A BASIC EVALUATION OF THE URANIUM POTENTIAL OF THE MORRISON FORMATION OF NORTHWESTERN CIMARRON COUNTY, OKLAHOMA, AND ADJOINING AREAS OF NEW MEXICO AND COLORADO

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PREFACE

Exploration for uranium on the Southern Great Plains has had very limited success in the past. Exposures of the Morrison Formation in the Dry Cimarron River Valley are centrally located in a region which has few other good exposures. Observations and relationships from these exposures were used to project trends of potential uranium mineralization into areas with limited outcrops.

The writer is sincerely grateful to Dr. Zuhair Al-Shaieb, thesis adviser, for proposing the study and lending his support to its completion. The comments and constructive criticism of the advisory committee, Dr. Gary F. Stewart and Dr. John D. Naff, are also greatly appreciated. Special thanks are extended to Dr. John W. Shelton and Dr. R. Nowell Donovan for their helpful suggestions.

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CHAPTER I

ABSTRACT

The undifferentiated Morrison was deposited on an alluvial plain by braided and meandering streams as well as fresh-water lakes. Thicker accumulations of Morrison sediment are found above or closely associated with changes in basement provinces and Precambrian faults. Sediment transport and deposition were controlled by structures associated with faulting. The major alluvial systems shifted to the east along the Oklahoma-New Mexico border during deposition of the upper Morrison.

In the mineralized samples, uranium has a high positive correlation with titanium, lead, strontium and magnesium, as well as a high negative correlation with manganese. The uranium was closely related to carbonaceous material. The localities of mineralization were controlled by low permeability and other stratigraphic conditions.

The areas which contain the highest probability for uranium mineralization are associated with the thicker Morrison sections. These areas form two trands. One is located along a line from Clayton, New Mexico, to Kenton, Oklahoma. The other is located parallel to the Sierra Grande Uplift and slightly east of the crest of the structure.

CHAPTER II

INTRODUCTION

Recent changes in energy awareness and the resulting economic conditions have caused an increase in exploration for new uranium reserves. The undifferentiated Morrison of the Southern Great Plains has received limited exploration activity since the mid-nineteen fifties. During that time localized high concentrations of uranium have been found in northeastern New Mexico and southeastern Colorado. The limited success has been due at least in part to poor exposures of the potential host rock.

Exploration efforts in this region should begin with an understanding of the geologic conditions present during and subsequent to deposition of the Morrison. The area of this investigation is located in Cimarron County, Oklahoma, T4-6N, R1-2ECM and Union County, New Mexico, T30-32N, R29-37E (Fig. 1). This area is located between the two previously mentioned areas of known mineralization. The Morrison Formation in this area was found to contain two stratigraphic horizons of uranium enrichment.

Purpose and Methodology

The study was undertaken to evaluate the potential uranium enrichment in the Morrison of the Southern High Plains and to predict areas for future possible exploration. Known evidence which suggested

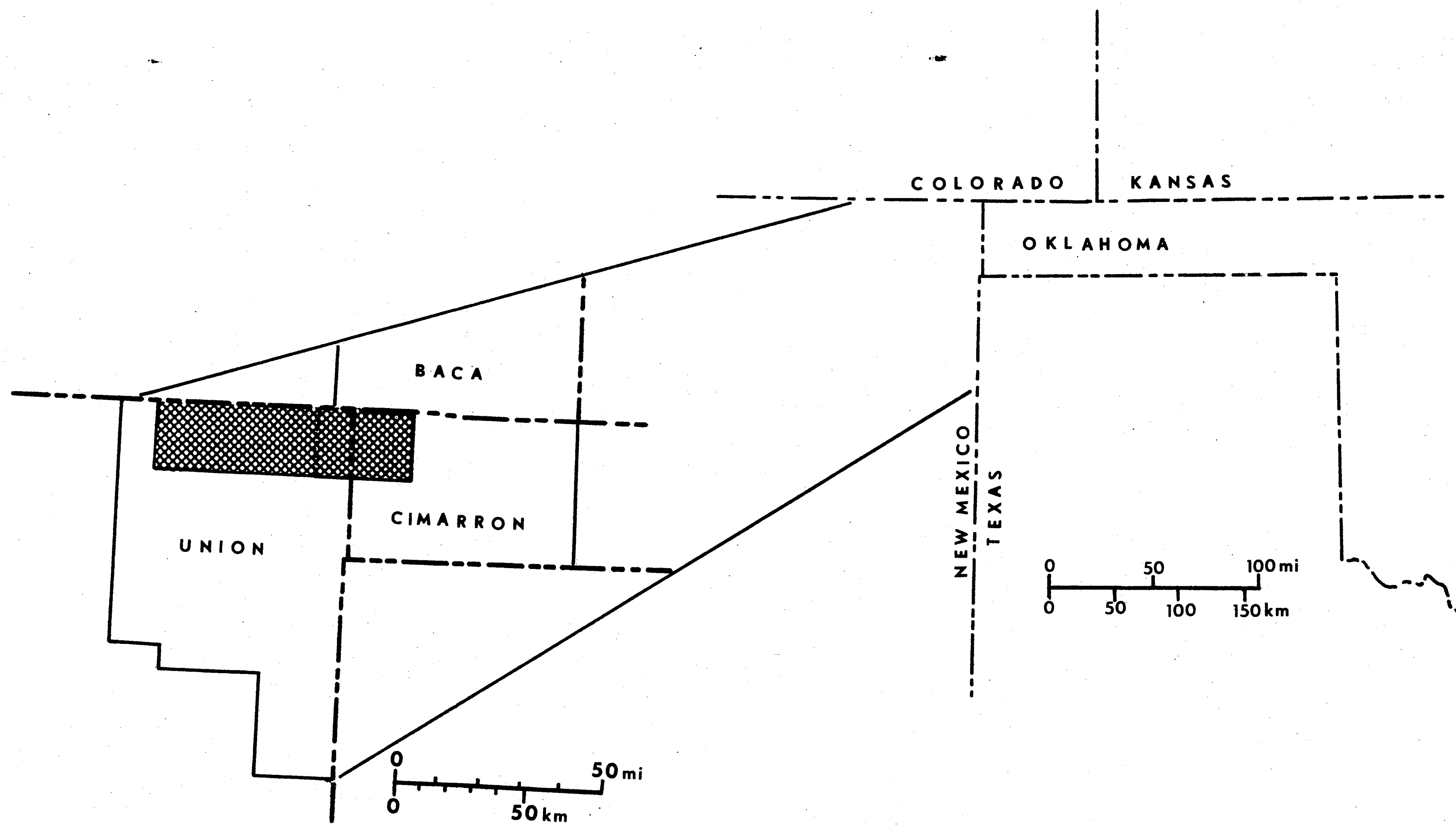

Fig. 1.-Index map of study area.

a possibility of mineralization included:

1. higher-than-normal uranium in ground water and surface water of the area;

2. reported localized "hot spots" in the Morrison south of the study area in Harding, Mora, San Miguel, and Quary Counties, New Mexico;

3. localized concentrations of uranium in the study area reported by Baldwin and Muehlberger (1959) and Zeller et al. (1976);

4. reported concentration of uranium north of the study area in Bent County, Colorado;

5. the reported presence of organic material in the formation; and

6. the reported favorable depositional environments of the Morrison in northeastern New Mexico, which are similar to those of Laguna and Ambrosia Lake districts of west-central New Mexico.

Several methods of investigation were used to evaluate the formation. Reconnaissance of the area was conducted by a carborne radiometric survey using a scintillometer and a gamma-ray spectrometer. Uranium concentrations reported from the literature and by ranchers in the area were investigated, as well as random samples of the Morrison outcrops. Stratigraphic sections of the sample localities were made at the time of sampling.

Samples were analyzed by several quantitative and qualitative methods. Thin sections were made of selected samples and analyzed on a Nuclide Luminoscope, as well as under plane-polarized light. The clay fraction was analyzed using x-ray diffraction to determine the mineralogic composition. Seventy samples were analyzed for uranium by Skyline Labs, Inc., Denver, Colorado, using a Galvanek-Morrison-type fluorometer. These samples were selected from 140 samples which were analyzed for 16 additional cations using a Perkin-Elmer 403 double-beam atomic-absorption spectrophotometer.

Previous Investigations

There have been several previous investigations in the area which have dealt with the Morrison Formation. Lee (1901, 1902) traced the Morrison from its type locality near Morrison, Colorado, into northeastern New Mexico and southeastern Colorado. Stanton (1905) discussed the relationship of the formation with the Lower Cretaceous beds of southern Colorado. Rothrock (1925) and DeFord (1927) described the areal geology of Cimarron County, Oklahoma.

The stratigraphy of Cimarron County was revised by Stovall (1938, 1943). Cooley (1955) described the stratigraphy and structures in the Dry Cimarron River Valley in Union County, New Mexico. Mankin (1958) discussed the regional geology of northeastern New Mexico, and concentrated on a mapping area in northern Harding County, New Mexico. West (1978) discussed a stratigraphic problem in the lower Morrison of Cimarron County, near Kenton, Oklahoma.

The geology and ground water conditions of Cimarron County, were described by Schoff (1943). The ground water resources of Cimarron County, were also shown in Irwin and Morton (1969) and Sapik and Goemaat (1973). Baldwin and Muehlberger (1959), Baldwin and Bushman (1957), and Cooper and Davis (1967) discussed the geology and ground water of Union County, New Mexico. McLaughlin (1954) described the geology and ground water resources of Baca County, Colorado.

Several geologic guidebooks have been published for the region.

These include Oklahoma City Geological Society (1956), Kansas Geological Society (1934), Panhandle Geological Society (1955), Muehlberger et al. (1967), Kelley and Trauger (1972), and Foster et al. (1972).

Finch (1972) and the United States Atomic Energy Commission (1970) have described the known uranium occurrences in northeastern New Mexico. Landis (1960) discussed the uranium content of ground and surface water in the region.

Finch et al. (1975) compiled an extensive bibliography dealing with uranium and related subjects for eastern New Mexico and western Texas, and nearby areas of Oklahoma, Colorado, and Kansas. Zeller et al. (1976) presented a regional reconnaissance of the uranium potential of the great plains of Kansas, Colorado, and adjoining areas.

A helicopter-borne radiometric survey using a scintillometer was conducted in the area in late May, 1955, extending 23 miles west from the Oklahoma-New Mexico state line to Peacock Canyon. The survey reported localized "hotspots" near the clastic plugs of Triassic age but no reported mineralization in the Morrison. Mr. Roy David, the president of Allied Helicopter Company of Tulsa, Oklahoma, reported that no maps or data of the survey were retained when economic deposits were not found (Dautenhahn, 1978).

CHAPTER III

STRATIGRAPHIC FRAMEWORK

The generalized Mesozoic stratigraphic section (Table I) of northeastern New Mexico, and nearby areas of Oklahoma and Colorado, includes several formations that are not found throughout the region. This is due in some cases because of nondeposition and in others because of post-depositional erosion of the units.

The Dockum Group records the Triassic Period. Baldwin and Muehlberger (1959) have divided the Dockum into the Sheep Pen Sandstone, the Sloan Canyon Formation, the Travesser Formation and the Baldy Hill Formation, in descending order. This division of the Dockum is recognized only in the Dry Cimarron River Valley of Union County, New Mexico.

The Jurassic Period is represented by the Exeter Sandstone and the Morrison Formation. The Exeter is probably equivalent to the Entrada Sandstone and the Ocate Sandstone (Baldwin and Muehlberger, 1959; Bachman, 1953; and Wood et al., 1953). The Morrison Formation is divided in Union County (Baldwin and Muehlberger, 1959), into the Brown-Silt Member which is the basal section and above which is undifferentiated Morrison except for an "agate bed" approximately ten feet above the basal member.

The Cretaceous is represented by the Dakota Group, the Benton Group, and the Niobrara Formation, in ascending order. The Dakota Group is composed of the Purgatoire Formation, which includes the lower

TABLE I

MESOZOIC STRATIGRAPHY WITHIN THE STUDY AREA

Cretaceous	Niobrara Formation	
	Benton Group	Carlile Shale Greenhorn Limestone Graneros Shale
	Dakota Group	Dakota Formation Purgatoire Formation
	ANGULAR UNCONFORMITY	
Jurassic	Morrison Formation	
	Exeter Sandstone	
	ANGULAR UNCONFORMITY	
Triassic	Dockum Group	Sheep Pen Sandstone Sloan Canyon Formation Travesser Formation Baldy Hill Formation

Cheyenne Sandstone Member and upper Kiowa Shale Member, and the Dakota Formation. The Carlile Shale and Niobrara Formation are not found in Oklahoma, but are present in Baca County, Colorado and in Union County, New Mexico.

Regional Stratigraphy of the Morrison

Cross (1894) was the first to use the name "Morrison", for beds exposed near Pikes Peak. Eldridge (1896) defined the Morrison Formation with a type section near Morrison, Colorado. Lee (1902) followed the Morrison exposures into northeastern New Mexico and southeastern Colorado. During this work, he reported the persistant "agate bed" found in the lower part of the formation. Stanton (1905) discussed the age and correlation of the formation in southern Colorado.

Rothrock (1925) described the areal geology of Cimarron County, Oklahoma, and stated that the eastern limit of the formation was in the western part of the county. DeFord (1927) corrected Rothrock by reporting the Morrison exposures and eastern limit of the formation in Cimarron County, as being north of Boise City (T5N, R6ECM). Stovall (1939,1943) established evidence of a major unconformity between the Morrison and Lower Cretaceous formations northeast of Kenton, Oklahoma, in northwestern Cimarron County.

Waldschmidt and LeRoy redefined the type section in 1944 to an area two miles north of the town of Morrison. Their new type section (Table II) is divided into six units according to lithology. These are:

1. Sandstone and Shale Unit-76.5 feet thick, lavender, marroon, and greenish-gray shales and light gray sandstones;

2. Red Shale Unit-36.75 feet thick, maroon, gray, lesser

greenish-gray shales and light gray to buff sandstones;

3. Gray Shale and Sandstone Unit-51.5 feet thick, gray and bluish-gray shales and sandstones and limestones present, lower 8 feet contains vertebrate fossils;

4. Gray Clay and Limestone Unit-49.75 feet thick, gray clay beds and limestones;

5. Gray and Red Shale Unit-55.6 feet thick, gray and reddish-gray silty shales and limestones;

and

6. Basal Sandstone Unit-7 feet thick.

Freeman and Hilpert (1957) defined the Morrison Formation in the Laguna mining district in central New Mexico, as being composed of the Recapture, Westwater Canyon, and Brushy Basin Members (Table II). They also described a sandstone underlying the Dakota Formation and overlying the Brushy Basin Member, which they informally called the Jackpile sandstone bed of the Brushy Basin Member. Flesch (1975) has suggested that the Jackpile be named a formal member of the Morrison Formation in this area, based on his work and that of others mapping in the area.[1]

Squyres (1970) described the Brushy Basin Member of west-central New Mexico, as similar to sediments in the upper section of the undifferentiated Morrison of the Colorado Front Range. Flesch (1974, p. 189) states,

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[1] It is not known if the Jackpile sandstone is a formal member of the Morrison Formation at this time but is so used in this investigation based on the work of Flesch (1975), Schlee and Moench (1961), and Kittel (1963).

TABLE II

MORRISON STRATIGRAPHY OF THE TYPE SECTION, LAGUNA DISTRICT, AND THE STUDY AREA

<table>
<tr><th colspan="2">Type Section

Waldschmidt & Leroy (1944)</th><th colspan="2">Dry Cimarron River Valley

Abbott (1979)</th><th>Laguna District

Flesch (1975)</th></tr>
<tr><td rowspan="4">Undifferentiated</td><td>Sandstone and Shale Unit
Red Shale Unit</td><td rowspan="2">Undifferentiated</td><td>Maroon Shale and Sandstone</td><td>Jackpile Sandstone Member</td></tr>
<tr><td>Gray Shale and Sandstone Unit
Gray Clay and Limestone Unit</td><td>Gray-Green Shale and Limestone</td><td rowspan="2">Bushy Basin Shale Member</td></tr>
<tr><td>Gray and Red Shale Unit</td><td colspan="2" rowspan="2">Brown-Silt</td></tr>
<tr><td>Basal Sandstone Unit</td><td>Westwater Canyon Sandstone Member</td></tr>
<tr><td></td><td></td><td colspan="2"></td><td>Recapture Shale Member</td></tr>
</table>

> The Brushy Basin consists of gray-green and red-brown, montmorillonitic claystone (69% of measured thicknesses), yellow to tan, iron oxide stained, well indurated arkosic arenites (29%), which contain conglomerate seams and clay galls, thin brown-gray micrite beds (2%), and trace amounts or red-brown, very thin, dense volcanic ash (?) beds.

Craig et al. (1955) described the undifferentiated Morrison as having a lithology and depositional environment similar to the Brushy Basin Member in western Colorado and northwest New Mexico.

Local Stratigraphy of the Morrison

In northeastern New Mexico, the thickness of the Morrison ranges from 0-500$^+$ feet. It is composed of variegated shales, lenticular sandstones, and lacustrine limestones. An informal subdivision of the Morrison for purposes of discussion in this report is shown in Table II. In the study area the basal member of the Morrison, the Brown-silt Member (Baldwin and Muehlberger, 1959), is equivalent to the unit Cooley (1955) termed the Wanakah Formation. Mankin (1958) did not divide the Morrison but described the lower Morrison as generally being reddish brown silty shale. Cooley (1955) described the Brown-silt interval as being 80 feet thick in Colfax County, New Mexico, (Woods et al., 1953) and thinning progressively to the east. Cooley interpretated the measured section of the Morrison by Stovall (1938) at Labrier Butte in Cimarron County, as containing the Brown-silt Member in the lower 8 feet of the section. The member is brown to tan and is gray-green at some localities. In the Dry Cimarron River Valley west of Guy Monocline, gypsum is present in the member but is absent to the east of the structure.

Cooley concluded that the Brown-silt Member was conformable above the Exeter Sandstone and suggested an interfingering relationship between the lower Brown-silt units and upper Exeter. This relationship can be seen in the Dry Cimarron River Valley just west of the Guy Monocline and south of Bueyeros (Baldwin and Muehlberger, 1959). Near Las Vegas, New Mexico, the Morrison overlies the Todilto Formation (Mankin, 1958). The Todilto also separates the Entrada and Morrison in west central New Mexico.

The "agate bed" was considered by Ogden (1954) to be a time stratigraphic marker throughout the Rocky Mountain area. The bed is composed of clear, red, and blue nodular chalcedony generally found about 10 feet above the Brown-silt Member. The best exposures are found near Guy, New Mexico (Baldwin and Muehlberger, 1959). Stovall (1938) did not identify the bed as being in Cimarron County, however, McLaughlin (1954) noted its presence in Baca County, Colorado.

Stovall (1938), Cooley (1955), and West (1978) describe the middle Morrison as being composed of shales and limestones which are pale olive gray to green in color. The upper Morrison contains red, brown, and maroon shales with more sandstone and fewer limestones near the top of the unit. Mankin (1958) and Cooley (1955) describe a well developed sandstone in the middle Morrison in the area east and along the trend of the Sierra Grande Uplift.

In the Kenton area, the Morrison is composed of the middle (limestones and gray green shales) and the upper (sandstones and maroon shales) sections. The middle Morrison contains a pelletoidal limestone which is the best stratigraphic marker in the region (West, 1978), because the "agate bed" has not been found.

Volcanic ash beds are better developed in the upper part of the formation throughout the area (Mankin, 1958). Volcanic ash has, however, been noted in the lower middle Morrison in the Dry Cimarron River Valley (Cooley, 1955) and near Bueyeros (Mankin, 1958).

Stovall (1938) reported the Morrison in Cimarron County, as unconformably underlying the Purgatoire Formation. To the west, at Flathead Canyon, in Union County, the contact is disconformable (Cooley, 1955). In Colfax County, the Morrison conformably underlies the Cretaceous units (Wood et al., 1953). In areas where sandstones of the upper Morrison are overlain disconformably or concordantly by the Cheyenne Sandstone, it is difficult to determine the boundary between the formations (Baldwin and Muehlberger, 1959; Cooley, 1955).

Finch (1972) describes an overlapping of the lower Morrison by the middle Morrison near Tucumcari, New Mexico. This is also shown in the Dry Cimarron Valley by the Brown-silt Member thinning to the east. The gypsum beds found in the lower part of the member are missing east of Guy Monocline. North of Boise City, the Brown-silt Member and the greenish gray shales and limestones are not present. The measured sections in this area by Stovall (1938) contain only the upper Morrison of maroon shales and sandstones. Near Las Vegas, the Morrison has as overstepping relationship with the underlying Todilto Limestone. In Baca County, the Lower Cretaceous formations overstep the Morrison (McLaughlin, 1954). These observations serve to illustrate the conclusion that as the late Jurassic sedimentary basin was filled the upper units covered the lower units and extended further to the east.

CHAPTER IV

STRUCTURAL FRAMEWORK

The major structural features which were influential during Morrison deposition in the study area were the Sierra Grande Uplift, Las Animas Arch, and Apishapa Uplift. To the west and south of the area the Mogollon Rim, Pedernal Uplift, Las Vegas Basin, Raton Basin, Tucumcari Basin, and the Umcompahgre Uplift were of importance (Fig. 2). All of the structures were partially or completely covered during the late Paleozoic, but continued to influence sedimentation through the Jurassic. The Mogollon Rim south of Gallup, New Mexico, is thought to be the source area for the "western" Morrison (Flesch, 1975).

The Bravo Dome in Hartley County, Texas, Clapham Anticline and Pasamonte Anticline in Union County, New Mexico, were smaller structures which were prominent during deposition of the Morrison. In the Dry Cimarron Valley the Guy Monocline and an unnamed smaller anticline in T29N, R35E (Winchester, 1934) were of importance.

Schoenfelt (1934) described a small anticline with a northeast trend in Baca County, Colorado (T35S, R49W). In Union County, New Mexico, T31N, R36E Winchester (1934) and Bates (1942) denoted a similar anticlinal structure. Stovall's (1943) stratigraphic section of the Morrison Formation was measured on the southeast limb of a pre-Cretaceous fold located near the Three Corners area north of Kenton, Oklahoma. Scott (1968) located a similar monocline in S½, T34S, R49W

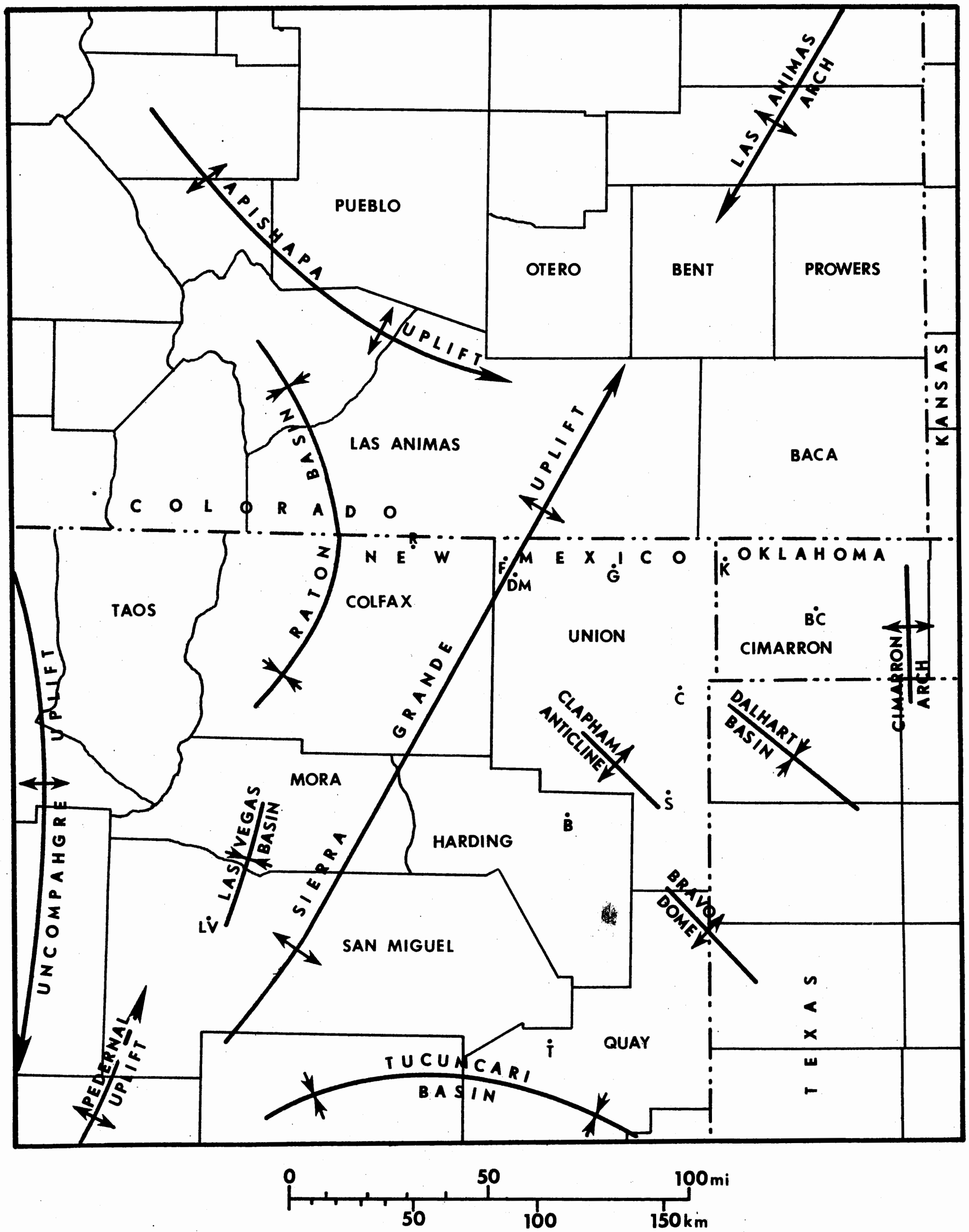

Fig. 2.-Generalized tectonic setting during the Late Jurassic for northeastern New Mexico and southeastern Colorado. Letters indicate towns referred to in the text.

in Baca County. These four locations are considered to be sections of a continuous structure, which for purposes of this report will be named the Three Corners Monocline. This structure is the most likely reason for the changes in direction of the basalt flow in Section 6, T31N, R37E.

