four Corners area formed a topographic high; possibly the crest of the Uncompahgre highland (Holmes, 1951) and the salt anticlines in west-central Colorado and east-central Utah (Cater, in preparation) extended a few feet above the general surface. This plain, which sloped gently northeastward, served as the surface for accumulation for Salt Wash sediments.

Salt Wash deposition was initiated by uplift southwest of the present junction of the Colorado and San Juan Rivers. This uplift created a source area for Salt Wash sediments, and a source of water to carry the sediments. An apex of a distributary stream system, fed by water and clastic sediments from the source area, developed near the present junction of the rivers. Then, from the apex of the system, sediments were spread north, east, and southeast on the plain of deposition by distributary streams. Once established, the general pattern of the drainage system persisted throughout the time of deposition of the Salt Wash member. Continued aggradation by the distributary streams resulted in deposition of the fan-shaped wedge of sediments now called the Salt Wash member of the Morrison formation.

Evidence that the drainage system persisted throughout the time of Salt Wash deposition is found in the basal part of the Brushy Basin member of the Morrison formation. The Brushy Basin is dominantly a lacustrine deposits, but over much of the area of study, the basal deposits of the Brushy Basin are fluviatile. The basal fluviatile deposits in the Brushy Basin are different in composition and texture than the underlying Salt Wash deposits, but they apparently represent a continuation of the Salt Wash distributary system during early Brushy Basin deposition (Craig, and others, in preparation).

The ideal fan-shaped wedge of sediments of alluvial fans was never developed in the Salt Wash. Irregularities on the surface of deposition interrupted the development of the fan. In the Four Corners area sand dunes that formed the Bluff sandstone stood as a topographic high. This topographic high split the Salt Wash drainage system into two distinct lobes. Irregularities in the wedge of sediments in west-central Colorado probably reflect local crustal movements around salt anticlines during Salt Wash deposition and the effect of the Uncompahgre highland.

The topographic high caused by the Bluff sand dunes did not persist throughout Salt Wash deposition. The Salt Wash streams in the Four Corners area eventually built up their base level enough to flow across the sand dunes. However, while it existed, the topographic high apparently affected the Salt Wash distributary streams in two ways. First, the topographic high split the Salt Wash distributary system into two lobes, and the Salt Wash member is thin between the two lobes because of restricted deposition. Second, the Salt Wash member contains a high proportion of stream deposits in this area. The high proportion of stream deposits is possibly due to restricted deposition of floodplain deposits. Probably the Salt Wash streams lost part of their energy and power to transport sediments as they approached the dune area. The remaining energy was used to rework the sand dunes, but the presumably hilly topography of the dune area prohibited the development of extensive floodplains adjacent to the streams. Consequently little floodplain material was deposited in the dune area.

Deviations from the ideal pattern of an alluvial fan in west-central Colorado, shown by all the maps, can not be directly correlated with a particular geologic feature. These deviations probably reflect local warps in the Salt Wash basin of deposition, but the lithofacies localities are too widely spaced to delimit the outlines of individual warps.

The salt anticlines in west-central Colorado and east-central Utah were rising through the time of Summerville deposition, and continued rising until early in the time of Salt Wash deposition (Cater, in preparation; Stokes and Phoenix, 1948). Upward movement of the salt anticlines caused topographic expression in the Salt Wash plain of deposition. The low gradient Salt Wash streams probably were locally dammed in many places by the topographic relief, and they probably deposited much of their sedimentary load near the flanks of the salt anticlines. Hence, part of the irregularity of the total thickness of the Salt Wash member, of the relative proportion, and the continuity of the stream deposits of the Salt Wash member in west-central Colorado is probably due to local crustal movements, and not to a change in the depositional environment of the Salt Wash member.