Similar continuity can be seen between the Tecolote Monocline (Scott, 1968), located in T33-34S, R51W Baca County, and the unnamed structure in T29N, R35E in Union County. The basalt flow also changes direction as it crosses the trend of this structure. The Baltillo Creek Monocline T34S, R53W may also be an extention of Guy Monocline by similar association. Continuity between the two structures is suggested by the structural maps by Scott (1968) and Baldwin and Muehlberger (1959). The structure map of the Mississippian surface by Anderman (1961) suggests that trends of the Guy and Tecolote Monoclines extend northeastward and converge to the Mustang Creek Monocline.

Amplitudes of the folds are largest on Guy Monocline and decrease progressively to the eastern structure at Three Corners. These monoclinal terraces associated with the eastern slope of the Sierra Grande Uplift have an eastern boundary developed along Precambrian faults and a western boundary developed along late Pennsylvanian faults (Martin, 1965).

The geologic map of the Precambrian and the major faults in northeastern New Mexico are shown in Fig. 3 (Foster et al., 1972). Structures in the study area and in southeastern Colorado, are shown in Fig. 4. The north-south fault in Union County (Fig. 3) is thought to be connected with the Freezeout Creek Fault (Kleindopf et al., 1972) by a fault along the Clapham Anticline. To the north, the Freezeout Creek

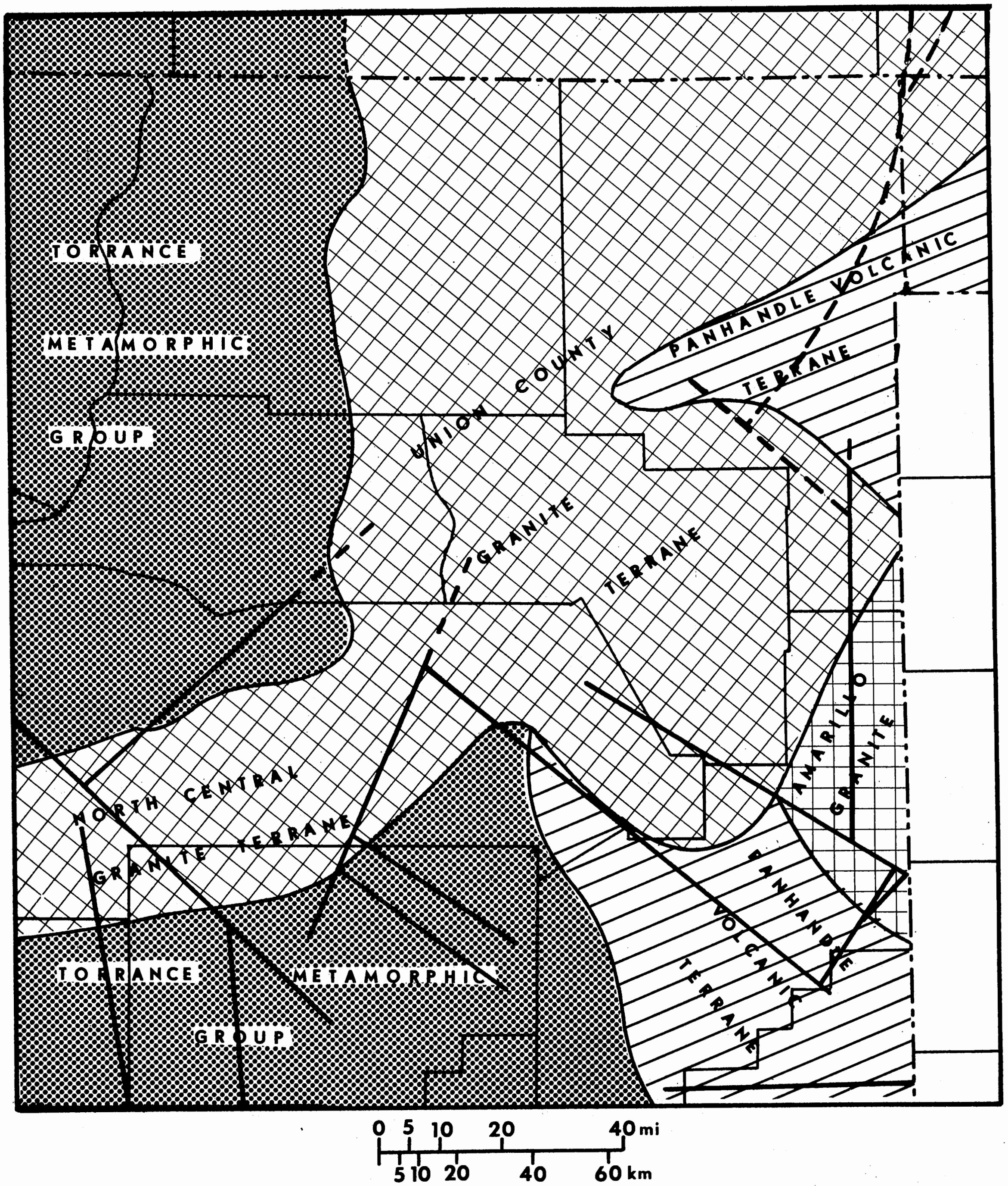

Fig. 3.-Precambrian provinces and faults for northeastern New Mexico, modified after Foster et al. (1972).

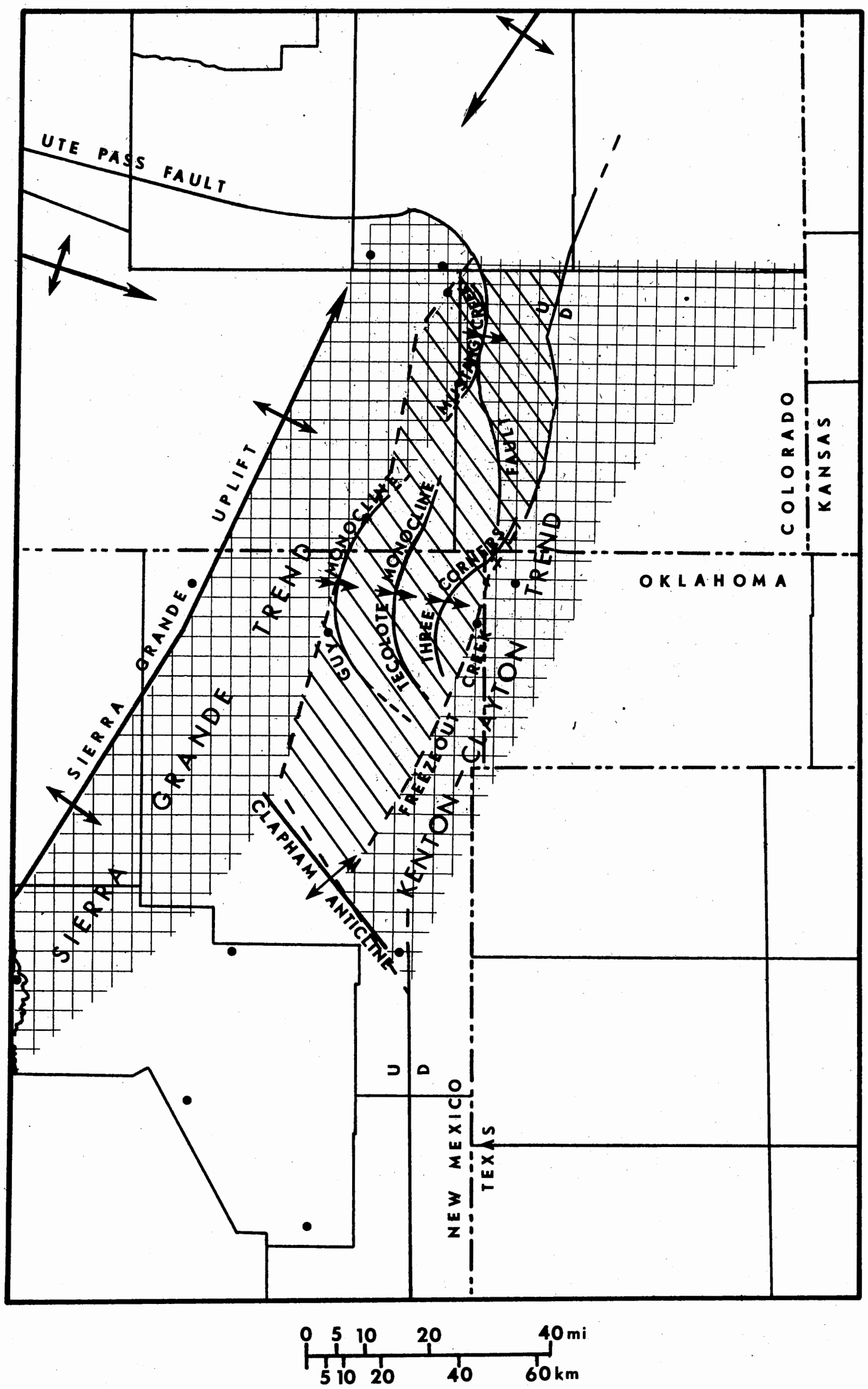

Fig. 4.-Structural map of the study area. Dots indicate known uranium mineralization localities.

Fault extends into the Ute Pass Fault in the saddle between the Sierra Grande Uplift and the Las Animas Arch. Thus the eastern and northern boundaries of the biotite granite of the Sierra Grande Uplift probably have a fault contact with the rhyolite and granite basement units to the east and north. Foster et al. (1972) interprets the basement complex as being tilted fault blocks and gives several lines of evidence to support this interpretation. The similarity between the fault patterns in San Miguel, Quay, and Quadalupe Counties, New Mexico, and the generalized basement provinces (Fig. 3) suggests that the faults may be associated with the basement province boundaries.

The location of the Freezeout Creek Fault could not be determined with any degree of certainty near Clayton, New Mexico, because of limited data. The fault may be associated with the boundary between the basement rocks (Fig. 3) which trends northeast-southwest, or the fault may extend through the panhandle volcanic terrane along a north-south trend near the Oklahoma-New Mexico state line.

Martin (1965) shows upper Pennsylvanian faulting in the western part of the monoclinal terrace (Fig. 4). Post-Exeter faulting with the same trend can be seen on the Tecolote Monocline in Union County. The faulting along the western boundary of the monoclinal terrace is not associated with movement in the basement rocks and is therefore of less magnitude than the faulting along the eastern boundary.

CHAPTER V

SEDIMENTOLOGY OF THE MORRISON

The Morrison in the study area is composed of variegated shales, limestones, and sandstones. The formation was deposited blanket like on an alluvial plain by meandering and braided streams separated by freshwater lakes. The micritic lacustrine beds are better developed along the eastern region of the depositional basin and in areas of maximum sedimentation (Mankin, 1958). The sandstones of the middle Morrison are generally lenticular in shape and grade vertically into shales. They have sharp erosional lower and lateral contacts, and are very discontinuous. Outcrop exposures are generally measured in tens or hundreds of feet. Two strong sandstone developments occurred within the Morrison, one in the middle Morrison and one in the upper Morrison. The latter is better developed than the first and contains slightly coarser sediment (Mankin, 1958). These sandstones are best exposed near Kenton, Oklahoma, Stead, New Mexico, and west of the Guy Monocline in Union County, New Mexico.

The thinner, less well developed sandstones contain medium and small scale crossbedding and horizontal bedding. Tabular crossbedding is better developed than trough crossbedding. These thinner sandstones were deposited by meandering stream systems.

The thicker sandstones contain massive and horizontal bedding along with medium scale trough and tangential crossbedding. Granular and pebble conglomeratic beds containing clay galls are also present. Grading within individual cross laminae can often be found. A slight decrease in size of the crossbeds upward within genetic units can be seen at some locations. These thicker sandstone units were deposited by braided stream systems.

The well developed upper Morrison sandstone near Kenton, Oklahoma, was deposited in a structural trough just east of the Three Corners Monocline. Field observations suggests pre-, syn-, and post-Morrison development of the Monocline and related trough. The paleocurrent data from the upper Morrison sandstones show a N47°E trend (Fig. 5), which is very similar to the trend of the Three Corners Monocline. Well log data suggests that the thicker Morrison development is confined to a trough extending from near Stead, New Mexico, to the Colorado-Oklahoma border north of Kenton (Fig. 6). The trough is thought to be controlled by tilted block-faulted basement. McLaughlin (1954) reports not finding any evidence to suggest a thicker Morrison section in Baca County. The thinning of the Morrison section to the north and the divergence of the Precambrian faults to the north suggests that the depositing streams were less confined in that direction.

The isopach map of the Morrison Formation in northeastern New Mexico (Fig. 6), shows several generalized trends in deposition. There is a remarkable similarity between Fig. 6 and the map of the basement provinces and faults (Fig. 3). The thicker Morrison section in T15-17N, R30-32E is bounded on two sides by faults near a change in basement terrains. The thicker section in T19-22N, R24-26E is flanked on both sides by the basement faults trending along the axis of the Sierra Grande Uplift. Mankin (1972) states that the Morrison shows a general

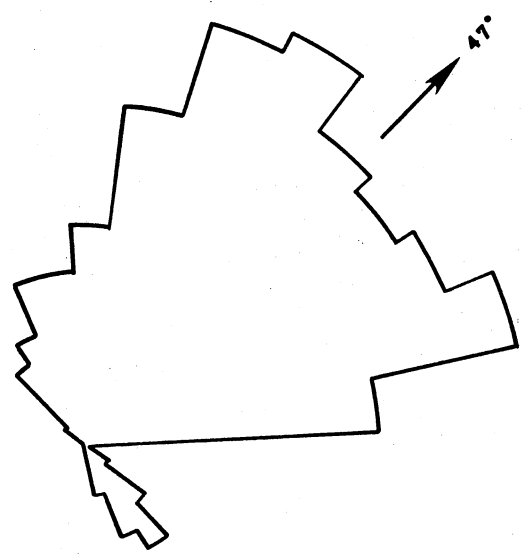

Fig. 5.-Rose diagram of current directions in sandstones of the upper Morrison from the Kenton area.

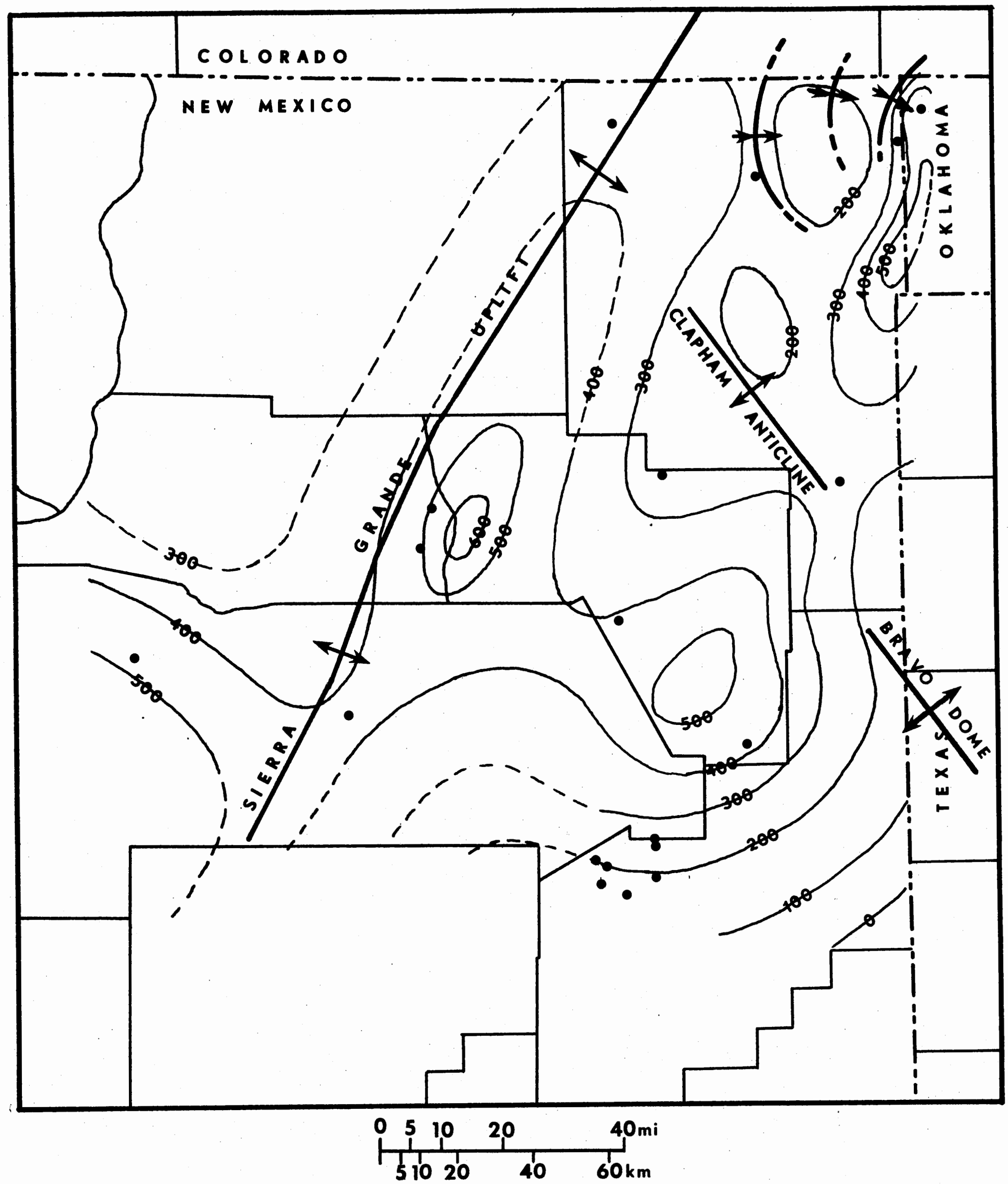

Fig. 6.-Isopach map of the Morrison Formation of northeastern New Mexico, modified after Mankin (1958). Dots indicate known uranium mineralization localities.

thinning across the axis of the uplift. Roberts et al. (1976) show a similar thinning of the formation across the axis of the structure near Des Moines in Union County. The thicker section in the Las Vegas Basin is also located along major faults and changes in basement terrain. The Raton Basin may also have developed similar thick Morrison sections to the west of the Sierra Grande Uplift in western Colfax County (Roberts et al., 1976 and Baltz, 1965). The Tucumcari Basin, Clapham Anticline, and the monoclinal terrace received very limited sediment during deposition of the Morrison.

Mankin (1958) describes the source area for the Morrison in northeastern New Mexico, as being to the west and northwest because of an increase in grain size, feldspar and apatite content in that direction. Several authors have described the paleocurrent directions within the Westwater Canyon Sandstone, the Brushy Basin Shale, and Jackpile Sandstone Members of the "western" Morrison as being in an east or northeasterly direction. These authors include Flesch (1975), Brookins (1975), Schlee and Moench (1961), and Rackley (1976). During late Morrison deposition, sedimentation was controlled by a structural trough possibly between the Uncompahgre Uplift in Colorado and northern New Mexico and the Pedernal Uplift to the south (Fig. 2). A similar drainage pattern during Early Cretaceous is shown by McGookey et al. (1972).

CHAPTER VI

PETROGRAPHY

Petrographic analysis was conducted on 25 thin sections from the middle and upper Morrison. These samples were collected near Kenton, Oklahoma, and represent a vertical sequence of the Morrison from the area (Table III). Stratigraphic positioning of the samples was possible because of work by West (1978).

The grain size ranges from silt ($<4.0\phi$) to pebble ($>-4.0\phi$). The mean grain size for the sandstones is approximately 3.5ϕ to 3.0ϕ or upper very fine. An overall coarsening upward sequence is present, with the pebbles only being found in the upper samples.

The sorting ranges from very poorly sorted to well sorted. The lower section, which is composed of samples NM-2 to NM-17 of Table III, is moderately sorted. The best sorting is found in the middle of the section (samples MR-1 to MR-11) which is the beginning of the upper Morrison and is predominantly sandstone. The sorting of the upper most samples (PA-22 to AB-4) is poor to very poor because of an introduction of a coarser mode.

The roundness ranges from angular to well rounded with a mean of subround. The roundness increases upward through the section. In the upper Morrison several samples contained angular and well rounded detrital grains. Mankin (1958) contributes this to two source areas.

The foregoing descriptions reflect changes in the depositional

TABLE III

PETROGRAPHIC ANALYSIS OF THE MIDDLE AND UPPER MORRISON FORMATION

	Terrigenous							
Sample Number	Quartz	Chert	Feldspar	Sedimentary Rock Fragments	Igneous Rock Fragments	Zircon	Tourmaline	Apatite
AB-4	64	20	6	<2	<2	<1	<1	--
AB-45	49	5	5	--†	--	<1	<1	--
AB-43	35	tr*	tr	56	<4	tr	tr	--
AB-44	24	15	1	--	--	1	1	--
PA-15	13	86	1	--	--	--	--	--
PA-3	86	10	2	--	--	1	1	--
PA-23	3	--	tr	--	--	--	--	--
PA-22	34	tr	tr	40	--	--	tr	--
MR-11	78	14	tr	--	--	tr	tr	--
MR-10	87	3	2	--	--	tr	--	--
MJ-7	76	<1	3	--	--	tr	tr	tr
MR-8	77	3	tr	--	--	tr	tr	--
MR-6	89	1	tr	--	--	tr	tr	--
MR-4	62	5	3	--	--	tr	tr	--
MR-2	63	5	2	--	--	tr	tr	--
MR-1	87	2	1	--	--	--	tr	--
NM-17	32	2	2	--	--	tr	--	tr
NM-15	20	3	3	--	--	tr	--	--
NM-13	17	5	3	15	--	tr	tr	tr
NM-12	25	tr	1	--	--	--	tr	tr
NM-10	25	4	3	--	--	--	tr	--
NM-8	37	tr	2	--	--	tr	tr	tr
NM-5	20	5	5	--	--	tr	tr	tr
NM-3	<1	--	--	--	--	--	--	--
NM-2	33	6	11	--	--	tr	tr	--

TABLE III (Continued)

	Terrigenous			Cement				
Sample Number	Biotite (mica)	Hematite	Pyrite	Carbonate	Quartz	Opal	Chalcedony	Clay
AB-4	--	tr	--	--	--	5	--	--
AB-45	tr	tr	--	--	--	--	40	tr
AB-43	tr	tr	--	--	--	4	--	tr
AB-44	--	tr	--	--	--	60	--	--
PA-15	--	tr	--	--	--	--	--	--
PA-3	--	tr	--	--	--	30	--	tr
PA-23	--	tr	tr	97	--	--	--	--
PA-22	--	tr	--	25	--	--	tr	--
MR-11	--	tr	--	--	7	--	--	tr
MR-10	--	tr	--	4	--	4	--	tr
MJ-7	--	tr	--	13	12	--	--	tr
MR-8	--	tr	--	14	16	--	--	--
MR-6	--	tr	--	--	9	--	--	tr
MR-4	--	tr	--	23	--	--	7	--
MR-2	tr	tr	--	30	--	--	--	tr
MR-1	--	tr	--	tr	3	--	6	tr
NM-17	tr	tr	1	20	--	43	--	--
NM-15	--	tr	4	--	--	55	--	--
NM-13	--	tr	--	--	--	60	--	--
NM-12	--	tr	tr	64	--	--	--	--
NM-10	1	tr	tr	65	--	--	--	--
NM-8	1	tr	--	55	--	--	--	--
NM-5	--	tr	--	30	--	--	--	--
NM-3	--	tr	tr	99	--	--	--	--
NM-2	tr	tr	--	50	--	tr	--	--

*Trace recorded.

†Not detectable.

environments and the energy of the transporting media. The lower samples were deposited in freshwater lakes and by low-energy meandering streams. The middle samples were from an environment with better sorting which suggests that the energy was sufficient to carry away the fines but was not strong enough to transport the coarser material found higher in the section. Sedimentation was predominately by braided streams. The upper samples show an increase in grain size and rounding and are very poorly sorted. These were deposited by braided streams which had higher energy than the streams of the middle unit.

Mineralogy

Quartz is the most abundant mineral found in the Morrison Formation. The middle braided stream interval has the highest percentage of quartz. This is due to a smaller proportion of chert and chalcedony as is found in the upper 1/3 of the formation. The quartz occurs as plain and undulose extinction. Overgrowths of quartz are found in most slides, but are better developed upward in the sequence.

Feldspar occurs as orthoclase, microcline, and a small plagioclase fraction. The amount ranges from <1% to 22% of the detrital assemblage. The percentage decreases upward thought the section except for the very coarse mode at the top of the sampled interval which contains granitic rock fragments. These results follow Mankin's analysis which suggested a decrease in feldspar content upward in the formation and to the east in Oklahoma. Overgrowths of authigenic feldspar were not found in any of the samples, although they have been reported in the Morrison. Sedimentary and igneous rock fragments were in several samples. The granitic rock fragments were only found in the coarser samples at the top of the stratigraphic section. The sedimentary rock fragments were present at several horizons. These are rounded fragments of micrite, opal, and chalcedony. The upper coarse mode contains pebbles which were once algal micrites from the lacustrine deposits of the middle Morrison and which have been altered to opal and chalcedony (Fig. 7).

Detrital chert has the most pronounced distribution of any mineral in the study area. The lower 2/3 of the formation has approximately 3% chert per slide. Chert represents about 10% of each sample in the upper 1/3 of the formation.

Anhedral crystals of ziron, tourmaline, and hematite are present in most of the samples. No significant changes in distribution for these minerals were found. Altered cubes of pyrite, distorted flakes of biotite, and anhedral and euhedral apatite were found preferentially distributed in the lower half of the formation.

The limestones examined represent freshwater lake deposits. Green-algae (Dasycladacean?), Charophytes, thin walled ostracodes, cryptalgal structures, and fecal pellets were found. Scholle (1978) describes Charophytes and thin walled ostrasodes as freshwater fauna. These are also present in the opal-chalcedony pebbles of the coarser upper samples. The pelletoidal limestone (Fig. 8) was used by West (1978) to correlate the Morrison beds in the Kenton area. The persistent redevelopment of lacustrine environments near the New Mexico-Oklahoma border suggests continuous subsidence along the Freezeout Creek Fault trend during Morrison deposition.

Cement

The most common cementing agents found in the thin section were

Fig. 7.-Algal limestone altered to opal and chalcedony, (0.7 X 0.5 mm; plane-polarized light).

Fig. 8.-Pelletoidal limestone from the middle Morrison near Kenton, Oklahoma; pellets (P), calcite (Ca), (0.7 X 0.5 mm; crossed nicols).

calcite, quartz, opal and chalcedony. Kaolinite, hematite, and siderite were present in several slides but were of lesser importance as cement. In most samples more than one cement was present. Calcite occurs both as sparite and micrite. Sparite is more often the carbonate cement present in sandstones and micrite is present predominately in the lacustrine limestones. The silica minerals are the predominate cementing agent in the study area. Quartz occurs as quartz overgrowths. Chalcedony is found as fiberous radiating crystals. Opal is generally an amorphous groundmass. Floating contacts between detrital grains are often present when calcite, opal, or chalcedony are the cements (Fig. 9 and 10).

The vertical distribution of the cements fluctuated with changes in depositional environments. Carbonate cements dominate the middle Morrison. This changes to a silica rich cement as the lower sandstones and limestones are replaced by the better developed meandering streams near the top of the middle Morrison. The better sorted braided stream deposits of the upper section are cemented by silicas, carbonates, and authigenic clays. The poorly sorted sediments near the top of the stratigraphic section are cemented almost exclusively by silicas.

Several diagenetic relationships can be seen in the cementing material. In the sandstones overgrowths of quartz were the first cement present. It is found along grain boundaries or encircling the entire grain. Calcite was next and is found corroding the overgrowths and detrital grains. The lesser cements of hematite, siderite, and clays are found with interrelationships with calcite and is thought to have been developed about the same time. Opal and chalcedony are a third generation cement developed after calcite. These relationships are

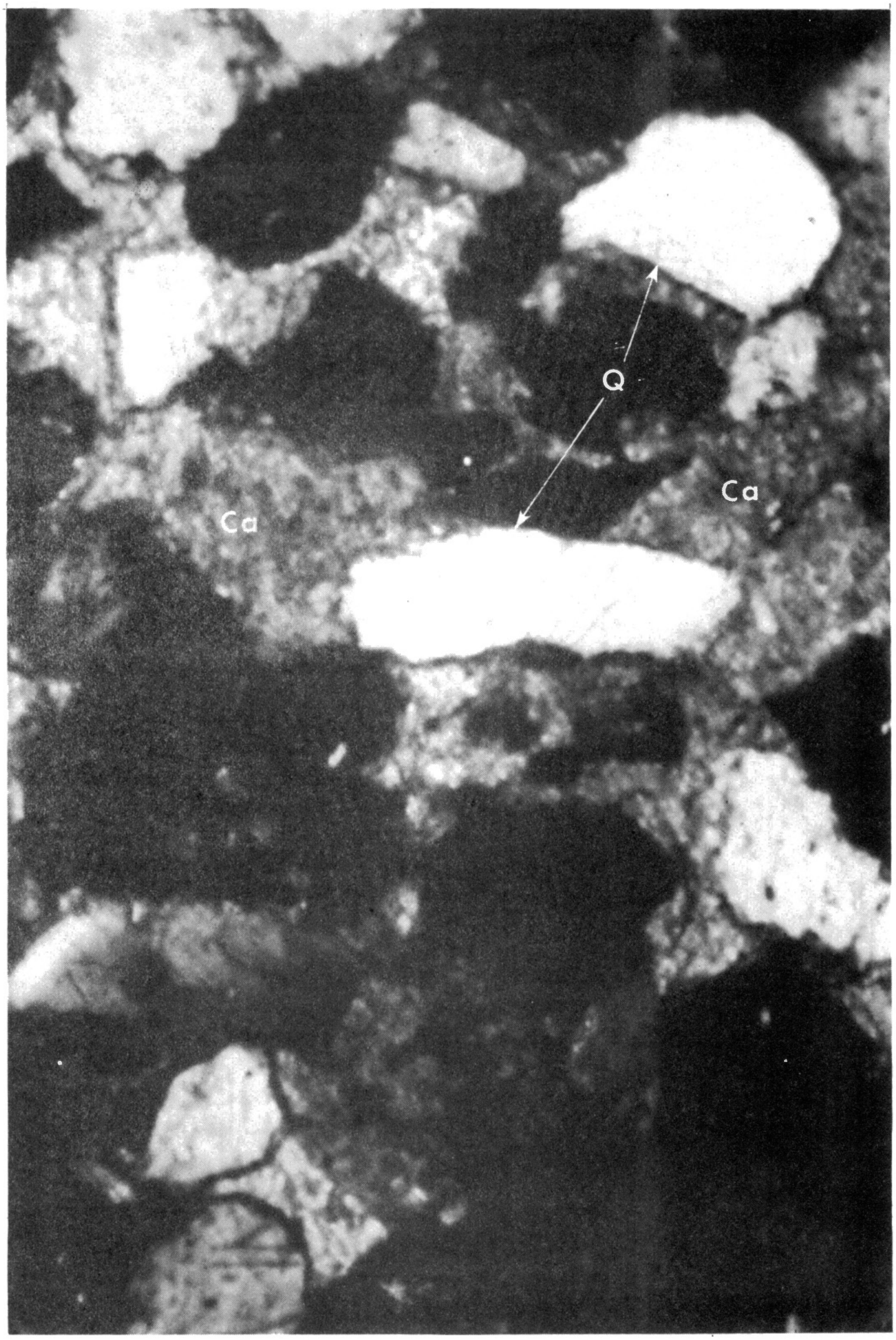

Fig. 9.-Floating contacts between detrital grains in calcite cement; calcite (Ca), quartz (Q), (0.7 X 0.5 mm; crossed nicols).

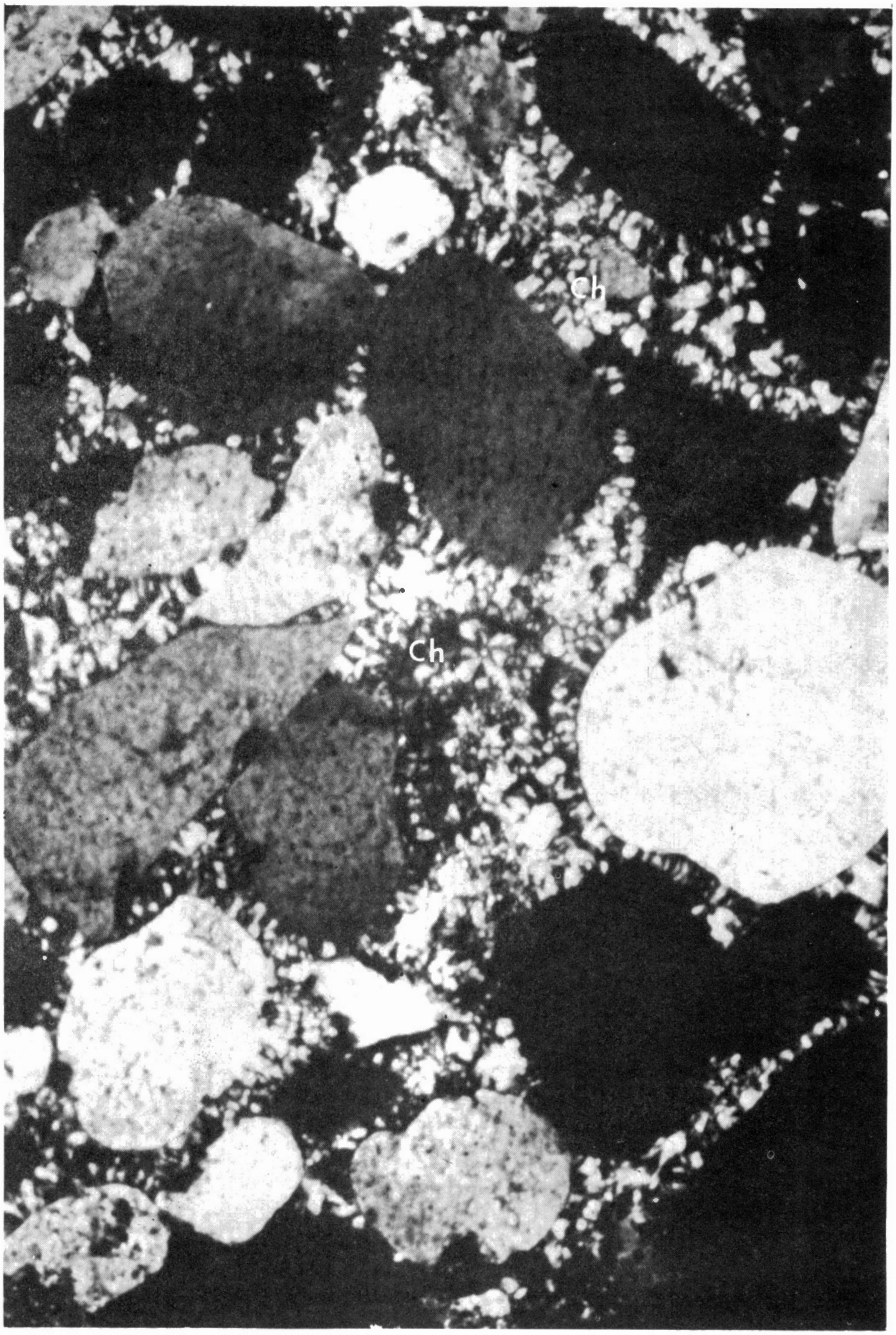

Fig. 10.-Floating contacts between detrital grains in chalcedony cement; chalcedony (Ch), (0.7 X 0.5 mm; crossed nicols).

illustrated by Fig. 11 which shows micrite replaced by chalcedony and Fig. 12 of a corroded quartz grain encompassed by opal cement. Fig. 13 clearly illustrates the three generations of cement. A second sequence of calcite cement is found filling fractures which occur within the cemented rock (Fig. 14).

The increase in silica minerals, both in the cement and the detrital fraction, upward in the section suggest a more alkaline environment. Kruskopf (1967, p. 115) states that, "Any solution in contact with silicate minerals cannot long remain appreciably acid, and if contact is continued, the solution must eventually become alkaline." The following reaction illustrates this very well:

$$4KAlSi_3O_8 + 22H_2O \rightarrow 4K^+ + 4OH^- + Al_4Si_4O_{10}(OH)_8 + 8H_4SiO_4.$$

Mankin (1958) reports an increase in volcanic activity during late Morrison deposition. The alteration of volcanic ash is thought to be the major contributor of the silica.

The $[K^+]$ would be increased by this means if the volcanic ash were of an acidic origin. Changes in alkalinity and $[K^+]$ are the major reasons for fluctuations in illite and mixed-layer illite-montmorillonite development. Therefore, the clay mineral composition is associated with the volcanic ash composition and its subsequent alteration. The following chapter discusses the clay mineralogy of the Morrison.

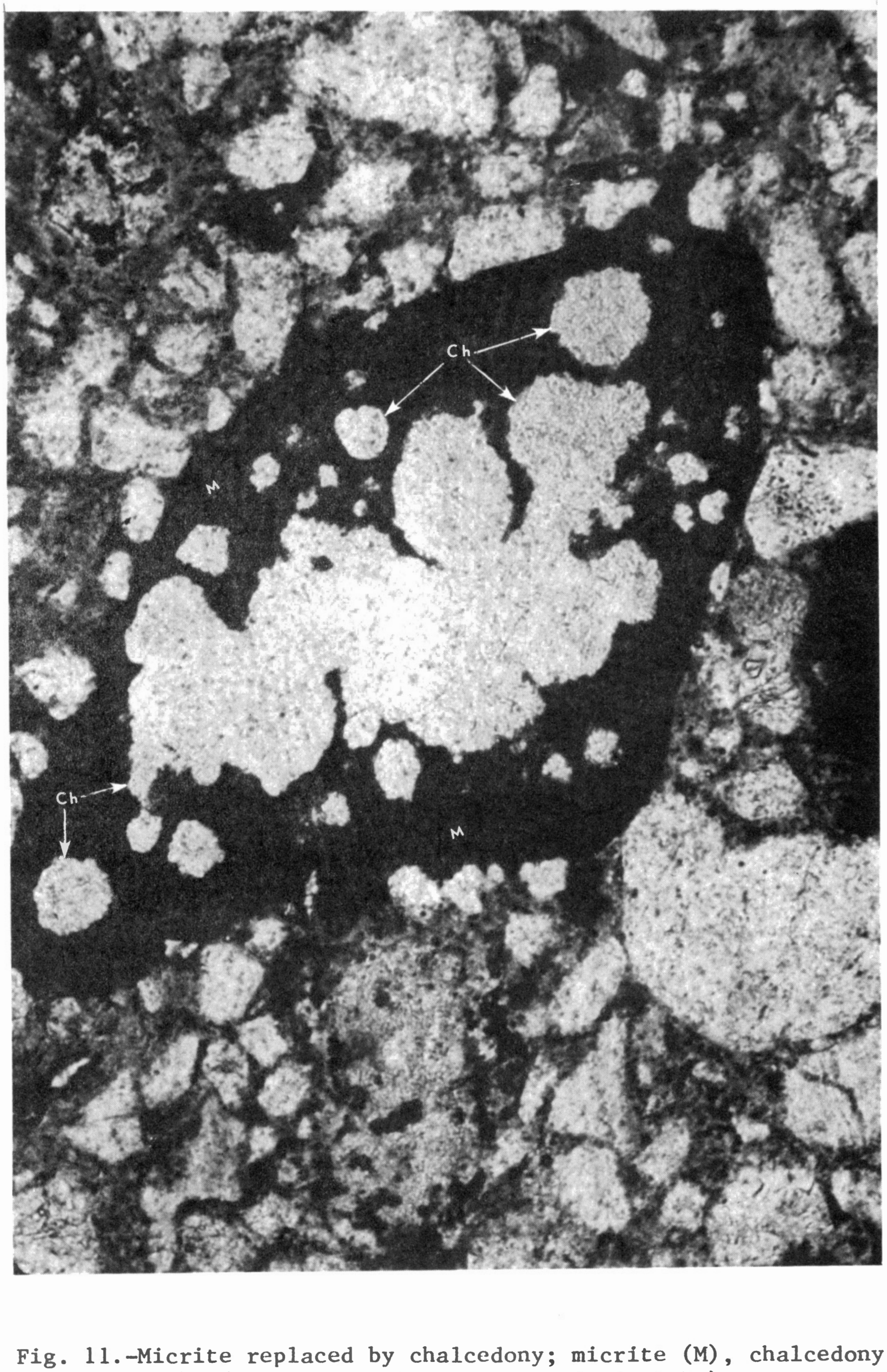

Fig. 11.-Micrite replaced by chalcedony; micrite (M), chalcedony (Ch), (2.5 X 1.7 mm; plane-polarized light).

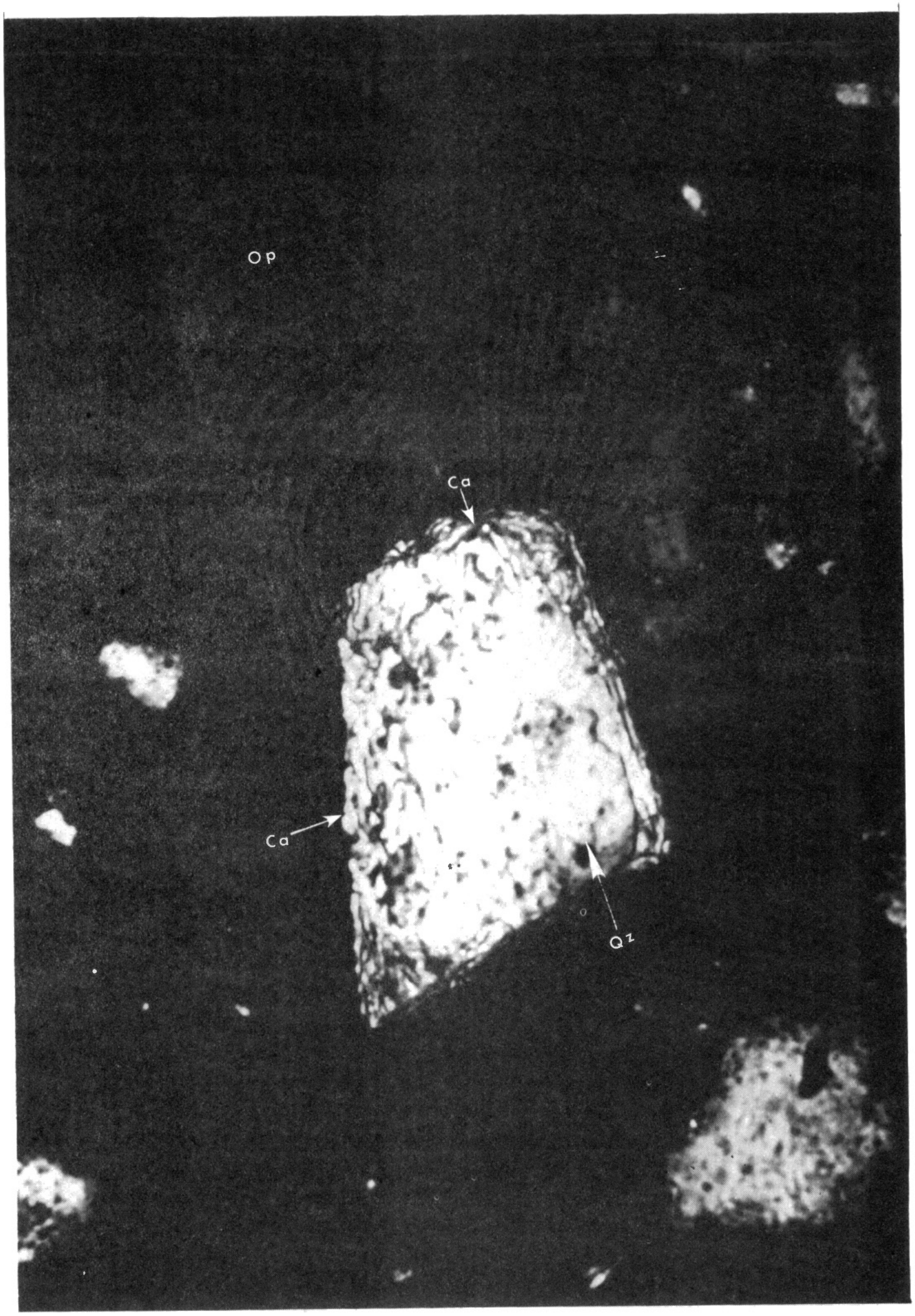

Fig. 12.-Quartz grain corroded by calcite in an opal cement; opal (Op), calcite (Ca), quartz (Qz), (0.7 X 0.5 mm; crossed micols).

Fig. 13.-Three generations of cement; detrital quartz (Qd), quartz overgrowths (Qo), calcite (Ca), chalcedony (Ch), (0.19 X 0.13 mm; crossed nicols).