Other deviations in western Colorado from the ideal fan-shaped pattern of an alluvial fan may be related to slight topographic relief of the Uncompahgre highland. During the time of Salt Wash deposition pre-Cambrian rocks of the Uncompahgre highland formed a topographic high which trended from north-central New Mexico through Gunnison, Colo. Just north of Grand Junction, Colo., the highland passed into a structural terrace and had no topographic expression during the time of Salt Wash deposition (Holmes, 1951). The Uncompahgre highland did not stand high enough to contribute more than a minor amount of sediment to the Salt Wash, but it possibly formed a barrier to the low gradient eastward flowing Salt Wash streams. Such a barrier would cause unequal distribution of sediments in the Salt Wash fan as a more than normal amount of sediments would be deposited on the west side and a less than normal amount on the east side. The thicker Salt Wash with a relatively high proportion and continuity of stream deposits centering at the Long Park locality may reflect the effect of the Uncompahgre highland.

Another possible effect of the Uncompahgre highland on the Salt Wash wedge of sediments is shown by the sharp curve in the line marking the extent of the Salt Wash member. Salt Wash sediments are present at the Burns and Elk Creek sections, but not at the South Canyon, Wolcott, or State Bridge sections. Southward from the South Canyon section there is no recognizable Salt Wash until the Almont section. This curve in the margin of the Salt Wash member does not correspond to the expected symmetrical margin of an alluvial fan. The northeastern part of the Salt Wash fan extends further from the apex than the eastern side. This asymmetrical extent of the Salt Wash member may have been caused by the configuration of the Uncompahgre highland. Salt Wash streams flowing west of Grand Junction, Colo., would not have been affected by the highland barrier. Streams flowing east of Grand Junction would decrease in gradient and lose part of their capacity to transport sediments as they neared the highland. Therefore, other things being equal, streams flowing west of Grand Junction could transport sediments further from the apex of the distributary system than streams flowing east of Grand Junction. This arrangement could produce an asymmetrical curve at the margin of the Salt Wash fan.

The interpretation of the depositional environment of the Salt Wash member presented here emphasizes a single source area of sediments and a single distributary drainage system to spread the sediments. This interpretation is based entirely on the lithofacies factors described in this report. Other factors which might indicate nearness to the source area, such as grain size and composition of the Salt Wash sediments, were not included in this lithofacies study. However, in the overall interpretation of the depositional environment and source areas of the Salt Wash, all factors must be considered.

Work done by the U. S. Geological Survey (Craig, and others, in preparation) on the paleogeography of the Salt Wash member, of which the lithofacies study was only a part, supports the interpretations made from the lithofacies study. Conglomerate is a dominant part of the Salt Wash at the apex of the fan and conglomerate decreases in importance away from the apex. A study based on cross-laminations in the stream deposits in the Salt Wash member indicates the Salt Wash streams formed a distributary pattern which had its apex near the apex determined by lithofacies study (Weir, 1951). One aspect of the Salt Wash deposition as determined by other stratigraphic studies is not reflected by the lithofacies maps. Conglomerate in the Salt Wash member near the Garden Ranch lithofacies locality indicates the Salt Wash probably had a minor contribution of sediment from west of east-central Utah. This minor source area is not reflected in the lithofacies maps.

The maps compiled in the lithofacies study do not indicate an outlet for the water that transported and deposited the Salt Wash sediments. Possibly no outlet existed, and the distributary system allowed the water to disappear by seepage and evaporation. Another possibility is that Salt Wash streams drained by numerous outlets into the Curtis Sea to the north of the Salt Wash fan.

No direct evidence which would prove or disprove the existence of the Curtis Sea during the time of Salt Wash deposition is known to the authors. However, study in northeastern Utah and northwestern Colorado suggests the possibility that the Salt Wash streams drained into the Curtis Sea. In this area sandy layers occur at the base of the Morrison formation. These sandy layers, which are correlated with the Salt Wash, directly overlie marine Curtis rocks. Locally the sandy layers thicken to as much as 100 feet, but generally they are less than 20 feet. The local thick lenses, which extend as much as 3 miles along strike, could represent stabilized drainage courses of Salt Wash streams near a body of water. Lack of suitable outcrop prohibited making detailed studies of these thick lenses to determine their relations to the Salt Wash distributary system. It should be noted that these thick lenses in northeastern Utah contain considerably more feldspar fragments than found in other Salt Wash sediments, and possibly these lenses are not related to Salt Wash sediments found further south.