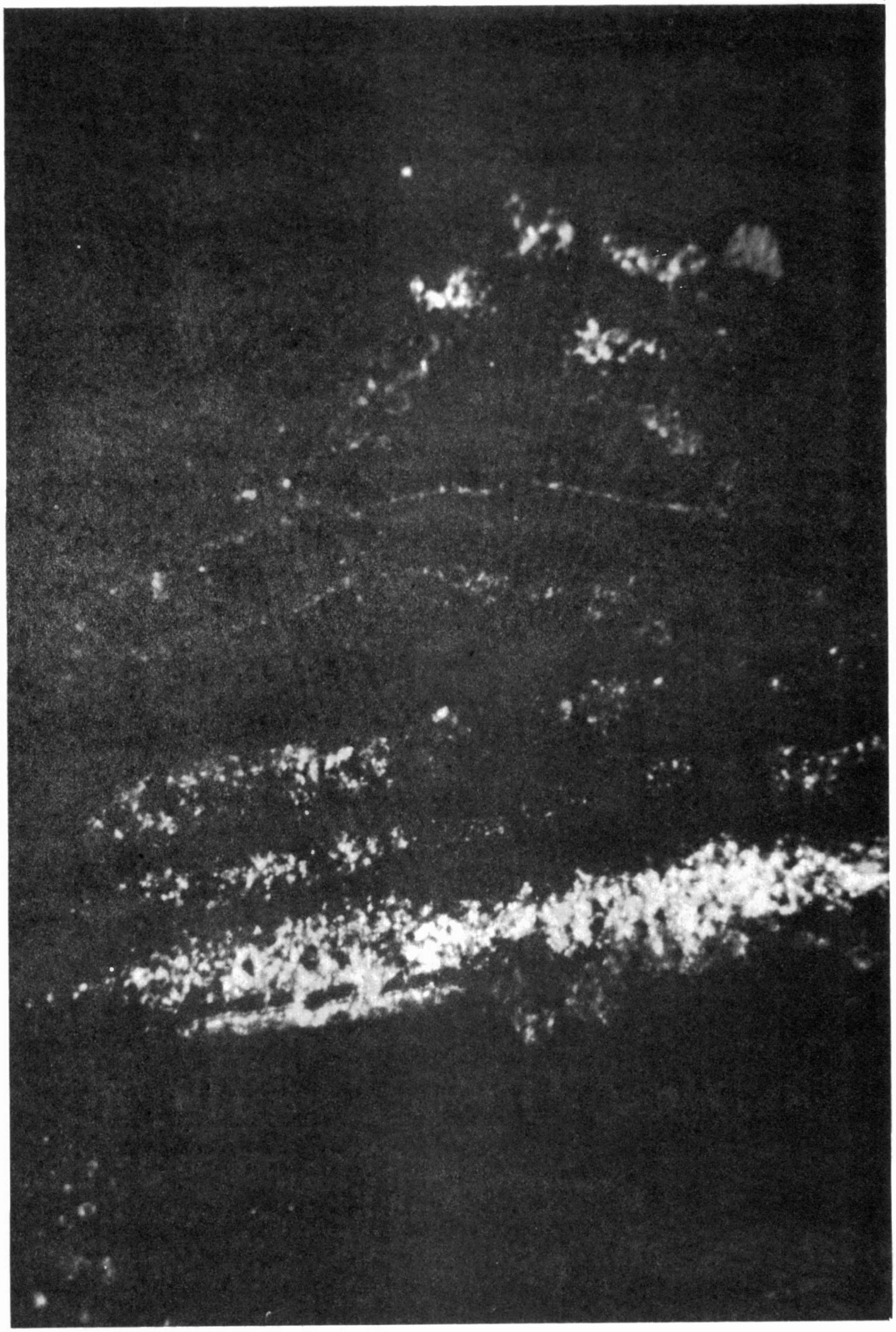

Fig. 14.-Calcite filled fractures; (2.5 X 1.7 mm; cathodo-
luminescence).

CHAPTER VII

CLAY MINERALOGY

The clay mineralogy of the undifferentiated Morrison has been determined by Keller (1953) and Mankin (1958). The former described the clay minerals found in the new type section for the Morrison (Waldschmidt and LeRoy, 1944). The latter determined the clay mineral content of northeastern New Mexico.

Mankin's analysis of the Morrison divides the formation into two units according to the clay mineral content (Fig. 15). The lower unit is composed of montmorillonite, illite, and lesser amounts of kaolinite. The clay minerals of the upper unit, from his report, were kaolinite and a mixed-layer clay of montmorillonite-illite.

In this study 25 clay samples were collected from selected locations and stratigraphic positions. The analysis was conducted using a Philips-Norelco diffractometer. Untreated slides were first x-rayed and then treated with ethylene glycol for 24 hours to determine expansion properties. The samples were then heated for one hour at 500° C and reanalyzed. Methods described by Grim (1968) and Carroll (1970) were used in the clay mineral identification. The results are shown in Table IV. Sample set "F" was collected at Section 31, T31N, R33E (Mankin's, Dry Cimarron section and Cooley's, Pipeline Canyon section). This sample set was taken to determine the change in defraction patterns described by the previous investigation and to observe the

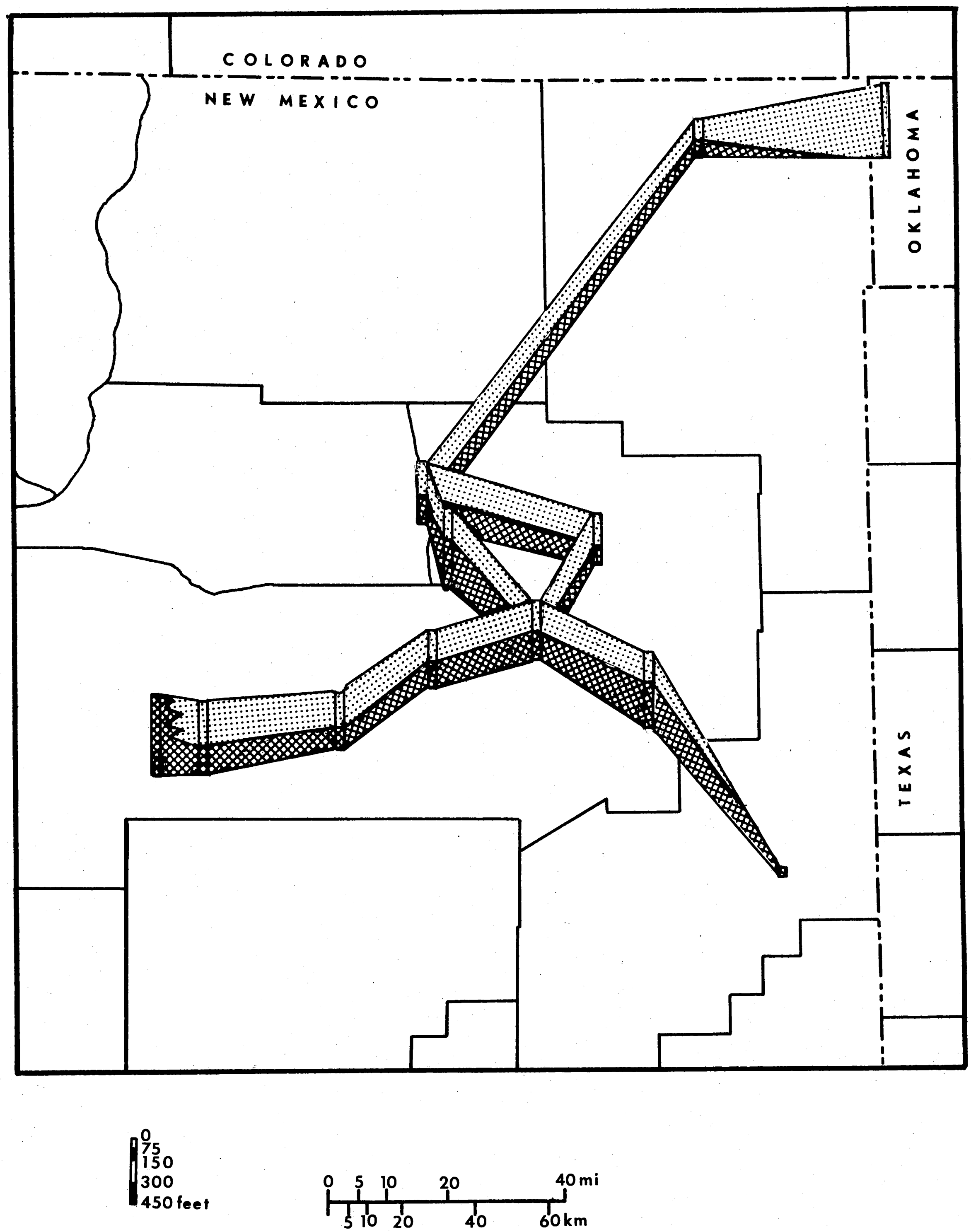

Fig. 15.-Fence diagram showing the distribution of clay mineral suites in northeastern New Mexico, modified after Mankin (1958).

TABLE IV

CLAY MINERAL COMPOSITION OF THE MORRISON FORMATION
OF THE DRY CIMARRON RIVER VALLEY*

Sample Number	Kaolinite	Illite	Illite-Montmorillonite (mixed-layer)	Montmorillonite
A-1	66	25	9	--
A-2	50	32	18	--
A-3	37	33	30	--
A-4	35	32	33	--
A-5	21	36	43	--
A-6	21	35	44	--
A-7	15	60	25	--
A-8	10	26	64	--
A-9	42	13	45	--
A-10	65	23	12	--
B-1	14	33	53	--
B-2	57	9	34	--
B-3	45	9	46	--
C-1	78	3	18	--
C-2	62	13	25	--
C-3	22	26	52	--
C-4	--	47	53	--
D-1	--	75	25	--
E-1	--	46	54	--
E-2	--	60	40	--
F-1	5	81	--	14
F-2	7	66	--	27
F-3	3	8	--	89
F-4	3	47	--	22
F-5	40	42	--	18

*Values present in the sample are in percent stratigraphic position of the change.

The remaining samples were collected from the middle and upper Morrison near Kenton, Oklahoma. Sets "A" and "B" are a vertical sequence of Stovall's Labrier Butte and upper Morrison section. Sets "C", "D", and "E" were taken at outcrops which had higher than normal scintillometer readings.

The illite in both units is thought to be of the 1Md type. The x-ray diffraction pattern is a poorly crystalline peak at a 10A°. The montmorillonite in the lower unit expands to 17A° from 12A° when glycolated. The amount of kaolinite increases upward in the formation. The kaolinite is generally well crystalline, however poorly crystalline kaolinite was found in several samples. The mixed-layer clays have variable expansion characteristics according to the amounts of illite and montmorillonite present. The heated slides revealed no chlorite present.

The clay minerals which were present in the Kenton area were kaolinite, illite, and a mixed-layer illite-montmorillonite. The illite present exceeded the amount of mixed-layer clay in much of the lower middle Morrison of the area (Table IV). The illite content approximately equaled the mixed-layer clay in the upper units until kaolinite is the dominate clay mineral near the top of the section. In the lower part of the section, where illite is better developed, kaolinite also has better crystallinity and a higher concentration.

The change in clay mineral suites at the Dry Cimarron section occurs approximately 65 feet above the basal Morrison section. No evidence was found to suggest the occurrence of the lower clay mineral zone in Cimarron County. Therefore, it is doubtful that the basal

Morrison extends as far east as the Oklahoma-New Mexico border.

The regional analysis (Fig. 15) by Mankin (1958) suggests that the thicker Morrison sections in Harding and San Miguel Counties, New Mexico, are the result of a thicker lower clay mineral zone. The upper unit was deposited with a relatively uniform thickness in the area. The thick Morrison section in Cimarron County, composed entirely of the upper clay mineral suite, is unique when compared to the uniform thicknesses observed to the southwest. This data supports the conclusion that the lower Morrison was overlapped by the upper Morrison and that much of the sediment transport shifted to the east of the monoclinal terrace during late Morrison deposition.

The foregoing conclusions should be considered only as general stratigraphic relationships. Since illite and montmorillonite are very susceptible to their geochemical environments (e.g. $[K^+]$ as well as acid concentrations), each location has had different influences to produce the clay mineral suites present. Carroll and Starkey (1971) and Huang and Keller (1971) have demonstrated that selective clay minerals are more soluable in different types of acids. Generally, in an acidic environment, montmorillonite is more readily dissolved than illite, and kaolinite is more stable than either of the other two clays.

CHAPTER VIII

GEOCHEMISTRY

The samples for elemental analysis were prepared by crushing the samples in a ceramic jaw crusher and then pulverizing in a Spec Ball Mill using tungsten carbide balls and chamber. The samples were then seived to less than 80 mesh.

Elemental concentrations were determined for vanadium, cobalt, nickel, lead, copper, chromium, molydenum, iron, magnesium, strontium, zinc, titanium, silver, manganese, cadmium, and calcium. The samples were prepared by digesting 1 gm of sample in 20 ml of aqua regia (75% hydrocloric acid and 25% nitric acid). The solution was allowed to digest the rock for 24 hours; 6 hours of which the sample was heated to 100°F. The resulting solution was filtered and then 1% lanthanum chloride was added. Each sample was then diluted to 50 ml with distilled water. Elemental analysis was conducted on 140 samples. Uranium concentrations were determined in 70 selected samples by Skyline Labs, Inc., Denver, Colorado. The results are presented in Appendix A.

Statistical Methods

A basic assumption used in analyzing the data was that different geochemical conditions were active in the different types of rocks (sandstones, shales, chert, and limestones). These varying conditions include Eh, pH, cation exchange capacity, and permeability. Therefore, the raw data was divided into discrete populations according to lithology. A second assumption used in analyzing the data was that the populations were normally distributed.

Trace elements occur in nature with normal, gamma, or lognormal distributions (Krumbein and Graybill, 1965). The Kolmogorov-Smirnov test (Conover, 1971) was used to determine the type of distribution each element had within each population. The test compared the distribution of an element with a normal distribution. A maximum difference between the two distributions was computed. This D_{max} value was compared to a critical value determined by the number of observations in the population and an acceptable level of statistical significance ($\alpha = 0.05$). The elements were found to be lognormally distributed in each lithology. Log base 10 was used for the transformation. The amount of each sample which did not go into solution (Resid) was found to be normally distributed.

A plot of uranium verses each of the elements by lithology revealed two discrete populations for uranium within the shale and limestone groups (e.g. Fig. 16). One population appeared to have normal background uranium concentrations and the other anomalously high uranium concentrations. A value of 100 ppm was chosen to delineate the boundary between the two groups. Further statistical analysis of the high uranium subgroup within the limestone group was not possible because only one observation was present.

Correlation matrices were calculated for each lithology and subgroup (Appendix B). A summary of the statistically significant correlations ($\alpha = 0.05$) from Appendix B is presented in Table V.

Factor analysis (Morrison, 1967) was, also, conducted for each

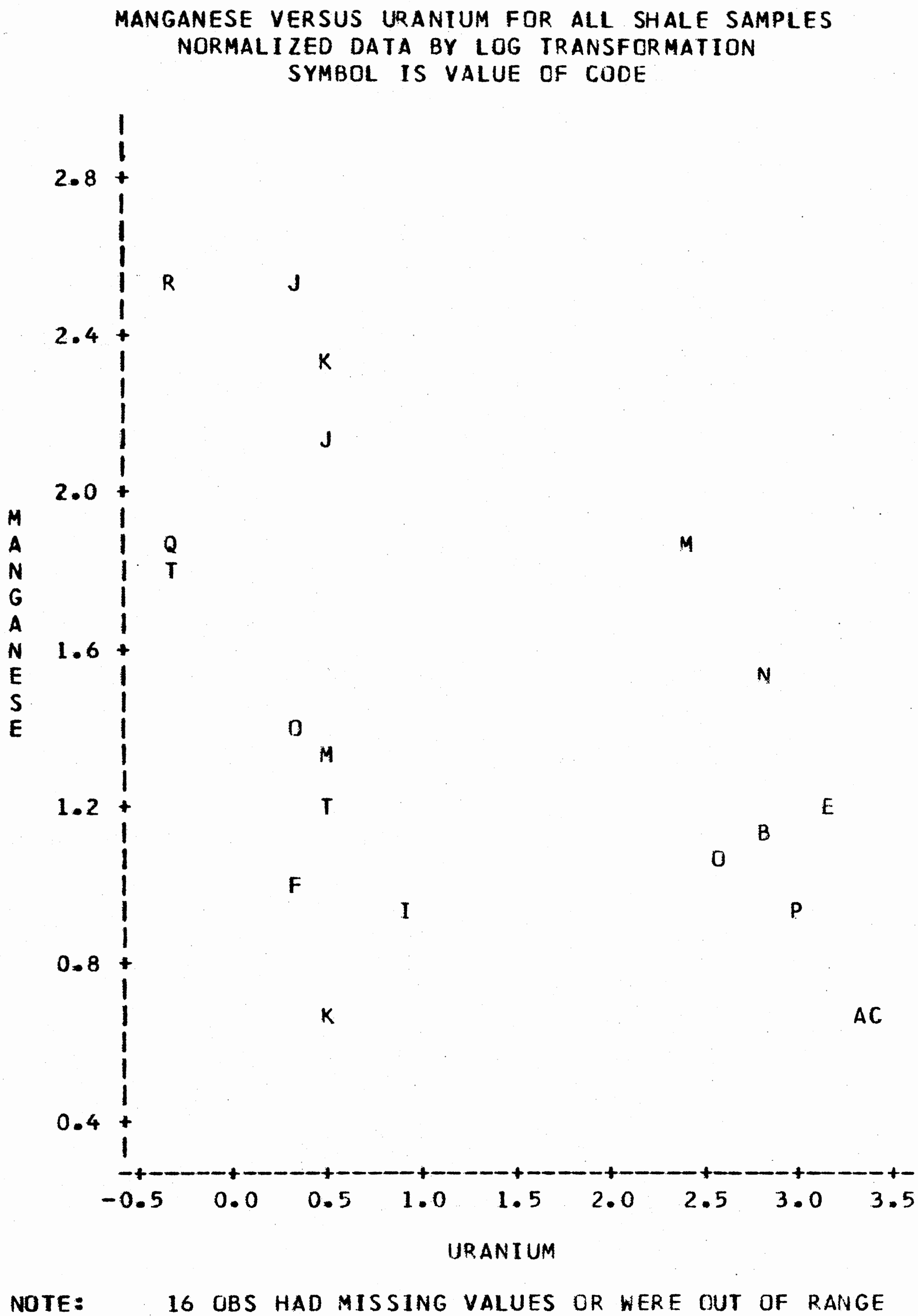

Fig. 16.-Plot of uranium versus manganese for shale using normalized data.

TABLE V

SUMMARY OF STATISTICALLY SIGNIFICANT CORRELATIONS

U	Fe	Cu	Zn	Pb	Cd	Mn	Sr	Cr	Ni	Co	Mo	Ag	V	Ti	Ca	Mg	
-<SS> {SH}	-<SS> {LS}	-<SH>	- SS {LS}	-<SS> -{LS}	-{SS} -[LS] -{CH}	-{SS} -(SH) -[LS] -{CH}	-{SS} -(SH) -{LS} -[CH]	-{SS} <SH> {CH}	-<SS>	-<SS>		-(SS) -{SH} -[LS] -[CH]	-<SS> -<SH>		-{SS} -{SH} -[CH]	-{SS}	Resid
	{CH}			{SH}	-(SH)	-(SH) -{SH}	-{SH} {SH}	(SS) -{CH}	<SS>		<SS> {CH}	-{SH}	{CH}	[SH]	-(SH)	{SH}	U
		<SS>	{SS} (SH) [LS] [CH]	<SS> {CH}	<SS>	(SS)	(SS)		<SS> [SH]	<SS>	{CH} {SH}	<SS>	{SS} <SH> {CH}	<SH>	<SS> <SH>	(SS) <SH> {CH}	Fe
			<SS> <SH>	<SS> <SH>	{CH}	<SS>	<SS>	<SS>				[CH]	<SS>		<SS> {SH}	<SS> <SH> {CH}	Cu
				<SS> <SH> {CH} {SH}	<SS>	(SS)	(SS) -(LS)	<SS>	<SS>	<SS>		<SS>	<SS> (CH) [SH]		<SS>	(SS) {CH}	Zn
					<SS>	(SS) {LS} [CH]	(SS) (CH)	<SS> {LS}	<SS> {LS} {CH}	<SS> {LS}		<SS> {LS}	<SS> {CH} {SH}		<SS>	(SS) {SH}	Pb
						(SS) (SH) [LS]	{SS} (SH) [LS] {SH}	<SS>	<SS> (CH)	(SS)		(SS) {SH} [LS] {CH}	<SS>		{SS} {CH} {SH}	(SS) {SH}	Cd
							(SS) {SH} {LS} [CH]	<SS> <SH> {LS}	(SS)	<SS>		<SS> {SH} [LS] {SH}	(SS) {CH}	{CH} -[SH]	(SS) {SH} [CH]	(SS) <SH>	Mn
								<SS> -(CH)	<SS> (SH) {CH}	<SS> <SH>		(SS) (SH) {LS} {CH}	<SS>	{CH} {SH}	[SS] {SH} {LS} [CH] {SH}	{SS} [SH]	Sr
									<SS>	(SS) {LS}		<SS> -{CH}	-{CH}		<SS> <SH> (LS) -{CH}	<SS> <SH>	Cr
										(SS) {LS}	<SS> {CH} {SH}	<SS>	(SS) {CH}		<SS>	<SS>	Ni
											<SS>	<SS>	<SS> {LS}	<SS>	<SS> {LS}	<SS>	Co
													<SS> {CH}				Mo
													<SS> {SH}	-{SH}	(SS) {SH} [LS] (CH)	(SS) {CH}	Ag
															<SS> (CH)	<SS>	V
															(LS)		Ti
																{SS}	Ca

Lithology

Sandstone = SS
Shale = SH
Limestone = LS
Chert = CH
High Uranium = SH

Correlation Coefficients

Very High = [ ] = 0.81-1.00
High = { } = 0.66-0.80
Moderate = ( ) = 0.50-0.65
Low = < > = <0.50

lithology and subgroup. This method of analysis was used to determine which elements were being influenced by the same geochemical factors. A second normality evaluation using the Lilliefors test was conducted prior to the factor analysis. The Lilliefors is a more conservative test for normality than the Kolmogorov-Smirnov test, because the empirical distribution function is obtained from a normalized sample and is unadjusted in the Kolmogorov-Smirnov test (Conover, 1971). Eigen values of 1.0 or greater were considered significant.

Results and Discussion

The correlation coefficients discussed below will be considered as follows:

< 0.50 = low correlation

0.50 - 0.65 = moderate correlation

0.66 - 0.80 = high correlation

0.81 - 1.00 = very high correlation.

Krauskopf (1956), Day (1963), Garrels and Christ (1965), and Röster and Lange (1972), were used in the interpretation of the results.

High Uranium Shale

These samples were found in Section 3, T5N, R1ECM. Unlike most shales found within the Morrison sequence these samples were taken from an organic fissile shale. The depositional sequence was determined to be a lacustrine environment located on the down thrown side of the Freezeout Creek Fault, onto which a coarse conglomeratic sandstone was deposited. The organic rich shale was developed after the sandstone deposition ceased. Since the shale has a very localized development, it is thought to have deposited as a peat bog with limited ground water circulation. The basal Cheyenne Sandstone was deposited directly above the shale. The contact between the two formations was found to be several feet lower at this location than in the surrounding area. The trend is thought to follow the paleocurrent direction (Fig. 5) and to have persisted into the Early Cretaceous deposition. Petrified wood fragments found in the basal Cheyenne are thought to have been confined to the subsiding area where the initial marine transgression would have taken place. A similar occurrence marking the Jurassic-Cretaceous boundary is found west of the monoclinal terrace near Folsom.

The association of uranium with carbonate forming cations (calcium, strontium, and magnesium) suggest that precipitation may have taken place as sexivalent uranium carbonate solutions were brought into reducing conditions. The correlation matrix and factor analysis revealed that uranium has a high correlation with titanium and lead (Fig. 17) and a high negative correlation with manganese. Many of the trace elements were transported as a HCO_3^- or $CO_3^=$ complex and precipitation occurred principally as sulfides, oxides, and carbonates.

Low Uranium Shale

These samples represent the remaining analysis conducted on shales. The samples were gathered from the middle and upper Morrison near Kenton, Oklahoma.