Relations of lithofacies to uranium-vanadium ore in the Salt Wash member

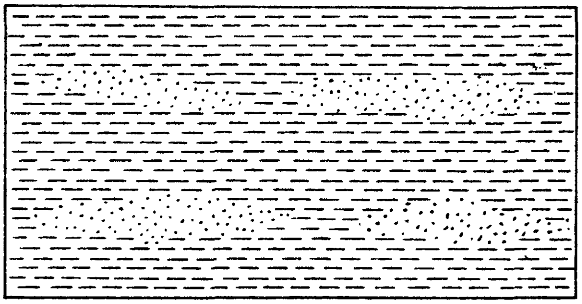
The second goal of the lithofacies study was to determine any relation between Salt Wash lithofacies and the uranium-vanadium deposits in the Salt Wash member.

Uranium and vanadium ore is mined from the Salt Wash member in many places in Colorado, Utah, and Arizona. The ore occurs as irregular tabular masses in the thicker part of stream deposited sandstone lenses and, in general, the ore is restricted to a single stratigraphic zone within the Salt Wash member. The ore deposits have been described in detail by Fischer (1942).

If the uranium and vanadium were transported in solution through the Salt Wash member, the movement of the metal-bearing solution would be affected by factors controlling the transmissibility of the Salt Wash. The stream deposits are more permeable than the floodplain deposits; therefore, major factors controlling the transmissibility of the Salt Wash member are the thickness, continuity, and relative proportion of stream deposits in the Salt Wash. Favorable conditions of continuity, thickness, and proportion of stream deposits might form traps favorable for local concentrations of metal-bearing solutions by density stratification or related phenomena.

Three conditions of transmissibility in the Salt Wash member and the possible relations of transmissibility to localization of ore deposits are illustrated in figure 8. Permeability of the stream deposits and hydraulic gradient are assumed to be the same in each case illustrated in figure 8.

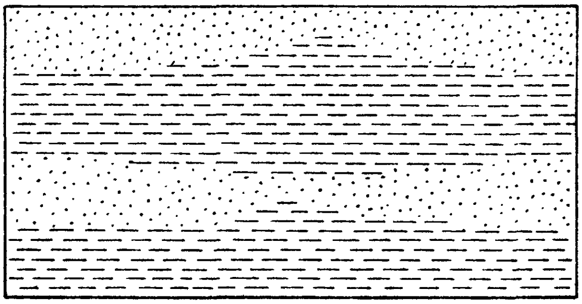
A low proportion of stream deposits to floodplain deposits with little continuity of the stream deposits is shown by A in figure 8. Movement of solutions through the stream deposits is impeded because



Noncontinuous stream deposits. Movement of solutions is hindered

Theoretically unfavorable for accumulation of ore minerals

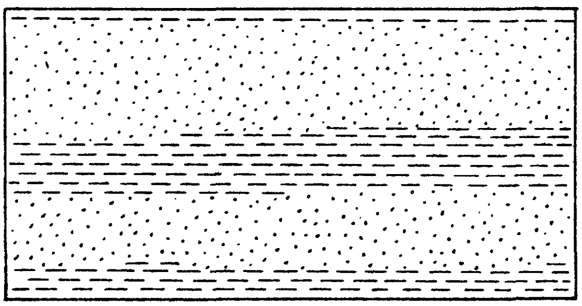
A



Continuous stream deposits with irregularities that restrain solutions in places

Theoretically favorable for accumulation of ore minerals

B

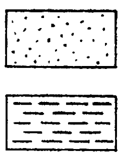


Continuous stream deposits with no irregularities to interrupt the movement of solutions

Theoretically unfavorable for accumulation of ore minerals

C

EXPLANATION



Stream deposits

Floodplain deposits

Figure 8. DIAGRAM SHOWING CONDITIONS OF TRANSMISSIBILITY IN THE SALT WASH MEMBER OF THE MORRISON FORMATION

little continuity exists between individual lenses of stream deposits. The opportunity for concentrations of dissolved metals from weak solution is unlikely because little solution passes through the stream deposits.