The uranium is thought to have precipitated as a silicate in a slightly alkaline environment. Uranium has a high correlation coefficient with residual and moderate to high negative correlations were

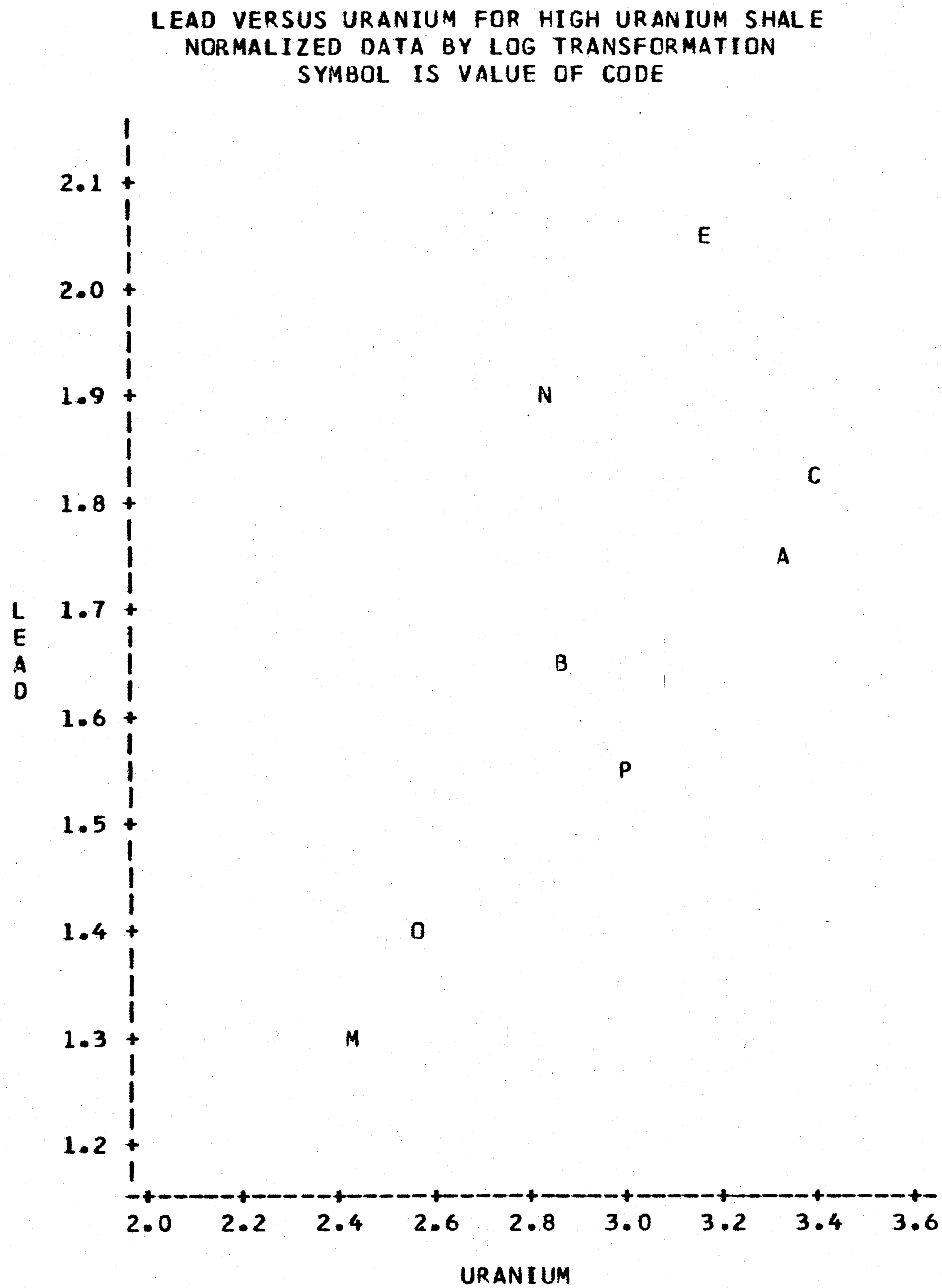

Fig. 17.-Plot of urnaium versus lead for mineralized shale.

found between uranium and cadmium, manganese, strontium, silver, and calcium.

Chert

These samples were collected from Section 3, T5N, R1ECM. Field evidence suggests the chert was interbedded with the fresh water limestone located below the high uranium shale. The chert unit could be recognized over much of the SE ¼ of Section 3 by higher scintillometer readings. The unit forms a resistant layer to erosion and caps many of the lower hills in the SE ¼ of the section. The coarse sandstone located between the high uranium shale and the interbedded limestone and chert is also cemented by opal and chalcedony. King and Merriam (1969) suggest the origin of the "agate bed" may be due to devitrification of tuffaceous material. The increase in volcanic ash upward in the Morrison sequence (Mankin, 1958) would account for the increase in opal and chalcedony cement in the upper Morrison. Smith et al. (1970) have examined the organic content of cherts and have determined two ways in which fatty acids can be retained in chert. The organic molecule may be enclosed within the chert matrix during deposition of the chert or the low permeability of chert (7-660 μd) may prove to be impervious to the large organic molecules. Both of these mechanisms are thought to have been important at this locality.

The correlation matrix shows high correlations between uranium and iron, vanadium and molybdenum. Factor analysis also indicates a strong relationship between these minerals. The association of these minerals is most likely found in the organic material which Smith et al. (1970) termed "free fatty acids" found on the outer surface of the chert.

Sandstone

The sandstone samples were collected from the middle and upper Morrison near Kenton, Oklahoma. Random samples from the thick Morrison section west of the monoclinal terrace (Fig. 6) are also included in the sandstone analysis.

The correlation matrix for sandstone contains many low and moderate correlations which were considered significant by the parameters previously selected ($\alpha = 0.05$). This relationship is created by a high variance within the population being analyzed. Subdivision of the population by different geologic parameters (e.g. stratigraphic position, cement, or grain size) did not lower the variance significantly. Therefore, the high variance may be a physical characteristic of the Morrison sandstones. This may reflect permeability of the sandstone, deposition in an alkaline-oxidizing environment (Squyres, 1970), or cation exchange capacity of the clays.

The sandstone correlation matrix shows uranium has a low positive correlation with nickel and molybdenum and a low negative correlation with residual. A moderate correlation between uranium and chromium is also shown.

Limestone

The limestone samples were collected from the interbedded limestone and chert described previously and from the middle Morrison located along New Mexico State Highway 18 Section 18, T30N, R37E. Petrographic analysis has shown the samples were deposited in lacustrine environments.

The correlation matrix and factor analysis revealed no significant associations between uranium and any of the other elements. The limestone sample which had an anomalously high uranium reading also contained organic material which was visible in hand specimen and pyrite cubes which were visible in thin-section. The uranium was closely associated with the organic material and not as previously reported (Zeller et al., 1976) in the dark brown coating on the weathered surface.

CHAPTER IX

URANIUM POTENTIAL

The Morrison Formation in the study area contains several factors which are considered favorable criteria when exploring for sandstone uranium deposits (Grutt, 1972). The formation was deposited on an alluvial plain. The sandstone content increases upward in the section. The grain size increases in the upper Morrison sandstones and is often poorly sorted. Volcanic ash content also increases upward in the section. The sediment is interpreted as having had a source area composed of granite and sedimentary rock (Mankin, 1958). Structural dip is generally less than 5° to the east. Paleocurrent data and an increase in grain size to the west suggest a sediment source associated with or similar to that for known uranium mineralization.

The investigation by Landis (1969) of the uranium content of ground and surface water for the area showed consistantly higher than normal concentrations for the samples closely associated with the Morrison. The highest readings were from near Kenton (Section 4, T5N, R1ECM), north of Boise City (Section 5, T5N, R5ECM), near Folsom (Section 28, T31N, R29E and Section 12, T31N, R31E), and in Las Animas County, Colorado (Section 34, T28S, R51W). The results of the ground water survey suggest that mineralization is more likely along the crest of the Sierra Grande Uplift and east of the Freezeout Creek Fault near Kenton. This is in agreement with the results of the helicopter-borne radiometric survey flown in the area.

Localized "hot spots" were reported (Baldwin and Muehlberger, 1959) near the northwest corner of T29N, R33E. The area contained higher than normal background scintillometer readings, but a thick soil profile prevented the location of any mineralization. The reported "hot spots" along Tramperos Creek are thought to be associated with the Morrison. A specific location or strata was not determined.

Finch (1972), Baldwin and Muehlberger (1959), and the United States Atomic Energy Commission (1970) report that most of the known uranium occurrences are associated with petrified wood. Mineralization is also found with dinosaur bones, coaly shale, and carbonaceous trash. Squyres (1970) contributes the origin of the humate material in the "western" Morrison to oxidation and leaching of Jurassic plant material. He also discussed several lines of evidence which suggest a limited migration of the organic material after leaching.

Mankin (1958) observed that lacustrine limestones occurred most often with thick Morrison section and increased to the east. Cooley (1955) and Baldwin and Muehlberger (1959) have shown that sandstone development is confined to the area west of the Guy Monocline in the Dry Cimarron River Valley. It is suggested this is the result of depositional conditions rather than post-Morrison erosion. These areas were probably relatively low throughout much of the Morrison deposition. Therefore, such areas would be probable locations for plant growth and decay, as well as, accumulation of humate masses.

The preceding interrelationships suggest that uranium mineralization might be more likely in areas of subsidence during Morrison deposition. Schlee and Moench (1961) attribute similar circumstances to the Jackpile Sandstone near Lahuna, New Mexico. The locations of known uranium mineralization are shown in Fig. 4 and Fig. 6. Most of these locations are associated with thick Morrison sequences. The isopach map (Fig. 6) shows two trends of thick Morrison development.

The Kenton-Clayton Trend

The southern limit of the trend is located in the area of T16N, R31E which has a Morrison section of 516 feet. The region also has two locations of known uranium mineralization (Fig. 4). Near Stead, New Mexico, (T21-22N, R34-35E) Baldwin and Muehlberger (1959) mapped a thick upper Morrison sandstone in the area, as well as reported localized "hot spots" along Tramperos Creek. The Herndon No. 1 Mock well located in NW ¼, Section 25, T27N, R36E contains a Morrison section which is over 500 feet thick. The Morrison in the study area near Kenton, Oklahoma, contains 467 feet of section and two horizons of mineralization.

A comparison of Fig. 3 with Fig. 4 and Fig. 6 clearly illustrates that the trend of thicker Morrison sections are located parallel to major faults. Emphasis should be placed on the fact that it is not known if the subsidence along the faults is related to movement of the faults or compaction of sediment along the trends.

Since McLaughlin (1954) did not find the thick Morrison section in western Baca County, the Jurassic stream systems may have been less confined or may have changed direction of the major drainage pattern away from the fault trends. Anderman (1961) and MacLachlan (1972) show a northeast trending trough which extends from T35, R49W to T28S, R43W and persisted from Mississippian through Jurassic sedimentation. McKee et al. (1956) suggests that sandstone development continues in this direction.

The Sierra Grande Trend

The southern part of the trend is the thick Morrison section found in T19-22N, R24-26E. Two locations of known uranium mineralization are associated with this area. The thick section is probably fault controlled (Fig. 3 and Fig. 6).

In the study area, the Morrison has a maximum thickness of 360 feet. One "hot spot" is reported in the northwest corner of T29N, R33E. Water samples from the Dry Cimarron Fiver contained 42 ppb (Section 28, T31N, R29E) and 23 ppb (Section 12, T31N, R31E). Background radiation readings on the scintillometer at the first location were 120-150 cps (average background ≃ 60 cps). Two of the grab samples from this location contained significantly higher than background uranium concentrations but not anomalous (34 and 24 ppm).

The northern limit of the trend is located in Bent County, Colorado. The area contains two known locations of mineralization (Finch, 1967). These are located in T27S, R53W and T27S, R51W. A water sample from the Cheyenne Sandstone (T28S, R51W) contained 50 ppb uranium. It is quite possible that chemical conditions in the upper Morrison might influence those in the lower Cheyenne aquifer. The thickness of the Morrison is not known for this area.

These three isolated exposures are thought to represent a continuous trend because the thicker Morrison of the exposures are bounded on the west by a thin Morrison along the axis of the Sierra Grande Uplift (Roberts et al., 1976, and Baltz, 1965). The Morrison thins to the east of the trend on the monoclinal terrace. Therefore, the trend is projected into an area to the north in which the thickness is not known.

The Monoclinal Terrace

The monoclinal terrace is situated between the Kenton-Clayton and Sierra Grande trends. The region is thought to have less potential for uranium mineralization than the areas to the east and west, which were described above. The monoclinal terrace contains no known uranium "hotspots" in the Morrison. The water samples from the Dry Cimarron River (Union County) and Carrizo Creek (Baca County) on the monoclinal terrace contained only background uranium concentrations. The radiometric survey located two small "hot spots" in the upper Dockum.

The locations are associated with the "clastic Plugs" (Parker, 1933) which are found where the Dry Cimarron River and its tributaries have exposed the upper Dockum on the monoclinal terrace (T31-32N, R33-37E). It is not known if these cylindrical structures were intruded from below and have the Baldy Hill Formation as a source or were collapse features and had the Jurassic formations as a source. Therefore, a comparison between the "clastic plugs" and Woodrow breccia pipe (Laguma District) should not be made at this time.

The boundaries of the monoclinal terrace in New Mexico and Oklahoma, are Precambrian faults on the east and Pennsylvanian faults on the west (Fig. 4). The southern limit is the Clapham Anticline in Union County.

The boundaries of the monoclinal terrace are less well defined in southeastern Colorado. The area in Fig. 4 between the Mustang Creek

Monocline and the Pennsylvanian fault (T29-32S, R51W) may be on the Sierra Grande trend or the monoclinal terrace. The area between the Precambrian faults (T27-34S, R49W) may be on the Kenton-Clayton trend or the monoclinal terrace. Additional information concerning the thickness and uranium content of the Morrison in these areas is needed.

CHAPTER X

CONCLUSIONS

Summary

The principal conclusions of this study are as follows:

1) The Morrison was deposited on an alluvial plain which was composed of braided and meandering streams. Lacustrine limestones are found throughout the Morrison stratigraphic sequence and often redevelop in the same geographic area.
2) The grain size and feldspar content of the formation decrease from west to east across northeastern New Mexico into Oklahoma.
3) The clay mineralogy of the Morrison near Kenton, Oklahoma, was composed of kaolinite, illite, and a mixed-layer illite-montmorillonite. The clay minerals are equivalent to the assemblage previously reported (Mankin, 1958) for the middle and upper Morrison of New Mexico. Therefore, it is doubtful if the basal Morrison extends into Oklahoma from Union County, New Mexico.
4) It was found that the diagenetic sequence within the cements was quartz overgrowths, followed by calcite with lesser amounts of hematite, siderite, and clays, followed by chalcedony and opal replacing calcite, followed by a second generation of calcite cement.
5) The grain size of the upper Morrison is much larger than that of

the lower and middle Morrison. Some of the larger pebbles are undoubtedly reworked Morrison.

6) Sediment transport and deposition shifted to the east during late Morrison deposition.

7) Paleocurrent data from the middle and upper Morrison near Kenton, Oklahoma, have the same direction as the trend of the Three Corners Monocline. Therefore, sediment transport and deposition were structurally influenced.

8) Locations which have thicker Morrison sequences are closely related to changes in basement province and/or basement faults.

9) The monoclinal terrace, located along the eastern limits of the Sierra Grande Uplift, has little potential for uranium mineralization.

10) The Sierra Grande trend and Kenton-Clayton trend have the greatest potential for uranium mineralization.

11) Uranium has a very high correlation with titanium in the mineralized samples, a high correlation with lead, strontium, and magnesium, and a high negative correlation with manganese.

12) The uranium was closely associated with organic material which had been preserved by stratigraphic and low permeability barriers.

13) Future areas of study should include:

    a) The Morrison in Baca and Las Animas Counties, Colorado;

    b) The Morrison in the Raton Basin, Colfax County, New Mexico;

    c) The relationship between the undifferentiated Morrison of the Front Range and the "western" Morrison.

Recommendations

Exploratory drilling should first be conducted along the Kenton-Clayton trend. This hypothesis is based on the following:

1) Volcanic activity increased during deposition of the upper Morrison.
2) Sedimentation shifted to the east during late Morrison deposition.
3) Precambrian faulting and Paleozoic structures strongly influenced the sedimentation.
4) Structural influence is more clearly seen along the Kenton-Clayton trend than along the Sierra Grande trend because of more outcrop exposures.
5) Known uranium mineralization is closely associated with the upper Morrison along the Kenton-Clayton trend.

The southern half of the Kenton-Clayton trend from T21N, R34E to T27N, R36E in New Mexico and the Late Paleozoic trough in Baca County, Colorado, which Anderman (1961) and MacLachlan (1972) locate in T35S, R49W and T28S, R43W should be evaluated first. This trend is down the paleoslope from known uranium "hot spots" and extends into the area of mineralization described by Zeller et al. (1976). The northern part of the Sierra Grande trend should also be evaluated from the Dry Cimarron River Valley near Folsom, New Mexico, to Bent County, Colorado. The southern limits of the Sierra Grande and Kenton-Clayton trends are considered to have less potential for uranium mineralization because of previous exploration activity in those areas.

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APPENDIXES

APPENDIX A

GEOCHEMICAL ANALYSIS OF THE MORRISON FORMATION

GEOCHEMICAL ANALYSIS OF THE MORRISON FORMATION-----ELEMENTAL CONCENTRATIONS IN PPM, RESIDUAL IN GM

LITHO=CHERT GP=LOW U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
1	PA-1	A	SE SEC3 T5N R1ECM	6.0	10	25	950	7.0	3.5	51.0	1	2	15	5	15.0	0.5	5.0	0.1	1000	135	0.8874
2	PA-2	B	SE SEC3 T5N R1ECM	9.0	15	50	7000	19.5	8.0	215.0	1	2	10	5	30.0	0.5	15.0	0.5	1000	760	0.8664
3	PA-4	D	SE SEC3 T5N R1ECM	28.0	25	50	3900	10.5	11.5	1650.0	1	10	10	10	45.0	5.0	175.0	3.5	56500	930	0.4243
4	PA-6	F	SE SEC3 T5N R1ECM	.	10	20	1675	10.0	7.5	10.0	1	2	2	10	7.5	1.0	5.0	0.5	500	515	0.8519
5	PA-8	H	SE SEC3 T5N R1ECM	70.0	10	20	3925	12.5	8.0	36.5	1	2	2	10	35.0	1.0	10.0	1.0	2000	915	0.7323
6	PA-11	K	SE SEC3 T5N R1ECM	24.0	25	20	9400	19.5	10.0	96.5	1	10	45	15	45.0	1.0	10.0	1.0	750	510	0.8050
7	PA-14	N	SE SEC3 T5N R1ECM	0.5	10	20	700	10.0	9.5	24.5	1	2	5	5	15.0	1.5	5.0	0.5	500	370	0.8858
8	PA-15	O	SE SEC3 T5N R1ECM	80.0	15	25	15300	22.0	8.0	101.0	1	10	25	60	85.0	2.0	20.0	0.5	2750	565	0.8490
9	PA-16	P	SE SEC3 T5N R1ECM	7.0	20	20	9100	27.5	8.5	197.5	1	2	10	10	20.0	1.5	15.0	0.5	1000	1070	0.9000
10	MR-12	L	NW SEC3 T5N R1ECM	3.0	5	20	1500	7.0	6.0	10.5	1	2	20	5	5.0	0.5	7.5	0.5	250	310	0.9122

LITHO=LIMESTONE GP=LOW U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
11	PA-5	E	SE SEC3 T5N R1ECM	.	30	50	2400	9.0	9.5	1975.0	1	2	5	10	20.0	5.0	305	4.0	6500	1410	0.2948
12	PA-23	W	SW SEC3 T5N R1ECM	.	30	20	925	7.0	10.5	2750.0	5	10	25	10	20.0	6.5	335	5.0	75000	1020	0.0654
13	PA-30	X	SE SEC2 T5N R1ECM	.	20	20	11600	54.0	7.5	186.0	1	5	15	10	30.0	2.0	70	2.0	24000	1210	0.7511
14	NM-2	B	NE SEC18 T30N R37E	0.5	15	20	10600	30.5	7.5	1060.0	1	2	5	25	10.0	3.5	205	2.5	31000	3750	0.6320
15	NM-4	D	NE SEC18 T30N R37E	7.0	15	20	11100	47.5	14.5	210.5	1	2	5	45	12.5	2.5	215	1.5	19000	2875	0.7805
16	NM-5	E	NE SEC18 T30N R37E	15.0	20	20	4350	12.5	9.0	975.0	5	2	5	10	10.0	4.0	310	2.5	28500	1525	0.6051
17	NM-8	G	NE SEC18 T30N R37E	8.0	15	20	9000	34.0	5.0	330.0	1	2	10	2	10.0	1.5	105	1.0	14000	11750	0.7634
18	NM-9	H	NE SEC18 T30N R37E	3.0	20	20	9700	30.0	10.5	550.0	5	2	10	2	20.0	2.0	105	1.5	20500	11000	0.7137
19	NM-10	I	NE SEC18 T30N R37E	5.0	35	20	15400	40.0	10.0	1985.0	5	5	15	2	20.0	4.0	170	3.0	37000	7250	0.4569
20	NM-12	K	NE SEC18 T30N R37E	0.5	40	20	21700	64.5	13.0	1750.0	10	15	20	5	15.0	4.0	145	3.0	36000	4000	0.4961
21	NM-15	N	NE SEC18 T30N R37E	4.0	20	20	10100	37.5	10.0	100.0	1	5	5	2	5.0	1.0	25	1.0	12000	940	0.8066

LITHO=LIMESTONE GP=HIGH U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
22	NM-3	C	NE SEC18 T30N R37E	260	15	50	7700	36	11.5	615	5	2	5	20	10	3.5	320	2.5	27000	3000	0.6631

LITHO=SANDSTONE GP=LOW U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
23	AB-4	D	NE SEC3 T5N R1ECM	.	25.0	20	11800	27.5	12.5	162.5	1	50	90	25	490.0	1.5	20.0	0.5	6500	520	0.9006
24	AB-23	Y	NE SEC3 T5N R1ECM	.	10.0	20	1925	8.5	3.5	78.0	1	2	5	5	15.0	1.0	5.0	0.1	2500	145	0.9313
25	AB-24	F	NE SEC3 T5N R1ECM	.	20.0	50	10400	29.5	14.5	257.5	1	2	20	5	35.0	2.5	65.0	2.0	25000	1425	0.7322
26	AB-25	G	NE SEC3 T5N R1ECM	.	10.0	20	2425	5.5	4.0	4.0	1	2	15	5	10.0	1.0	5.0	0.5	1000	180	0.9372
27	AB-26	H	NE SEC3 T5N R1ECM	.	5.0	20	925	3.0	4.0	4.5	1	2	10	5	2.0	1.5	10.0	0.5	3250	300	0.9037
28	AB-28	J	NE SEC3 T5N R1ECM	.	15.0	50	3850	6.0	5.5	13.5	1	2	15	5	10.0	1.0	20.0	0.5	1250	765	0.8860
29	AB-30	L	NE SEC3 T5N R1ECM	.	10.0	20	1100	2.0	1.5	6.0	1	2	5	5	5.0	1.0	15.0	0.5	1500	655	0.9608
30	AB-43	Q	NE SEC3 T5N R1FCM	.	50.0	25	13400	67.5	2.2	630.0	1	140	205	20	230.0	2.0	20.0	0.5	1000	545	0.8761
31	AB-44	R	NE SEC3 T5N R1ECM	6.0	5.0	20	900	7.5	9.0	17.0	1	2	5	5	15.0	0.2	10.0	0.3	1000	1020	0.9470
32	AB-45	S	NE SEC3 T5N R1ECM	14.0	10.0	25	1950	7.5	5.0	54.5	1	2	25	20	20.0	0.5	15.0	0.1	250	105	0.9394
33	AB-47	U	NE SEC3 T5N R1ECM	.	15.0	20	9000	15.0	9.0	13.0	1	2	5	5	10.0	1.0	25.0	0.5	10000	890	0.9110
34	AB-48	V	NE SEC3 T5N R1ECM	0.5	15.0	20	1215	6.5	2.5	56.5	1	2	2	5	7.5	1.0	2.5	0.1	375	225	0.9310