The assumed ideal lithofacies for concentration of ore minerals in the Salt Wash stream deposits is shown by B in figure 8. Stream deposits comprise about one-half the total thickness and the stream deposits are continuous but slightly lenticular. Movement of metal-bearing solutions would be restricted to the stream deposits which comprise about one-half the total thickness; this would cause a relative concentration of solution when compared to the total thickness. At the same time, the movement of the solution is locally impeded by the lenticularity of the stream deposits. Dissolved ore metals might be concentrated at stratigraphically favorable places. As the stream deposits are continuous enough to allow inflow of new solution, ore deposits might accumulate at the favorable places.

Stream deposits that have high continuity and comprise about three-fourths of the total thickness are shown by C in figure 8. This lithofacies may be unfavorable for the accumulation of ore deposits. Movement of metal-bearing solutions would not be restricted to a small part of the total thickness of the Salt Wash, nor would movement of the solutions be restricted by irregularities in the stream deposits. The metal-bearing solutions could pass freely through this lithofacies, with relative freedom and there would be little chance for concentration of the ore metals.

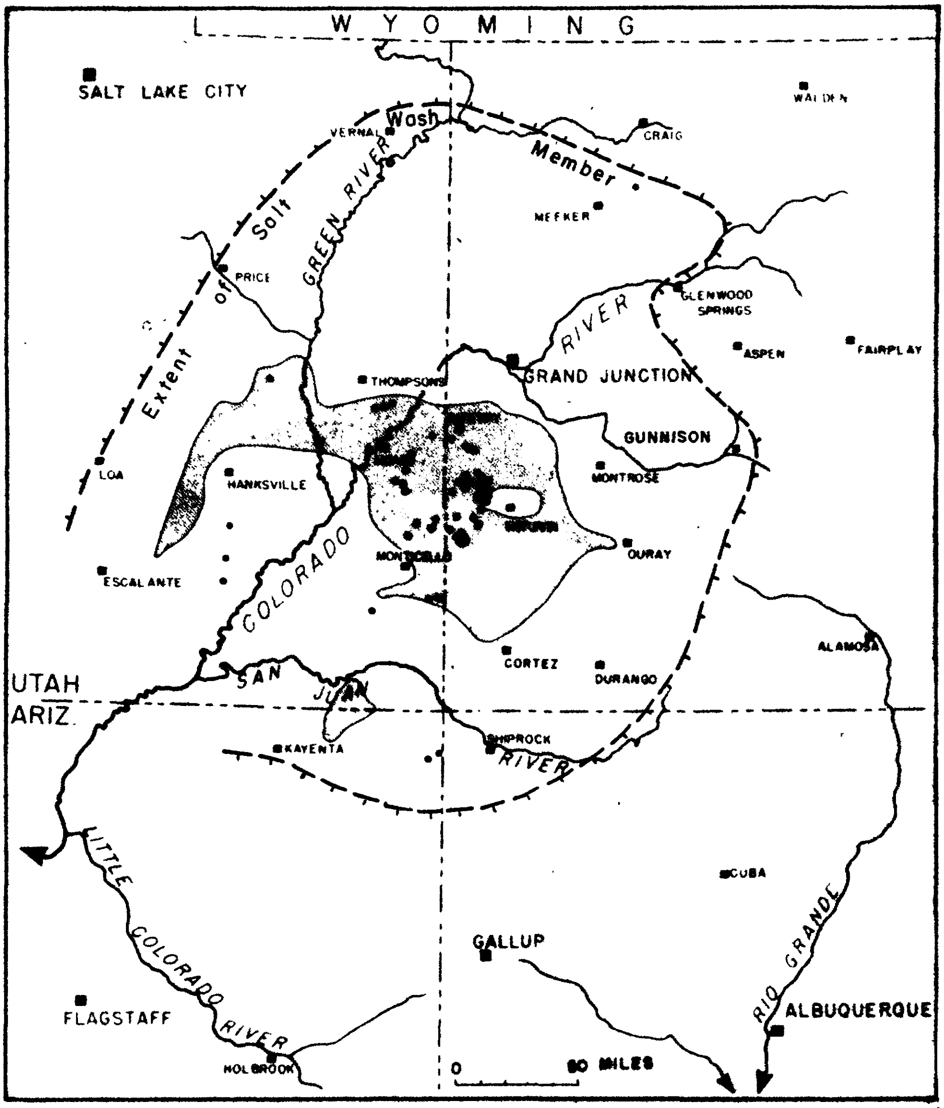
Regionally, transmissibility of the Salt Wash member probably is greatest near the apex of the fan in south-central Utah. The stream deposits show greatest thickness and continuity and comprise over one-half the total thickness of the Salt Wash in this area. Transmissibility of the Salt Wash member probably decreases away from the apex as the thickness, continuity, and relative proportion of stream deposits decrease. Near the margin of the fan the transmissibility of the Salt Wash is probably lowest as stream deposits comprise little of the total thickness, and little continuity exists between individual lenses. The assumed ideal conditions of transmissibility for accumulation of ore deposits would be found in the central part of the Salt Wash wedge of sediments.