GEOCHEMICAL ANALYSIS OF THE MORRISON FORMATION-----ELEMENTAL CONCENTRATIONS IN PPM, RESIDUAL IN GM

--- LITHO=SANDSTONE GP=LOW U ---

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
35	AB-49	W	NE SEC3 T5N R1ECM	.	5.0	20	2450	12.0	8.5	133.0	1	2	5	5	15.0	1.5	2.5	0.5	500	290	0.9459
36	AB-50	X	NE SEC3 T5N R1ECM	.	5.0	20	1675	7.0	6.0	9.0	1	2	5	5	10.0	1.0	2.5	0.1	250	180	0.9638
37	PA-3	C	SE SEC3 T5N R1ECM	13.0	15.0	20	1675	12.5	6.5	29.5	1	2	5	10	15.0	1.0	5.0	0.5	250	255	0.9066
38	PA-7	G	SE SEC3 T5N R1ECM	.	10.0	20	1750	13.0	8.0	21.0	1	2	2	5	20.0	1.0	10.0	0.5	500	300	0.9316
39	PA-9	I	SE SEC3 T5N R1ECM	.	5.0	20	1150	6.5	3.0	35.5	1	2	2	5	20.0	0.5	1.0	1.0	250	125	0.9563
40	PA-12	L	SE SEC3 T5N R1ECM	0.5	10.0	20	10200	23.0	4.0	136.5	1	2	5	5	45.0	1.5	25.0	1.5	14000	680	0.8428
41	PA-13	M	SE SEC3 T5N R1ECM	.	5.0	20	3200	12.0	7.0	50.5	1	2	5	5	15.0	1.5	2.5	0.5	500	350	0.9580
42	PA-17	Q	SE SEC3 T5N R1ECM	0.5	5.0	20	2300	7.5	3.0	51.5	1	2	20	10	30.0	1.0	5.0	16.5	250	100	0.9274
43	PA-19	S	SW SEC2 T5N R1ECM	.	10.0	25	2200	16.0	8.5	99.0	1	2	10	5	10.0	1.0	5.0	0.5	8500	425	0.8846
44	PA-20	T	SW SEC3 T5N R1ECM	.	10.0	20	1600	5.0	4.5	44.5	1	2	10	10	20.0	1.5	7.5	0.5	4250	225	0.9377
45	PA-22	V	SW SEC3 T5N R1ECM	.	10.0	20	1950	3.5	13.0	10.5	1	2	10	5	10.0	0.5	5.0	0.5	1250	1120	0.8524
46	PA-31	Y	SE SEC2 T5N R1ECM	.	5.0	20	5100	16.0	5.5	92.5	1	2	5	10	15.0	1.0	10.0	0.5	6500	400	0.9203
47	PA-32	1	SE SEC2 T5N R1ECM	.	10.0	20	1100	6.5	6.0	7.5	1	2	2	10	2.0	0.2	2.5	0.5	750	695	0.9375
48	PA-34	3	SE SEC2 T5N R1ECM	.	0.2	20	2500	6.5	5.0	2.0	1	2	2	5	5.0	0.5	1.0	0.5	250	175	0.9542
49	PA-35	4	SE SEC2 T5N R1ECM	.	10.0	20	1600	9.5	12.0	32.5	1	2	2	5	10.0	0.5	1.0	0.5	250	220	0.9420
50	PA35A	5	SE SEC2 T5N R1ECM	.	15.0	20	2700	13.5	6.0	27.5	1	2	2	5	10.0	0.5	1.0	0.5	250	280	0.9465
51	NM-1	A	NE SEC18 T30N R37E	2.0	25.0	25	3400	23.0	9.0	39.0	1	2	2	35	15.0	1.5	50.0	1.0	5500	1860	0.8108
52	NM-13	L	NE SEC18 T30N R37E	2.0	15.0	20	3700	18.0	11.0	17.5	1	2	5	2	15.0	0.5	15.0	0.5	8000	615	0.9038
53	NM-17	P	NE SEC18 T30N R37E	0.5	15.0	20	6400	13.0	12.5	76.0	1	2	5	5	10.0	1.0	40.0	0.5	8000	1005	0.8423
54	NM-19	R	NE SEC18 T30N R37E	0.5	15.0	20	8700	37.0	7.0	240.0	1	2	5	2	15.0	1.0	27.5	1.0	6500	775	0.8536
55	RL-1	A	NW SEC12 T5N R1ECM	.	10.0	20	3350	9.5	6.0	76.5	1	2	2	5	15.0	0.5	5.0	0.5	500	20	0.9538
56	RL-2	B	NW SEC12 T5N R1ECM	.	35.0	20	20400	38.0	8.5	5550.0	1	5	10	2	25.0	4.0	285.0	3.5	37000	50500	0.2406
57	RL-3	C	NW SEC12 T5N R1ECM	.	10.0	20	13000	11.0	10.5	40.5	1	2	2	2	30.0	0.5	10.0	0.5	1000	1000	0.9177
58	RL-4	D	NW SEC12 T5N R1ECM	.	20.0	20	1300	3.5	10.0	6.0	1	2	2	2	10.0	0.5	5.0	0.5	750	580	0.9379
59	RL-6	F	SE SEC11 T5N R1ECM	0.5	25.0	20	7800	24.5	5.0	725.0	5	2	10	5	10.0	2.0	60.0	1.5	24000	2250	0.7448
60	RL-7A	H	SE SEC11 T5N R1ECM	0.5	10.0	20	1700	13.5	3.0	21.5	1	2	2	5	10.0	0.2	5.0	0.5	250	115	0.9661
61	RL-10	L	SE SEC14 T5N R1ECM	.	5.0	20	750	7.0	3.0	4.0	1	2	2	2	5.0	2.0	15.0	0.5	2500	980	0.9109
62	RL-11	M	SE SEC14 T5N R1ECM	.	5.0	20	450	3.5	3.5	8.5	1	2	2	2	2.0	1.5	10.0	0.5	750	405	0.9647
63	RL-12	N	SE SEC14 T5N R1ECM	0.5	30.0	200	3300	13.5	7.0	300.0	1	5	10	2	30.0	3.5	80.0	2.5	27000	915	0.6915
64	RL-13	O	SE SEC14 T5N R1ECM	.	30.0	20	23800	15.5	5.5	450.0	1	5	5	2	160.0	2.0	35.0	1.0	7000	6500	0.8129
65	RL-14	P	SE SEC14 T5N R1ECM	0.5	15.0	20	2200	8.5	4.0	250.0	1	10	10	2	10.0	3.5	55.0	2.0	27000	6000	0.6985
66	RL-15	Q	SW SEC13 T5N R1ECM	.	10.0	25	1650	5.5	3.0	17.5	1	5	5	2	5.0	1.0	15.0	1.0	7250	300	0.9328
67	RL-16	R	SW SEC13 T5N R1ECM	.	10.0	25	4000	6.5	7.0	3.5	1	2	5	2	15.0	0.5	15.0	0.5	750	375	0.9192
68	RL-17	S	SW SEC13 T5N R1ECM	0.5	10.0	25	7900	4.5	2.0	2.0	1	2	5	5	30.0	1.0	20.0	0.5	1000	425	0.9528
69	RL-19	U	SW SEC13 T5N R1ECM	0.5	15.0	25	4500	10.0	16.5	16.5	1	2	10	2	30.0	1.0	5.0	1.0	6000	1465	0.8728
70	MJ-1	A	NW SEC10 T5N R1ECM	.	5.0	50	1375	7.5	5.5	14.0	1	2	10	5	2.0	0.5	10.0	0.5	750	205	0.9457
71	MJ-2	B	NW SEC10 T5N R1ECM	.	10.0	20	1450	7.5	4.0	4.5	1	2	10	5	2.0	0.5	5.0	0.5	750	235	0.9600
72	MJ-3	C	NW SEC10 T5N R1ECM	.	15.0	50	11400	23.0	5.5	95.0	1	2	15	5	20.0	1.5	45.0	1.5	18000	1200	0.6644
73	MJ-5	E	NW SEC10 T5N R1ECM	.	5.0	20	7000	16.5	7.0	43.0	1	2	5	5	10.0	0.2	7.5	0.3	250	350	0.9383
74	MJ-7	G	NW SEC10 T5N R1ECM	.	10.0	20	950	6.0	3.5	34.5	1	2	5	5	10.0	0.5	15.0	0.5	9000	385	0.8959
75	MJ-8	H	NW SEC10 T5N R1ECM	.	25.0	20	800	6.0	4.5	120.0	1	2	2	2	10.0	0.5	5.0	0.1	250	135	0.9400
76	MJ-10	J	NW SEC10 T5N R1ECM	.	15.0	20	16900	43.0	12.5	287.5	1	10	5	10	240.0	1.5	15.0	0.5	250	310	0.8499
77	MR-1	A	NW SEC3 T5N R1ECM	0.5	10.0	20	2450	14.5	4.0	60.0	1	2	2	5	5.0	1.5	15.0	0.5	5500	805	0.8382
78	MR-2	B	NW SEC3 T5N R1ECM	0.5	20.0	20	9600	35.0	7.0	840.0	1	5	10	2	15.0	4.0	150.0	2.0	22500	12500	0.7137
79	MR-3	C	NW SEC3 T5N R1ECM	0.5	10.0	20	8700	18.0	13.5	87.5	1	2	5	2	10.0	1.0	25.0	0.5	3500	1000	0.9066
80	MR-4	D	NW SEC3 T5N R1ECM	0.5	25.0	25	12600	37.5	5.0	425.0	1	2	25	5	35.0	4.5	70.0	2.0	23500	25000	0.7418
81	MR-5	E	NW SEC3 T5N R1ECM	0.5	5.0	20	650	5.0	5.0	15.0	1	2	5	2	5.0	1.5	5.0	0.5	250	120	0.8988
82	MR-6	F	NW SEC3 T5N R1ECM	.	10.0	20	1500	6.0	4.0	9.0	1	2	5	2	5.0	1.0	5.0	0.5	125	100	0.9525
83	MR-7	G	NW SEC3 T5N R1ECM	.	15.0	20	2850	8.5	6.5	18.5	1	2	5	5	7.5	1.0	5.0	0.5	1000	205	0.9552
84	MR-8	H	NW SEC3 T5N R1ECM	.	20.0	20	8000	21.0	9.5	93.0	1	2	10	5	20.0	1.5	30.0	1.0	13000	655	0.8679
85	MR-9	I	NW SEC3 T5N R1ECM	0.5	10.0	20	3450	14.5	5.0	54.0	1	2	10	2	15.0	0.5	5.0	0.5	250	160	0.9277
86	MR-10	J	NW SEC3 T5N R1ECM	0.5	10.0	20	2800	11.0	6.0	122.5	1	5	10	2	15.0	2.5	30.0	1.5	15500	755	0.8125

GEOCHEMICAL ANALYSIS OF THE MORRISON FORMATION-----ELEMENTAL CONCENTRATIONS IN PPM, RESIDUAL IN GM

LITHO=SANDSTONE GP=LOW U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
87	MR-11	K	NW SEC3 T5N R1ECM	0.5	15	20	1150	8.0	6.5	21.0	1	5	10	2	10	1.0	7.5	0.5	750	340	0.9624
88	MR-13	M	NW SEC3 T5N R1ECM	0.5	10	25	3250	6.5	7.0	35.0	1	2	10	5	10	1.0	10.0	0.5	750	775	0.9307
89	EA-2	B	SW SEC18 T5N R2ECM	.	15	25	13500	43.5	11.5	725.0	1	10	15	5	10	1.0	45.0	0.5	7000	885	0.8986
90	EA-5	E	SW SEC18 T5N R2ECM	.	20	20	1050	27.5	9.0	22.0	5	2	5	2	15	2.5	190.0	2.0	30000	1405	0.9111
91	EA-6	F	SW SEC18 T5N R2ECM	.	50	20	23000	43.0	29.0	925.0	5	20	15	15	135	7.0	250.0	2.0	3150	6750	0.6107
92	EA-7	G	SW SEC18 T5N R2ECM	.	25	20	23800	67.0	10.5	460.0	5	5	5	5	40	6.0	320.0	2.5	34500	22500	0.5055
93	EA-7A	H	SW SEC18 T5N R2ECM	.	15	20	1350	10.0	16.0	21.0	1	2	2	5	10	1.0	30.0	0.5	4250	850	0.9664
94	EA-8	I	SW SEC18 T5N R2ECM	.	10	20	4500	12.0	10.5	27.0	1	2	5	5	5	1.0	90.0	0.5	7500	2500	0.8957
95	EA-9	K	SW SEC23 T5N R1ECM	.	5	20	1800	10.5	8.0	107.5	1	2	5	2	5	1.5	5.0	0.8	7500	415	0.5350
96	EA-11	M	SW SEC23 T5N R1ECM	.	20	20	10900	33.0	5.5	1350.0	1	5	15	2	15	2.5	220.0	2.0	24500	18250	0.6893
97	EA-13	O	SW SEC23 T5N R1ECM	0.5	10	20	2150	8.5	4.5	42.5	1	2	5	5	2	0.5	5.0	0.5	125	105	0.9602
98	FL-3	B	SEC29 T30N R29E	2.0	20	20	3700	9.0	52.5	127.5	1	10	15	2	10	1.0	70.0	0.8	3750	1920	0.9292
99	FL-4	C	SEC29 T30N R29E	34.0	35	20	4700	19.0	10.5	3635.0	10	15	25	5	15	4.5	280.0	3.3	38500	3500	0.4754
100	FL-5	D	SEC29 T30N R29E	24.0	40	20	4150	16.5	10.0	5700.0	10	20	20	5	25	4.5	315.0	3.5	48000	3250	0.3838
101	FL-6	E	SEC29 T30N R29E	3.0	15	20	1650	7.5	3.0	74.0	1	10	5	5	10	0.5	45.0	0.5	7000	1280	0.9318

LITHO=SHALE GP=LOW U

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
102	AB-27	I	NE SEC3 T5N R1ECM	.	10	25	8000	8.0	3.5	18.0	1	2	15	5	10.0	1.0	30.0	0.5	5000	840	0.9222
103	AB-29	K	NE SEC3 T5N R1ECM	3.0	5	20	3800	2.5	6.0	4.5	1	2	5	5	10.0	1.5	15.0	1.0	1625	935	0.9415
104	AB-46	T	NE SEC3 T5N R1ECM	3.0	10	100	22000	30.0	10.5	16.0	1	2	5	5	30.0	0.5	40.0	0.5	4000	1445	0.8480
105	PA-10	J	SE SEC3 T5N R1ECM	.	15	50	19200	12.5	11.5	60.5	1	2	2	5	65.0	1.0	35.0	1.0	11000	885	0.8583
106	PA-18	R	SW SEC2 T5N R1ECM	0.5	15	20	12300	24.5	30.5	360.0	1	2	10	5	25.0	3.0	50.0	1.3	20000	1635	0.7817
107	PA-21	U	SW SEC3 T5N R1ECM	.	10	20	650	3.0	3.0	342.5	1	2	10	5	2.0	1.5	60.0	1.0	14500	480	0.8498
108	PA31A	Z	SE SEC2 T5N R1ECM	.	10	20	8500	14.0	15.5	19.5	1	2	2	10	10.0	0.5	15.0	0.5	1750	745	0.8908
109	PA-33	2	SE SEC2 T5N R1ECM	.	10	20	1850	5.5	14.0	10.0	1	2	2	10	10.0	0.5	12.5	0.5	3250	1250	0.9102
110	NM-6	F	NE SEC18 T30N R37E	2.0	30	20	900	9.5	13.5	10.5	1	2	2	2	15.0	1.5	15.0	0.8	750	1645	0.8761
111	NM-11	J	NE SEC18 T30N R37E	3.0	15	25	11200	34.5	8.5	128.5	5	5	10	2	10.0	1.0	20.0	0.8	9500	995	0.8860
112	NM-14	M	NE SEC18 T30N R37E	3.0	15	20	4450	20.0	7.5	21.0	1	2	5	2	5.0	0.5	15.0	0.5	6000	640	0.8998
113	NM-16	O	NE SEC18 T30N R37E	2.0	20	20	7300	34.5	16.5	24.0	1	2	2	2	15.0	1.0	30.0	1.0	8500	840	0.8242
114	NM-18	Q	NE SEC18 T30N R37E	0.5	20	20	10200	33.0	8.5	68.5	1	2	2	2	15.0	1.0	30.0	1.0	7500	895	0.8535
115	RL-5	E	SE SEC11 T5N R1ECM	.	35	20	3550	8.0	21.0	550.0	1	2	5	5	20.0	2.0	85.0	2.0	17500	1925	0.7250
116	RL-7	G	SE SEC11 T5N R1ECM	0.5	20	20	13500	21.5	28.5	350.0	5	2	5	2	30.0	2.0	80.0	1.5	25000	2500	0.7495
117	RL-7B	I	SE SEC11 T5N R1ECM	8.0	30	20	1100	10.5	12.5	8.0	1	2	2	2	10.0	0.2	10.0	0.5	750	315	0.9432
118	RL-8	J	NE SEC15 T5N R1ECM	2.0	15	25	11500	13.0	15.5	325.0	5	2	2	2	15.0	1.0	95.0	1.0	20500	3125	0.7901
119	RL-9	K	NE SEC15 T5N R1ECM	3.0	25	20	9500	21.0	19.0	208.0	1	2	5	5	0.5	1.5	35.0	0.5	3200	2500	0.9421
120	RL-18	T	SW SEC13 T5N R1ECM	0.5	5	25	8800	7.0	9.5	66.5	1	2	10	2	15.0	1.0	55.0	1.0	6000	1255	0.8858
121	MJ-4	D	NW SEC10 T5N R1ECM	.	15	20	3800	9.5	25.0	11.0	1	2	5	5	5.0	0.5	15.0	0.5	1250	1640	0.9028
122	MJ-6	F	NW SEC10 T5N R1ECM	.	15	20	8500	7.0	24.5	7.5	1	2	5	2	15.0	0.2	20.0	0.5	2000	1200	0.7968
123	MJ-9	I	NW SEC10 T5N R1ECM	.	30	20	7000	17.0	10.5	7.0	1	5	5	2	10.0	0.5	15.0	0.3	1500	860	0.9090
124	MJ-11	K	NW SEC10 T5N R1ECM	.	15	20	7700	14.5	32.0	25.5	1	10	2	5	45.0	1.5	30.0	0.5	2000	800	0.9163
125	EA-1	A	SW SEC18 T5N R2ECM	.	20	20	14100	18.0	23.5	50.5	5	10	10	5	25.0	1.0	85.0	0.5	10500	2750	0.8327
126	EA-3	C	SW SEC18 T5N R2ECM	.	15	20	9800	11.0	13.0	14.0	1	2	2	5	20.0	0.5	40.0	0.5	2000	1455	0.9433
127	EA-4	D	SW SEC18 T5N R2ECM	.	10	20	2300	9.5	21.5	20.0	1	2	5	2	15.0	1.0	30.0	0.5	1500	2500	0.9329
128	EA-8A	J	SW SEC23 T5N R1ECM	.	10	20	9000	4.5	5.0	5.5	1	2	2	5	10.0	1.5	20.0	0.5	3750	1030	0.9590
129	EA-10	L	SW SEC23 T5N R1ECM	.	15	20	10400	12.5	9.0	53.0	1	2	5	2	20.0	1.5	45.0	1.0	14500	1775	0.8900
130	EA-12	N	SW SEC23 T5N R1ECM	.	55	20	2650	20.5	20.5	330.0	1	2	10	5	15.0	2.0	55.0	1.5	5500	1650	0.8792
131	EA-14	P	SW SEC23 T5N R1ECM	3.0	35	20	1300	6.0	12.0	16.5	1	2	15	2	10.0	1.0	15.0	0.8	1500	440	0.9219
132	FL-2	A	SEC29 T30N R29E	0.5	20	20	5700	23.5	19.0	68.5	1	10	15	5	15.0	1.5	360.0	1.5	10000	435	0.8158

GEOCHEMICAL ANALYSIS OF THE MORRISON FORMATION-----ELEMENTAL CONCENTRATIONS IN PPM, RESIDUAL IN GM

---------- LITHO=SHALE GP=HIGH U ----------

OBS	SAMPLE	CODE	LOC	U	PB	TI	FE	ZN	CU	MN	CR	NI	CO	MO	V	CD	SR	AG	CA	MG	RESID
133	AB-1	A	NE SEC3 T5N R1ECM	2200	55	100	3175	8.0	17.5	4.5	1	2	2	70	12.5	2.5	50	0.5	6500	1590	0.8663
134	AB-2	B	NE SEC3 T5N R1ECM	720	45	50	23500	14.5	35.0	13.0	1	30	20	815	20.0	2.0	50	0.5	7000	1475	0.8765
135	AB-3	C	NE SEC3 T5N R1ECM	2600	65	200	3250	7.5	18.0	5.0	1	2	5	80	15.0	1.5	55	0.5	7250	1620	0.8927
136	AB-5	E	NE SEC3 T5N R1ECM	1450	110	50	3275	18.0	13.0	16.0	1	2	15	10	85.0	2.5	45	1.0	5000	1830	0.8391
137	AB-39	M	NE SEC3 T5N R1ECM	270	20	20	6300	7.0	12.0	76.5	1	2	10	55	10.0	1.5	30	1.0	3750	685	0.8626
138	AB-40	N	NE SEC3 T5N R1ECM	700	80	20	3750	18.0	20.0	35.5	1	2	20	5	125.0	1.5	30	1.5	5250	960	0.8783
139	AB-41	O	NE SEC3 T5N R1ECM	375	25	50	4200	4.5	9.0	12.0	1	2	15	75	10.0	1.0	30	0.5	2000	1010	0.8380
140	AB-42	P	NE SEC3 T5N R1ECM	1000	35	50	3000	8.0	6.0	8.5	1	2	5	5	25.0	1.0	30	0.5	3750	780	0.9105

APPENDIX B

DESCRIPTIVE STATISTICS OF THE

GEOCHEMICAL ANALYSIS

DESCRIPTIVE STATISTICS OF THE GEOCHEMICAL ANALYSIS-----NORMALIZED DATA BY LOG TRANSFORMATION

LITHO=CHERT GP=LOW U

VARIABLE	N	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
U	9	1.03657115	0.69853620	-0.61492247	0.30927713
FE	10	3.53682282	0.46040659	-0.17635343	-1.39579266
ZN	10	1.11685575	0.21061640	0.16528905	-1.39544671
CU	10	0.88728284	0.14260236	-1.64273961	3.64828318
PB	10	1.11465000	0.21800896	-0.34359894	-0.03169486
MN	10	1.85129941	0.67218517	0.65731972	0.60458611
CD	10	0.04475300	0.31483180	0.78487816	0.77867313
CO	10	0.98277413	0.44367072	-0.39019158	-0.49697836
CR	10	-0.00015625	0.00025409	-0.83495011	-0.64222676
NI	10	0.51056475	0.33749285	1.03509712	-1.22448968
TI	10	1.39984375	0.16239707	1.54256641	0.84676212
V	10	1.34827145	0.37777644	-0.32934068	-0.45695947
MO	10	0.97485600	0.33201701	1.67710279	3.57355255
AG	10	-0.22636744	0.38395313	0.03435152	2.84025456
CA	10	3.11617899	0.64765885	1.98312321	4.95760374
SR	10	1.08666593	0.46050146	1.94832315	4.67315788
MG	10	2.71998619	0.27187457	-1.08780488	1.29696647

------------------------ LITHO=LIMESTONE GP=LOW U ----------------------

VARIABLE	N	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
U	8	0.51254632	0.54395918	-0.80635580	-0.56546514
FE	11	3.87202276	0.39474277	-1.43361993	1.82766915
ZN	11	1.43517219	0.32237191	-0.92094317	-0.45078847
CU	11	0.97288671	0.12482400	-0.78958277	1.45533398
PB	11	1.34870632	0.15311187	0.41879961	-1.22208034
MN	11	2.83133234	0.49071686	-0.41904946	-1.27174483
CD	11	0.45829344	0.24431055	-0.48699778	-0.44735726
CO	11	0.95900070	0.27277179	0.34806011	-1.58656260
CR	11	0.34535320	0.40520540	0.38841315	-1.91536633
NI	11	0.55292604	0.32118711	0.90506761	-0.44315720
TI	11	1.33747956	0.12077431	3.31660862	10.99992199
V	11	1.15056525	0.21755272	-0.63830136	0.46457573
MO	11	0.81429525	0.47434620	0.31260857	-0.93036405
AG	11	0.33703366	0.23008412	-0.12353925	-0.88571273
CA	11	4.35979260	0.28347713	-0.19899577	0.66600668
SR	11	2.16592159	0.33547690	-1.19824046	1.60716785
MG	11	3.45513684	0.40723944	0.37094165	-1.39495496

DESCRIPTIVE STATISTICS OF THE GEOCHEMICAL ANALYSIS-----NORMALIZED DATA BY LOG TRANSFORMATION

LITHO=LIMESTONE GP=HIGH U

VARIABLE	N	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
U	1	2.41497335	.	.	.
FE	1	3.88636046	.	.	.
ZN	1	1.55617223	.	.	.
CU	1	1.06056757	.	.	.
PB	1	1.17596099	.	.	.
MN	1	2.78874485	.	.	.
CD	1	0.54393778	.	.	.
CO	1	0.69883974	.	.	.
CR	1	0.69883974	.	.	.
NI	1	0.30089973	.	.	.
TI	1	1.69883974	.	.	.
V	1	0.99986973	.	.	.
MO	1	1.30089973	.	.	.
AG	1	0.39780974	.	.	.
CA	1	4.43123350	.	.	.
SR	1	2.50501971	.	.	.
MG	1	3.47699099	.	.	.