The relation of uranium-vanadium ore to Salt Wash lithofacies was tested by plotting quantitative lithofacies parameters of ore-bearing localities in relation to all quantitative lithofacies data. For this purpose a lithofacies locality was considered an ore-bearing locality if ore has been produced within 1 mile of the locality. Of the 63 lithofacies localities, 22 are ore-bearing localities.

Of the 22 ore-bearing lithofacies localities 18 occur where the Salt Wash member that is over 240 feet thick, is composed of 40 to 55 percent stream deposits, contain 90 to 200 feet of stream deposits, and has a 5 to 18 percent mean deviation in the thickness of stream deposits. As 18 of 22 ore-bearing localities occur in lithofacies limited by these parameters, the parameters seemingly delimit a lithofacies that is more favorable for the accumulation of ore deposits than other lithofacies. These quantitative parameters of Salt Wash lithofacies are medial in respect to all lithofacies data, and they seem to fit best the hypothetical case of transmissibility outlined in B of figure 8. The remaining 4 ore-bearing localities are in Salt Wash lithofacies that deviate greatly from the limits outlined above. In fact, if all ore-bearing localities are considered in determining a favorable lithofacies for ore deposits the resulting quantitative lithofacies parameters include about 90 percent of the Salt Wash wedge of sediments.

Figure 9 shows the areal distribution of sediments of the Salt Wash member that conforms to the quantitative lithofacies limits outlined as most favorable for ore deposits. The figure also shows the location of major ore deposits in the Salt Wash (Fischer, op. cit., pl. 1). Figure 9 shows that most major ore deposits are in Salt Wash that conforms to the limits of favorableness as determined by the lithofacies study. This high degree of correlation may be explained as a function of the transmissibility outlined in B of figure 8. An alternate explanation is that the correlation between a medial lithofacies and the occurrence of ore deposits is coincidental.