---------------------- LITHO=SANDSTONE GP=LOW U ----------------------

VARIABLE	N	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
U	30	0.03361647	0.58069546	1.54913691	1.07982174
FE	79	3.51314603	0.41953895	0.33718128	-0.76645015
ZN	79	1.06642393	0.32149205	0.30442988	-0.22576178
CU	79	0.80630454	0.25774828	0.45366538	1.33254120
PB	79	1.07078609	0.32517191	-1.89893172	10.14718564
MN	79	1.73618655	0.76414304	0.52589531	0.17361080
CD	79	0.03666572	0.33577238	0.08834157	0.13042033
CO	79	0.80578312	0.38628197	0.95277511	2.28954247
CR	79	0.06038723	0.21679347	3.46372015	10.82152404
NI	79	0.46772772	0.35367952	2.57832412	7.41938334
TI	79	1.34701077	0.14190151	4.77776314	27.28695241
V	79	1.12548049	0.44989464	0.94246905	2.47516442
MO	79	0.63640925	0.28585614	0.72009736	0.85552257
AG	79	-0.17317287	0.37148236	0.52913985	2.33504771
CA	79	3.36079725	0.74499144	0.04943390	-1.29677433
SR	79	1.17479589	0.61928264	0.36290150	-0.27248702
MG	79	2.80745039	0.61467578	0.86527545	1.23555852

DESCRIPTIVE STATISTICS OF THE GEOCHEMICAL ANALYSIS-----NORMALIZED DATA BY LOG TRANSFORMATION

LITHO=SHALE GP=LOW U

VARIABLE	N	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
U	15	0.21091717	0.39991976	-0.28847639	-1.17733339
FE	31	3.75625532	0.39637587	-0.90478177	0.01057306
ZN	31	1.08834994	0.29806395	-0.44648472	-0.21735543
CU	31	1.11478339	0.26099301	-0.68854120	0.18656279
PB	31	1.20392925	0.23355887	-0.03153789	0.37492869
MN	31	1.58512035	0.62826820	0.43932249	-1.06410374
CD	31	-0.02310345	0.27942035	-0.77952713	0.46540597
CO	31	0.66220243	0.31230543	0.14144709	-1.29445204
CR	31	0.09018973	0.23816758	2.32733483	3.64805068
NI	31	0.39434586	0.22458547	2.20944203	3.44997961
TI	31	1.34891876	0.14299205	3.85917583	15.65574160
V	31	1.10006779	0.38574252	-1.66398876	5.37629403
MO	31	0.53867651	0.23109621	0.20326798	-1.25065456
AG	31	-0.13176709	0.20237954	0.31904812	-0.82386109
CA	31	3.65620429	0.44499247	-0.05216440	-1.14295325
SR	31	1.51024245	0.33772219	0.94198111	1.48066169
MG	31	3.05894600	0.25213368	-0.27238724	-0.39924034
------------------------ LITHO=SHALE GP=HIGH U ------------------------					
U	8	2.95332370	0.34789398	-0.14711255	-1.02952602
FE	8	3.67161381	0.30096039	2.25629646	5.25980243
ZN	8	0.98134084	0.21784139	0.12550267	-1.17920913
CU	8	1.15852360	0.23306633	-0.03801917	0.37151373
PB	8	1.67415890	0.25178178	-0.13094584	-0.90745136
MN	8	1.13899971	0.41496322	0.72821105	0.08300709
CD	8	0.20305571	0.15592414	-0.05571585	-1.20056183
CO	8	0.95655930	0.35811973	-0.88292091	-0.18579684
CR	8	-0.00009226	0.00011473	-0.43953934	1.33811078
NI	8	0.44794914	0.41581326	2.82842669	7.99999817
TI	8	1.71227899	0.33133429	0.46407884	0.33998139
V	8	1.37469526	0.41961443	1.06254348	-0.32652674
MO	8	1.58399644	0.75102591	0.37309991	-0.08470319
AG	8	-0.16622460	0.19391290	0.96643859	-0.80123960
CA	8	3.67322914	0.18715951	-1.13591045	1.21518920
SR	8	1.58740776	0.12028562	0.13702462	-2.49581024
MG	8	3.06947436	0.16127807	-0.27990680	-1.74470034

APPENDIX C

CORRELATION MATRICES

CORRELATION MATRICES-----NORMALIZED DATA BY LOG TRANSFORMATION

LITHO=CHERT GP=LOW U

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	RESID	U	FE	ZN	CU	PB	MN	CD	CO	CR	NI	TI	V	MO	AG	CA	SR	MG
RESID	1.00000 0.0000 10	-0.45266 0.2212 9	-0.15271 0.6736 10	0.08264 0.8205 10	-0.50476 0.1368 10	-0.50218 0.1391 10	-0.67811 0.0311 10	-0.72598 0.0174 10	0.10187 0.7794 10	0.74130 0.0141 10	-0.56097 0.0916 10	-0.56715 0.0873 10	-0.44554 0.1969 10	-0.14633 0.6867 10	-0.80491 0.0050 10	-0.91699 0.0002 10	-0.85079 0.0018 10	-0.43977 0.2035 10
U	-0.45266 0.2212 9	1.00000 0.0000 9	0.73354 0.0245 9	0.40923 0.2741 9	0.18321 0.6371 9	0.43147 0.2462 9	0.42028 0.2600 9	0.29431 0.4420 9	0.08667 0.8245 9	-0.74621 0.0209 9	0.57974 0.1018 9	0.20048 0.6050 9	0.75958 0.0176 9	0.71542 0.0302 9	0.38468 0.3067 9	0.54528 0.1289 9	0.48796 0.1827 9	0.45337 0.2203 9
FE	-0.15271 0.6736 10	0.73354 0.0245 9	1.00000 0.0000 10	0.88429 0.0007 10	0.44731 0.1949 10	0.66247 0.0369 10	0.54405 0.1040 10	0.28260 0.4289 10	0.39296 0.2613 10	-0.41476 0.2333 10	0.56814 0.0866 10	0.22614 0.5298 10	0.73694 0.0150 10	0.70694 0.0223 10	0.36705 0.2968 10	0.32053 0.3665 10	0.47461 0.1657 10	0.65843 0.0384 10
ZN	0.08264 0.8205 10	0.40923 0.2741 9	0.88429 0.0007 10	1.00000 0.0000 10	0.50328 0.1381 10	0.67627 0.0318 10	0.45246 0.1892 10	0.24826 0.4892 10	0.24257 0.4995 10	-0.19137 0.5964 10	0.32981 0.3520 10	0.08455 0.8164 10	0.63656 0.0478 10	0.55979 0.0924 10	0.21215 0.5562 10	0.11116 0.7598 10	0.25375 0.4793 10	0.66901 0.0344 10
CU	-0.50476 0.1368 10	0.18321 0.6371 9	0.44731 0.1949 10	0.50328 0.1381 10	1.00000 0.0000 10	0.58765 0.0740 10	0.44478 0.1978 10	0.69319 0.0262 10	-0.07584 0.8350 10	-0.48795 0.1525 10	0.48512 0.1553 10	0.20708 0.5659 10	0.45160 0.1901 10	0.31891 0.3691 10	0.86094 0.0014 10	0.41169 0.2372 10	0.54648 0.1022 10	0.78760 0.0068 10
PB	-0.50218 0.1391 10	0.43147 0.2462 9	0.66247 0.0369 10	0.67627 0.0318 10	0.58765 0.0740 10	1.00000 0.0000 10	0.82708 0.0032 10	0.59833 0.0676 10	0.29734 0.4041 10	-0.41160 0.2373 10	0.66145 0.0373 10	0.41292 0.2356 10	0.73924 0.0146 10	0.41887 0.2283 10	0.49031 0.1502 10	0.60693 0.0628 10	0.62947 0.0512 10	0.54208 0.1055 10
MN	-0.67811 0.0311 10	0.42028 0.2600 9	0.54405 0.1040 10	0.45246 0.1892 10	0.44478 0.1978 10	0.82708 0.0032 10	1.00000 0.0000 10	0.60112 0.0660 10	0.30110 0.3979 10	-0.50120 0.1400 10	0.56495 0.0888 10	0.74814 0.0128 10	0.68930 0.0275 10	0.21354 0.5536 10	0.51947 0.1238 10	0.82957 0.0030 10	0.87873 0.0008 10	0.50972 0.1323 10
CD	-0.72598 0.0174 10	0.29431 0.4420 9	0.28260 0.4289 10	0.24826 0.4892 10	0.69319 0.0262 10	0.59833 0.0676 10	0.60112 0.0660 10	1.00000 0.0000 10	-0.05531 0.8794 10	-0.56324 0.0900 10	0.63157 0.0502 10	0.24646 0.4924 10	0.52021 0.1232 10	0.49278 0.1479 10	0.70454 0.0229 10	0.77999 0.0078 10	0.74541 0.0133 10	0.52991 0.1152 10
CO	0.10187 0.7794 10	0.08667 0.8245 9	0.39296 0.2613 10	0.24257 0.4995 10	-0.07584 0.8350 10	0.29734 0.4041 10	0.30110 0.3979 10	-0.05531 0.8794 10	1.00000 0.0000 10	0.04949 0.8920 10	0.57148 0.0844 10	0.11177 0.7585 10	0.29822 0.4026 10	0.27693 0.4386 10	-0.08130 0.8233 10	0.00829 0.9819 10	0.18731 0.6043 10	-0.26308 0.4627 10
CR	0.74130 0.0141 10	-0.74621 0.0209 9	-0.41476 0.2333 10	-0.19137 0.5964 10	-0.48795 0.1525 10	-0.41160 0.2373 10	-0.50120 0.1400 10	-0.56324 0.0900 10	0.04949 0.8920 10	1.00000 0.0000 10	-0.55758 0.0940 10	-0.25464 0.4777 10	-0.72749 0.0171 10	-0.42255 0.2238 10	-0.69971 0.0243 10	-0.72000 0.0189 10	-0.62197 0.0549 10	-0.51278 0.1296 10
NI	-0.56097 0.0916 10	0.57974 0.1018 9	0.56814 0.0866 10	0.32981 0.3520 10	0.48512 0.1553 10	0.66145 0.0373 10	0.56495 0.0888 10	0.63157 0.0502 10	0.57148 0.0844 10	-0.55758 0.0940 10	1.00000 0.0000 10	0.27942 0.4343 10	0.72429 0.0178 10	0.71259 0.0207 10	0.55150 0.0984 10	0.60946 0.0614 10	0.64066 0.0460 10	0.22566 0.5308 10
TI	-0.56715 0.0873 10	0.20048 0.6050 9	0.22614 0.5298 10	0.08455 0.8164 10	0.20708 0.5659 10	0.41292 0.2356 10	0.74814 0.0128 10	0.24646 0.4924 10	0.11177 0.7585 10	-0.25464 0.4777 10	0.27942 0.4343 10	1.00000 0.0000 10	0.38283 0.2749 10	-0.10147 0.7803 10	0.34535 0.3284 10	0.65866 0.0384 10	0.71027 0.0214 10	0.27250 0.4462 10
V	-0.44554 0.1969 10	0.75958 0.0176 9	0.73694 0.0150 10	0.63656 0.0478 10	0.45160 0.1901 10	0.73924 0.0146 10	0.68930 0.0275 10	0.52021 0.1232 10	0.29822 0.4026 10	-0.72749 0.0171 10	0.72429 0.0178 10	0.38283 0.2749 10	1.00000 0.0000 10	0.67798 0.0312 10	0.40403 0.2469 10	0.63294 0.0495 10	0.57111 0.0846 10	0.45764 0.1835 10
MO	-0.14633 0.6867 10	0.71542 0.0302 9	0.70694 0.0223 10	0.55979 0.0924 10	0.31891 0.3691 10	0.41887 0.2283 10	0.21354 0.5536 10	0.49278 0.1479 10	0.27693 0.4386 10	-0.42255 0.2238 10	0.71259 0.0207 10	-0.10147 0.7803 10	0.67798 0.0312 10	1.00000 0.0000 10	0.24508 0.4950 10	0.32006 0.3673 10	0.30581 0.3902 10	0.32714 0.3562 10
AG	-0.80491 0.0050 10	0.38468 0.3067 9	0.36705 0.2968 10	0.21215 0.5562 10	0.86094 0.0014 10	0.49031 0.1502 10	0.51947 0.1238 10	0.70454 0.0229 10	-0.08130 0.8233 10	-0.69971 0.0243 10	0.55150 0.0984 10	0.34535 0.3284 10	0.40403 0.2469 10	0.24508 0.4950 10	1.00000 0.0000 10	0.64563 0.0438 10	0.75075 0.0123 10	0.73449 0.0156 10
CA	-0.91699 0.0002 10	0.54528 0.1289 9	0.32053 0.3665 10	0.11116 0.7598 10	0.41169 0.2372 10	0.60693 0.0628 10	0.82957 0.0030 10	0.77999 0.0078 10	0.00829 0.9819 10	-0.72000 0.0189 10	0.60946 0.0614 10	0.65866 0.0384 10	0.63294 0.0495 10	0.32006 0.3673 10	0.64563 0.0438 10	1.00000 0.0000 10	0.91790 0.0002 10	0.44672 0.1956 10
SR	-0.85079 0.0018 10	0.48796 0.1827 9	0.47461 0.1657 10	0.25375 0.4793 10	0.54648 0.1022 10	0.62947 0.0512 10	0.87873 0.0008 10	0.74541 0.0133 10	0.18731 0.6043 10	-0.62197 0.0549 10	0.64066 0.0460 10	0.71027 0.0214 10	0.57111 0.0846 10	0.30581 0.3902 10	0.75075 0.0123 10	0.91790 0.0002 10	1.00000 0.0000 10	0.58082 0.0783 10
MG	-0.43977 0.2035 10	0.45337 0.2203 9	0.65843 0.0384 10	0.66901 0.0344 10	0.78760 0.0068 10	0.54208 0.1055 10	0.50972 0.1323 10	0.52991 0.1152 10	-0.26308 0.4627 10	-0.51278 0.1296 10	0.22566 0.5308 10	0.27250 0.4462 10	0.45764 0.1835 10	0.32714 0.3562 10	0.73449 0.0156 10	0.44672 0.1956 10	0.58082 0.0783 10	1.00000 0.0000 10

CORRELATION MATRICES-----NORMALIZED DATA BY LOG TRANSFORMATION
LITHC=LIMESTONE GP=LOW U

CORRELATION CCEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	RESID	U	FE	ZN	CU	PB	MN	CD	CO	CR	NI	TI	V	MO	AG	CA	SR	MG
RESID	1.00000	0.34600	0.71484	0.71323	-0.22056	-0.70133	-0.85604	-0.85838	-0.45389	-0.43840	-0.42833	-0.40340	-0.42962	-0.10884	-0.90366	-0.40038	-0.65117	0.28683
	0.0000	0.4012	0.0134	0.0137	0.5146	0.0162	0.0008	0.0007	0.1608	0.1774	0.1887	0.2186	0.1873	0.7501	0.0001	0.2224	0.0300	0.3925
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
U	0.34600	1.00000	-0.65799	-0.51953	-0.15799	-0.29805	-0.38005	-0.26570	-0.31598	-0.15087	-0.48856	-0.12876	-0.12367	-0.14497	-0.40169	-0.42254	0.03802	-0.09657
	0.4012	0.0000	0.0761	0.1870	0.7087	0.4734	0.3531	0.5248	0.4458	0.7214	0.2193	0.7612	0.7705	0.7320	0.3239	0.2970	0.9288	0.8200
	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
FE	0.71484	-0.65799	1.00000	0.95259	0.03362	-0.13448	-0.40784	-0.50913	-0.04906	-0.02029	0.02136	-0.41044	-0.16410	-0.22300	-0.52834	-0.10340	-0.51396	0.50646
	0.0134	0.0761	0.0000	0.0001	0.9218	0.6934	0.2131	0.1097	0.8861	0.9528	0.9503	0.2099	0.6297	0.5098	0.0948	0.7623	0.1058	0.1119
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
ZN	0.71323	-0.51953	0.95259	1.00000	0.05635	-0.17073	-0.52647	-0.57244	0.08541	-0.09933	0.14891	-0.49150	-0.10049	-0.16155	-0.56468	-0.03941	-0.59272	0.40865
	0.0137	0.1870	0.0001	0.0000	0.8693	0.6157	0.0962	0.0657	0.8028	0.7714	0.6621	0.1247	0.7688	0.6351	0.0703	0.9084	0.0546	0.2121
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CU	-0.22056	-0.15799	0.03362	0.05635	1.00000	0.42702	0.16221	0.30518	0.04997	0.42344	0.34873	0.01885	0.10157	0.27212	0.29345	0.19957	0.17867	-0.22568
	0.5146	0.7087	0.9218	0.8693	0.0000	0.1902	0.6337	0.3615	0.8840	0.1944	0.2932	0.9561	0.7663	0.4182	0.3811	0.5563	0.5991	0.5046
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
PB	-0.70133	-0.29805	-0.13448	-0.17073	0.42702	1.00000	0.67349	0.57772	0.59112	0.66591	0.71511	0.28375	0.42729	-0.28489	0.68773	0.28463	0.22160	-0.13156
	0.0162	0.4734	0.6934	0.6157	0.1902	0.0000	0.0231	0.0627	0.0555	0.0253	0.0134	0.3978	0.1899	0.3958	0.0193	0.3963	0.5126	0.6998
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
MN	-0.85604	-0.38005	-0.40784	-0.52647	0.16221	0.67349	1.00000	0.91516	0.37881	0.60867	0.26502	0.31542	0.41511	0.06854	0.87818	0.43982	0.77045	0.08966
	0.0008	0.3531	0.2131	0.0962	0.6337	0.0231	0.0000	0.0001	0.2506	0.0469	0.4309	0.3447	0.2042	0.8413	0.0004	0.1758	0.0055	0.7932
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CD	-0.85838	-0.26570	-0.50913	-0.57244	0.30518	0.57772	0.91516	1.00000	0.29464	0.48793	0.23776	0.32997	0.48696	0.41309	0.95670	0.47850	0.88957	-0.16887
	0.0007	0.5248	0.1097	0.0657	0.3615	0.0627	0.0001	0.0000	0.3791	0.1279	0.4814	0.3217	0.1287	0.2067	0.0001	0.1365	0.0002	0.6196
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CO	-0.45389	-0.31598	-0.04906	0.08541	0.04997	0.59112	0.37881	0.29464	1.00000	0.58505	0.77029	-0.31286	0.58734	-0.31262	0.37891	0.65627	0.04337	0.13787
	0.1608	0.4458	0.8861	0.8028	0.8840	0.0555	0.2506	0.3791	0.0000	0.0587	0.0055	0.3489	0.0574	0.3493	0.2505	0.0283	0.8993	0.6860
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CR	-0.43840	-0.15087	-0.02029	-0.09933	0.42344	0.66591	0.60867	0.48793	0.58505	1.00000	0.52615	-0.28115	0.26763	-0.29817	0.45208	0.63855	0.30779	0.20424
	0.1774	0.7214	0.9528	0.7714	0.1944	0.0253	0.0469	0.1279	0.0587	0.0000	0.0964	0.4023	0.4263	0.3731	0.1627	0.0345	0.3572	0.5469
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
NI	-0.42833	-0.48856	0.02136	0.14891	0.34873	0.71511	0.26502	0.23776	0.77029	0.52615	1.00000	-0.25734	0.19756	-0.20039	0.38373	0.56023	-0.14827	-0.27733
	0.1887	0.2193	0.9503	0.6621	0.2932	0.0134	0.4309	0.4814	0.0055	0.0964	0.0000	0.4449	0.5604	0.5547	0.2440	0.0731	0.6635	0.4090
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
TI	-0.40340	-0.12876	-0.41044	-0.49150	0.01885	0.28375	0.31542	0.32997	-0.31286	-0.28115	-0.25734	1.00000	0.23309	0.13138	0.38550	-0.63703	0.31705	-0.24653
	0.2186	0.7612	0.2099	0.1247	0.9561	0.3978	0.3447	0.3217	0.3489	0.4023	0.4449	0.0000	0.4903	0.7002	0.2416	0.0350	0.3421	0.4649
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
V	-0.42962	-0.12367	-0.16410	-0.10049	0.10157	0.42729	0.41511	0.48696	0.58734	0.26763	0.19756	0.23309	1.00000	0.10462	0.55372	0.25774	0.37641	0.07425
	0.1873	0.7705	0.6297	0.7688	0.7663	0.1899	0.2042	0.1287	0.0574	0.4263	0.5604	0.4903	0.0000	0.7595	0.0772	0.4442	0.2539	0.8282
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
MO	-0.10884	-0.14497	-0.22300	-0.16155	0.27212	-0.28489	0.06854	0.41309	-0.31262	-0.29817	-0.20039	0.13138	0.10462	1.00000	0.33261	0.12781	0.54209	-0.40448
	0.7501	0.7320	0.5098	0.6351	0.4182	0.3958	0.8413	0.2067	0.3493	0.3731	0.5547	0.7002	0.7595	0.0000	0.3176	0.7080	0.0849	0.2172
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
AG	-0.90366	-0.40169	-0.52834	-0.56468	0.29345	0.68773	0.87818	0.95670	0.37891	0.45208	0.38373	0.38550	0.55372	0.33261	1.00000	0.45654	0.73642	-0.32118
	0.0001	0.3239	0.0948	0.0703	0.3811	0.0193	0.0004	0.0001	0.2505	0.1627	0.2440	0.2416	0.0772	0.3176	0.0000	0.1581	0.0098	0.3355
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CA	-0.40038	-0.42254	-0.10340	-0.03941	0.19957	0.28463	0.43982	0.47850	0.65627	0.63855	0.56023	-0.63703	0.25774	0.12781	0.45654	1.00000	0.32188	0.00524
	0.2224	0.2970	0.7623	0.9084	0.5563	0.3963	0.1758	0.1365	0.0283	0.0345	0.0731	0.0350	0.4442	0.7080	0.1581	0.0000	0.3344	0.9878
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
SR	-0.65117	0.03802	-0.51396	-0.59272	0.17867	0.22160	0.77045	0.88957	0.04337	0.30779	-0.14827	0.31705	0.37641	0.54209	0.73642	0.32188	1.00000	0.00957
	0.0300	0.9288	0.1058	0.0546	0.5991	0.5126	0.0055	0.0002	0.8993	0.3572	0.6635	0.3421	0.2539	0.0849	0.0098	0.3344	0.0000	0.9777
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
MG	0.28683	-0.09657	0.50646	0.40865	-0.22568	-0.13156	0.08966	-0.16887	0.13787	0.20424	-0.27733	-0.24653	0.07425	-0.40448	-0.32118	0.00524	0.00957	1.00000
	0.3925	0.8200	0.1119	0.2121	0.5046	0.6998	0.7932	0.6196	0.6860	0.5469	0.4090	0.4649	0.8282	0.2172	0.3355	0.9878	0.9777	0.0000
	11	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