In the assumed ideal lithofacies for accumulation of ore deposits, the ore deposits should not be confined to a particular stratigraphic zone. Actually, ore deposits in the Salt Wash member in a given mining district are generally confined to one stratigraphic zone of stream deposits. Because of the restricted stratigraphic position of the ore deposits in the Salt Wash member, the validity of a correlation between the total lithologic aspect of the Salt Wash member and ore deposits confined to a single zone in the Salt Wash may be questioned. The favorable lithofacies may represent a depositional environment in which single zones favorable for deposition of ore are more likely to occur than in other lithofacies. Or the ore deposits may be restricted to a certain zone for reasons not related to the total lithologic aspect of the Salt Wash member. If the ore deposits are not related to the total lithologic aspect of the Salt Wash member, then the occurrence of ore deposits in the medial lithofacies is a coincidental relationship.



EXPLANATION

• LOCATION OF MAJOR URANIUM-VANADIUM DEPOSIT

AREA OF FAVORABLE SALT WASH AS DETERMINED BY LITHOFACIES STUDY (SALT WASH MEMBER OVER 240 FEET; STREAM DEPOSITS COMPRISE 40 TO 55 PERCENT OF MEMBER; THICKNESS OF STREAM DEPOSITS IS 90 TO 200 FEET; PERCENTAGE MEAN DEVIATION OF STREAM DEPOSITS IS 5 TO 15 PERCENT

EXTENT OF SALT WASH MEMBER

Figure 9. MAP SHOWING THE LOCATION OF MAJOR URANIUM-VANADIUM DEPOSITS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION AND THE AREAS OF FAVORABLE SALT WASH AS DETERMINED BY LITHOFACIES STUDY

Some evidence exists that the good correlation between ore deposits and a particular lithofacies is coincidental. Although the discussion of transmissibility in relation to ore deposits was based on theory, the quantitative limits of favorability were based on measurements from ore localities. Most ore deposits are in west-central Colorado and east-central Utah. Most lithofacies localities considered as ore localities were also in west-central Colorado and east-central Utah and the favorable lithofacies were determined by the parameters of the ore localities in this area. The west-central Colorado and east-central Utah area, containing many ore localities, is relatively small; but the lithofacies of the small area is the same as a much larger area. Consequently, all Salt Wash of the same lithofacies as the small area was considered as favorable for the accumulation of ore deposits. It is possible that the ore deposits are more abundant in the small area because of local structural features, localized hydrothermal activity, or other local features not yet known, and not because of a particular lithofacies. The evidence that the ore deposits are related to local features is that the ore deposits are not distributed uniformly through the particular lithofacies. Also most ore deposits in Salt Wash lithofacies considered as unfavorable for the accumulation of ore deposits are geographically removed from the west-central Colorado and east-central Utah area where the quantitative parameters were developed.

SUMMARY

Lithofacies, as used here, denotes the lithologic aspect of the Salt Wash member of the Morrison formation. The specific lithofacies of a given locality is determined by the thickness, the relative proportions, and the continuity of the stream and floodplain deposits that comprise the Salt Wash member at the locality.

Regional variations in Salt Wash lithofacies determined in this study served as a base for interpretations of the depositional environment of the Salt Wash member. The regional variations in lithofacies indicate that the Salt Wash member was deposited by a distributary stream system from an apex in south-central Utah. The distributary system spread sediments to the north, east, and southeast over a nearly flat plain. The sediments form a pattern generally similar to an alluvial fan and the

Salt Wash member is best explained as a huge alluvial fan. The symmetry of the Salt Wash "alluvial fan" was destroyed by irregularities in the surface of deposition in the Four Corners area and in west-central Colorado.

Theoretical considerations of the various lithofacies of the Salt Wash member indicate a medial lithofacies should be ideal for the accumulation of the uranium-vanadium ore deposits found in the Salt Wash member. Quantitative parameters of Salt Wash lithofacies indicate that many uranium-vanadium ore deposits are restricted to a medial lithofacies. However, the ore deposits are not distributed uniformly through the zone of medial lithofacies, instead most known ore deposits are concentrated in a small area in the zone of medial lithofacies. Because local geologic features not related to Salt Wash depositional environment might control the distribution of the ore deposits, the high degree of correlation of lithofacies and ore deposits may be coincidental.

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