CORRELATION MATRICES-----NORMALIZED DATA BY LOG TRANSFORMATION
LITHO=SANDSTONE GP=LOW U

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	RESID	U	FE	ZN	CU	PB	MN	CD	CO	CR	NI	TI	V	MO	AG	CA	SR	MG
RESID	1.00000 0.0000 79	-0.40443 0.0266 30	-0.48921 0.0001 79	-0.51491 0.0001 79	-0.25725 0.0221 79	-0.46765 0.0001 79	-0.73604 0.0001 79	-0.69441 0.0001 79	-0.33135 0.0029 79	-0.55522 0.0001 79	-0.39065 0.0004 79	-0.14121 0.2145 79	-0.28534 0.0108 79	0.09341 0.4129 79	-0.63223 0.0001 79	-0.66000 0.0001 79	-0.69012 0.0001 79	-0.71164 0.0001 79
U	-0.40443 0.0266 30	1.00000 0.0000 30	-0.18594 0.3252 30	0.00124 0.9948 30	0.27739 0.1378 30	0.31913 0.0856 30	0.31599 0.0889 30	0.01398 0.9415 30	0.31499 0.0900 30	0.55837 0.0014 30	0.45789 0.0109 30	-0.10386 0.5849 30	0.15949 0.3999 30	0.42010 0.0208 30	-0.02992 0.8753 30	0.09066 0.6337 30	0.34476 0.0621 30	0.08988 0.6367 30
FE	-0.48921 0.0001 79	-0.18594 0.3252 30	1.00000 0.0000 79	0.77630 0.0001 79	0.36780 0.0009 79	0.44957 0.0001 79	0.61301 0.0001 79	0.43905 0.0001 79	0.41985 0.0001 79	0.19549 0.0842 79	0.40721 0.0002 79	0.10300 0.3663 79	0.66743 0.0001 79	0.13788 0.2256 79	0.39902 0.0003 79	0.44465 0.0001 79	0.54941 0.0001 79	0.56533 0.0001 79
ZN	-0.51491 0.0001 79	0.00124 0.9948 30	0.77630 0.0001 79	1.00000 0.0000 79	0.38285 0.0005 79	0.49714 0.0001 79	0.73444 0.0001 79	0.48943 0.0001 79	0.36619 0.0009 79	0.32761 0.0032 79	0.45684 0.0001 79	0.06477 0.5707 79	0.59184 0.0001 79	0.17741 0.1178 79	0.42108 0.0001 79	0.48084 0.0001 79	0.56819 0.0001 79	0.53060 0.0001 79
CU	-0.25725 0.0221 79	0.27739 0.1378 30	0.36780 0.0009 79	0.38285 0.0005 79	1.00000 0.0000 79	0.27599 0.0138 79	0.28964 0.0096 79	0.16053 0.1576 79	0.10720 0.3470 79	0.24123 0.0322 79	0.16792 0.1391 79	0.02076 0.8559 79	0.25120 0.0255 79	-0.02658 0.8161 79	0.16858 0.1375 79	0.25484 0.0234 79	0.31115 0.0053 79	0.34376 0.0019 79
PB	-0.46765 0.0001 79	0.31913 0.0856 30	0.44957 0.0001 79	0.49714 0.0001 79	0.27599 0.0138 79	1.00000 0.0000 79	0.60383 0.0001 79	0.46625 0.0001 79	0.39653 0.0003 79	0.37435 0.0007 79	0.49413 0.0001 79	0.14848 0.1916 79	0.47323 0.0001 79	0.05874 0.6071 79	0.30875 0.0056 79	0.47659 0.0001 79	0.62620 0.0001 79	0.51188 0.0001 79
MN	-0.73604 0.0001 79	0.31599 0.0889 30	0.61301 0.0001 79	0.73444 0.0001 79	0.28964 0.0096 79	0.60383 0.0001 79	1.00000 0.0000 79	0.61626 0.0001 79	0.44888 0.0001 79	0.45216 0.0001 79	0.57734 0.0001 79	0.06493 0.5697 79	0.51052 0.0001 79	0.04984 0.6627 79	0.49652 0.0001 79	0.56107 0.0001 79	0.63764 0.0001 79	0.57892 0.0001 79
CD	-0.69441 0.0001 79	0.01398 0.9415 30	0.43905 0.0001 79	0.48943 0.0001 79	0.16053 0.1576 79	0.46625 0.0001 79	0.61626 0.0001 79	1.00000 0.0000 79	0.42182 0.0001 79	0.48233 0.0001 79	0.44126 0.0001 79	0.14939 0.1889 79	0.38553 0.0005 79	-0.04941 0.6654 79	0.59636 0.0001 79	0.65221 0.0001 79	0.68896 0.0001 79	0.63666 0.0001 79
CO	-0.33135 0.0029 79	0.31499 0.0900 30	0.41985 0.0001 79	0.36619 0.0009 79	0.10720 0.3470 79	0.39653 0.0003 79	0.44888 0.0001 79	0.42182 0.0001 79	1.00000 0.0000 79	0.20320 0.0725 79	0.62431 0.0001 79	0.24127 0.0322 79	0.44996 0.0001 79	0.26689 0.0174 79	0.33044 0.0029 79	0.34253 0.0020 79	0.42061 0.0001 79	0.27885 0.0128 79
CR	-0.55522 0.0001 79	0.55837 0.0014 30	0.19549 0.0842 79	0.32761 0.0032 79	0.24123 0.0322 79	0.37435 0.0007 79	0.45216 0.0001 79	0.48233 0.0001 79	0.20320 0.0725 79	1.00000 0.0000 79	0.34056 0.0021 79	-0.09127 0.4237 79	0.17228 0.1290 79	0.07575 0.5070 79	0.42999 0.0001 79	0.39084 0.0004 79	0.53043 0.0001 79	0.36780 0.0009 79
NI	-0.39065 0.0004 79	0.45789 0.0109 30	0.40721 0.0002 79	0.45684 0.0001 79	0.16792 0.1391 79	0.49413 0.0001 79	0.57734 0.0001 79	0.44126 0.0001 79	0.62431 0.0001 79	0.34056 0.0021 79	1.00000 0.0000 79	0.01479 0.8970 79	0.56470 0.0001 79	0.22428 0.0469 79	0.27400 0.0145 79	0.29443 0.0084 79	0.46264 0.0001 79	0.34602 0.0018 79
TI	-0.14121 0.2145 79	-0.10386 0.5849 30	0.10300 0.3663 79	0.06477 0.5707 79	0.02076 0.8559 79	0.14848 0.1916 79	0.06493 0.5697 79	0.14939 0.1889 79	0.24127 0.0322 79	-0.09127 0.4237 79	0.01479 0.8970 79	1.00000 0.0000 79	0.07884 0.4898 79	-0.02367 0.8360 79	0.17641 0.1199 79	0.19120 0.0914 79	0.17685 0.1190 79	0.04199 0.7133 79
V	-0.28534 0.0108 79	0.15949 0.3999 30	0.66743 0.0001 79	0.59184 0.0001 79	0.25120 0.0255 79	0.47323 0.0001 79	0.51052 0.0001 79	0.38553 0.0005 79	0.44996 0.0001 79	0.17228 0.1290 79	0.56470 0.0001 79	0.07884 0.4898 79	1.00000 0.0000 79	0.31495 0.0047 79	0.27321 0.0148 79	0.22224 0.0490 79	0.32677 0.0033 79	0.28787 0.0101 79
MO	0.09341 0.4129 79	0.42010 0.0208 30	0.13788 0.2256 79	0.17741 0.1178 79	-0.02658 0.8161 79	0.05874 0.6071 79	0.04984 0.6627 79	-0.04941 0.6654 79	0.26689 0.0174 79	0.07575 0.5070 79	0.22428 0.0469 79	-0.02367 0.8360 79	0.31495 0.0047 79	1.00000 0.0000 79	-0.11120 0.3292 79	-0.15569 0.1707 79	-0.06887 0.5464 79	-0.15913 0.1613 79
AG	-0.63223 0.0001 79	-0.02992 0.8753 30	0.39902 0.0003 79	0.42108 0.0001 79	0.16858 0.1375 79	0.30875 0.0056 79	0.49652 0.0001 79	0.59636 0.0001 79	0.33044 0.0029 79	0.42999 0.0001 79	0.27400 0.0145 79	0.17641 0.1199 79	0.27321 0.0148 79	-0.11120 0.3292 79	1.00000 0.0000 79	0.57094 0.0001 79	0.57753 0.0001 79	0.55509 0.0001 79
CA	-0.66000 0.0001 79	0.09066 0.6337 30	0.44465 0.0001 79	0.48084 0.0001 79	0.25484 0.0234 79	0.47659 0.0001 79	0.56107 0.0001 79	0.65221 0.0001 79	0.34253 0.0020 79	0.39084 0.0004 79	0.29443 0.0084 79	0.19120 0.0914 79	0.22224 0.0490 79	-0.15569 0.1707 79	0.57094 0.0001 79	1.00000 0.0000 79	0.80068 0.0001 79	0.75147 0.0001 79
SR	-0.69012 0.0001 79	0.34476 0.0621 30	0.54941 0.0001 79	0.56819 0.0001 79	0.31115 0.0053 79	0.62620 0.0001 79	0.63764 0.0001 79	0.68896 0.0001 79	0.42061 0.0001 79	0.53043 0.0001 79	0.46264 0.0001 79	0.17685 0.1190 79	0.32677 0.0033 79	-0.06887 0.5464 79	0.57753 0.0001 79	0.80068 0.0001 79	1.00000 0.0000 79	0.79502 0.0001 79
MG	-0.71164 0.0001 79	0.08988 0.6367 30	0.56533 0.0001 79	0.53060 0.0001 79	0.34376 0.0019 79	0.51188 0.0001 79	0.57892 0.0001 79	0.63666 0.0001 79	0.27885 0.0128 79	0.36780 0.0009 79	0.34602 0.0018 79	0.04199 0.7133 79	0.28787 0.0101 79	-0.15913 0.1613 79	0.55509 0.0001 79	0.75147 0.0001 79	0.79502 0.0001 79	1.00000 0.0000 79

CORRELATION MATRICES-----NORMALIZED DATA BY LOG TRANSFORMATION
LITHO=SHALE GP=LOW U

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	RESID	U	FE	ZN	CU	PB	MN	CD	CO	CR	NI	TI	V	MO	AG	CA	SR	MG
RESID	1.00000	0.67249	-0.25146	-0.31000	-0.40153	-0.22590	-0.62739	-0.27760	-0.14378	-0.38146	-0.04848	-0.09561	-0.36191	0.10515	-0.64004	-0.69056	-0.60873	-0.30173
	0.0000	0.0060	0.1724	0.0897	0.0252	0.2217	0.0002	0.1305	0.4403	0.0342	0.7957	0.6089	0.0454	0.5735	0.0001	0.0001	0.0003	0.0990
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
U	0.67249	1.00000	-0.44948	-0.24574	-0.40948	0.19915	-0.56609	-0.64925	-0.28479	-0.06746	-0.22391	0.16955	-0.40705	-0.08294	-0.79516	-0.64119	-0.68910	-0.27124
	0.0060	0.0000	0.0928	0.3773	0.1296	0.4767	0.0278	0.0088	0.3036	0.8112	0.4224	0.5458	0.1321	0.7689	0.0004	0.0100	0.0045	0.3281
	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
FE	-0.25146	-0.44948	1.00000	0.52721	0.17950	-0.22261	0.15608	0.06000	-0.06083	0.33679	0.19397	0.41763	0.37432	0.05532	-0.02659	0.43156	0.31171	0.37708
	0.1724	0.0928	0.0000	0.0023	0.3339	0.2287	0.4018	0.7485	0.7451	0.0639	0.2958	0.0194	0.0380	0.7675	0.8871	0.0153	0.0878	0.0365
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
ZN	-0.31000	-0.24574	0.52721	1.00000	0.41248	0.40509	0.33207	0.05463	-0.01079	0.29081	0.29939	0.21885	0.20074	-0.21098	0.08751	0.31008	0.26502	0.16342
	0.0897	0.3773	0.0023	0.0000	0.0211	0.0238	0.0680	0.7704	0.9541	0.1125	0.1018	0.2369	0.2789	0.2546	0.6397	0.0896	0.1496	0.3797
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
CU	-0.40153	-0.40948	0.17950	0.41248	1.00000	0.40354	0.21370	0.04054	-0.10606	0.18235	0.25938	-0.14828	0.31098	0.02442	0.12018	-0.01268	0.22571	0.43610
	0.0252	0.1296	0.3339	0.0211	0.0000	0.0244	0.2484	0.8286	0.5701	0.3262	0.1588	0.4260	0.0886	0.8962	0.5196	0.9460	0.2221	0.0142
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
PB	-0.22590	0.19915	-0.22261	0.40509	0.40354	1.00000	0.27154	0.08378	0.02949	0.05786	0.13611	-0.22736	-0.00438	-0.22391	0.18943	-0.01742	0.08638	0.00722
	0.2217	0.4767	0.2287	0.0238	0.0244	0.0000	0.1395	0.6541	0.8749	0.7572	0.4653	0.2187	0.9813	0.2259	0.3074	0.9259	0.6440	0.9693
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
MN	-0.62739	-0.56609	0.15608	0.33207	0.21370	0.27154	1.00000	0.61749	0.31817	0.39345	0.01106	-0.02107	-0.02984	0.01027	0.70056	0.78979	0.68455	0.34735
	0.0002	0.0278	0.4018	0.0680	0.2484	0.1395	0.0000	0.0002	0.0811	0.0285	0.9529	0.9104	0.8734	0.9563	0.0001	0.0001	0.0001	0.0555
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
CD	-0.27760	-0.64925	0.06000	0.05463	0.04054	0.08378	0.61749	1.00000	0.29482	0.13761	0.10276	-0.14700	0.07768	0.12390	0.66811	0.53972	0.52298	0.30645
	0.1305	0.0088	0.7485	0.7704	0.8286	0.6541	0.0002	0.0000	0.1074	0.4604	0.5822	0.4300	0.6779	0.5066	0.0001	0.0017	0.0025	0.0936
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
CO	-0.14378	-0.28479	-0.06083	-0.01079	-0.10606	0.02949	0.31817	0.29482	1.00000	0.10979	0.23380	-0.02841	-0.17981	-0.02773	0.24710	0.26839	0.37398	-0.06309
	0.4403	0.3036	0.7451	0.9541	0.5701	0.8749	0.0811	0.1074	0.0000	0.5566	0.2056	0.8794	0.3331	0.8823	0.1802	0.1443	0.0382	0.7360
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
CR	-0.38146	-0.06746	0.33679	0.29081	0.18235	0.05786	0.39345	0.13761	0.10979	1.00000	0.31532	0.00138	0.16526	-0.23392	0.14744	0.45807	0.31009	0.42424
	0.0342	0.8112	0.0639	0.1125	0.3262	0.7572	0.0285	0.4604	0.5566	0.0000	0.0840	0.9941	0.3743	0.2053	0.4286	0.0096	0.0896	0.0174
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
NI	-0.04848	-0.22391	0.19397	0.29939	0.25938	0.13611	0.01106	0.10276	0.23380	0.31532	1.00000	-0.10339	0.21909	0.09477	-0.11939	0.06154	0.34520	-0.12408
	0.7957	0.4224	0.2958	0.1018	0.1588	0.4653	0.9529	0.5822	0.2056	0.0840	0.0000	0.5799	0.2364	0.6121	0.5223	0.7423	0.0572	0.5060
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
TI	-0.09561	0.16955	0.41763	0.21885	-0.14828	-0.22736	-0.02107	-0.14700	-0.02841	0.00138	-0.10339	1.00000	0.32831	0.12357	-0.06140	0.11849	0.08428	0.04877
	0.6089	0.5458	0.0194	0.2369	0.4260	0.2187	0.9104	0.4300	0.8794	0.9941	0.5799	0.0000	0.0714	0.5078	0.7428	0.5255	0.6521	0.7944
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
V	-0.36191	-0.40705	0.37432	0.20074	0.31098	-0.00438	-0.02984	0.07768	-0.17981	0.16526	0.21909	0.32831	1.00000	-0.06813	0.25219	0.19866	0.22548	0.11133
	0.0454	0.1321	0.0380	0.2789	0.0886	0.9813	0.8734	0.6779	0.3331	0.3743	0.2364	0.0714	0.0000	0.7157	0.1711	0.2840	0.2226	0.5510
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
MO	0.10515	-0.08294	0.05532	-0.21098	0.02442	-0.22391	0.01027	0.12390	-0.02773	-0.23392	0.09477	0.12357	-0.06813	1.00000	-0.07332	-0.00297	0.09640	0.00503
	0.5735	0.7689	0.7675	0.2546	0.8962	0.2259	0.9563	0.5066	0.8823	0.2053	0.6121	0.5078	0.7157	0.0000	0.6951	0.9873	0.6059	0.9786
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
AG	-0.64004	-0.79516	-0.02659	0.08751	0.12018	0.18943	0.70056	0.66811	0.24710	0.14744	-0.11939	-0.06140	0.25219	-0.07332	1.00000	0.65219	0.60755	0.09962
	0.0001	0.0004	0.8871	0.6397	0.5196	0.3074	0.0001	0.0001	0.1802	0.4286	0.5223	0.7428	0.1711	0.6951	0.0000	0.0001	0.0003	0.5939
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
CA	-0.69056	-0.64119	0.43156	0.31008	-0.01268	-0.01742	0.78979	0.53972	0.26839	0.45807	0.06154	0.11849	0.19866	-0.00297	0.65219	1.00000	0.71226	0.27358
	0.0001	0.0100	0.0153	0.0896	0.9460	0.9259	0.0001	0.0017	0.1443	0.0096	0.7423	0.5255	0.2840	0.9873	0.0001	0.0000	0.0001	0.1364
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
SR	-0.60873	-0.68910	0.31171	0.26502	0.22571	0.08638	0.68455	0.52298	0.37398	0.31009	0.34520	0.08428	0.22548	0.09640	0.60755	0.71226	1.00000	0.28399
	0.0003	0.0045	0.0878	0.1496	0.2221	0.6440	0.0001	0.0025	0.0382	0.0896	0.0572	0.6521	0.2226	0.6059	0.0003	0.0001	0.0000	0.1215
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
MG	-0.30173	-0.27124	0.37708	0.16342	0.43610	0.00722	0.34735	0.30645	-0.06309	0.42424	-0.12408	0.04877	0.11133	0.00503	0.09962	0.27358	0.28399	1.00000
	0.0990	0.3281	0.0365	0.3797	0.0142	0.9693	0.0555	0.0936	0.7360	0.0174	0.5060	0.7944	0.5510	0.9786	0.5939	0.1364	0.1215	0.0000
	31	15	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31

CORRELATION MATRICES-----NORMALIZED DATA BY LOG TRANSFORMATION
LITHO=SHALE GP=HIGH U

CORRELATICN COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 8

	RESID	U	FE	ZN	CU	PB	MN	CD	CO	CR	NI	TI	V	MO	AG	CA	SR	MG
RESID	1.00000	0.31401	-0.03242	0.03177	-0.03270	-0.00778	-0.26397	-0.31235	-0.36772	0.37373	0.09778	0.21105	0.00831	-0.15868	-0.24048	0.40213	0.03452	-0.23956
	0.0000	0.4488	0.9392	0.9405	0.9387	0.9854	0.5276	0.4513	0.3702	0.3618	0.8178	0.6159	0.9844	0.7074	0.5662	0.3233	0.9353	0.5677
U	0.31401	1.00000	-0.39063	0.23097	0.20621	0.71265	-0.78812	0.47170	-0.59231	0.20889	-0.11143	0.80049	0.17946	-0.07517	-0.30933	0.68648	0.76212	0.74996
	0.4488	0.0000	0.3387	0.5821	0.6242	0.0473	0.0202	0.2380	0.1218	0.6196	0.7928	0.0170	0.6707	0.8596	0.4559	0.0601	0.0279	0.0321
FE	-0.03242	-0.39063	1.00000	0.21844	0.62460	-0.25802	0.25577	0.17574	0.49091	-0.06219	0.93893	-0.22817	-0.18574	0.75133	-0.13549	0.20958	0.18866	0.03174
	0.9392	0.3387	0.0000	0.6033	0.0978	0.5372	0.5409	0.6772	0.2167	0.8837	0.0005	0.5868	0.6597	0.0316	0.7491	0.6184	0.6546	0.9405
ZN	0.03177	0.23097	0.21844	1.00000	0.52602	0.75847	0.22941	0.57787	0.43439	-0.21340	0.33370	-0.28170	0.86181	-0.23169	0.58156	0.57265	0.23293	0.36073
	0.9405	0.5821	0.6033	0.0000	0.1805	0.0292	0.5847	0.1335	0.2822	0.6119	0.4192	0.4991	0.0059	0.5809	0.1305	0.1379	0.5788	0.3800
CU	-0.03270	0.20621	0.62460	0.52602	1.00000	0.39618	-0.00712	0.62895	0.24199	0.23358	0.66832	0.10848	0.15265	0.59532	0.09669	0.73171	0.62101	0.53712
	0.9387	0.6242	0.0978	0.1805	0.0000	0.3312	0.9867	0.0948	0.5637	0.5777	0.0700	0.7982	0.7182	0.1195	0.8198	0.0391	0.1003	0.1698
PB	-0.00778	0.71265	-0.25802	0.75847	0.39618	1.00000	-0.28556	0.60057	0.04695	-0.07828	-0.03378	0.27549	0.76375	-0.30737	0.31394	0.62010	0.52425	0.72215
	0.9854	0.0473	0.5372	0.0292	0.3312	0.0000	0.4930	0.1154	0.9121	0.8538	0.9367	0.5090	0.0274	0.4590	0.4489	0.1010	0.1823	0.0431
MN	-0.26397	-0.78812	0.25577	0.22941	-0.00712	-0.28556	1.00000	-0.10857	0.62683	-0.38221	-0.02459	-0.90522	0.24254	-0.19161	0.78063	-0.30246	-0.62364	-0.60760
	0.5276	0.0202	0.5409	0.5847	0.9867	0.4930	0.0000	0.7980	0.0963	0.3501	0.9539	0.0020	0.5628	0.6494	0.0222	0.4665	0.0985	0.1101
CD	-0.31235	0.47170	0.17574	0.57787	0.62895	0.60057	-0.10857	1.00000	-0.12063	-0.06667	0.25365	0.17677	0.24896	0.24255	0.17733	0.69114	0.70155	0.72238
	0.4513	0.2380	0.6772	0.1335	0.0948	0.1154	0.7980	0.0000	0.7760	0.8754	0.5444	0.6754	0.5521	0.5627	0.6744	0.0577	0.0525	0.0430
CO	-0.36772	-0.59231	0.49091	0.43439	0.24199	0.04695	0.62683	-0.12063	1.00000	-0.47039	0.38843	-0.61025	0.45033	0.03684	0.50038	-0.25430	-0.32623	-0.13585
	0.3702	0.1218	0.2167	0.2822	0.5637	0.9121	0.0963	0.7760	0.0000	0.2395	0.3416	0.1081	0.2628	0.9310	0.2066	0.5433	0.4303	0.7484
CR	0.37373	0.20889	-0.06219	-0.21340	0.23358	-0.07828	-0.38221	-0.06667	-0.47039	1.00000	0.01934	0.19903	-0.21752	0.13557	-0.28321	0.20933	0.05374	-0.04745
	0.3618	0.6196	0.8837	0.6119	0.5777	0.8538	0.3501	0.8754	0.2395	0.0000	0.9637	0.6366	0.6048	0.7489	0.4967	0.6188	0.8994	0.9112
NI	0.09778	-0.11143	0.93893	0.33370	0.66832	-0.03378	-0.02459	0.25365	0.38843	0.01934	1.00000	-0.01628	-0.07108	0.71402	-0.28115	0.37092	0.37448	0.24860
	0.8178	0.7928	0.0005	0.4192	0.0700	0.9367	0.9539	0.5444	0.3416	0.9637	0.0000	0.9695	0.8672	0.0466	0.5000	0.3657	0.3607	0.5527
TI	0.21105	0.80049	-0.22817	-0.28170	0.10848	0.27549	-0.90522	0.17677	-0.61025	0.19903	-0.01628	1.00000	-0.35091	0.32195	-0.72065	0.40447	0.76526	0.67315
	0.6159	0.0170	0.5868	0.4991	0.7982	0.5090	0.0020	0.6754	0.1081	0.6366	0.9695	0.0000	0.3941	0.4368	0.0437	0.3203	0.0269	0.0673
V	0.00831	0.17946	-0.18574	0.86181	0.15265	0.76375	0.24254	0.24896	0.45033	-0.21752	-0.07108	-0.35091	1.00000	-0.62784	0.69974	0.24344	-0.09260	0.16909
	0.9844	0.6707	0.6597	0.0059	0.7182	0.0274	0.5628	0.5521	0.2628	0.6048	0.8672	0.3941	0.0000	0.0956	0.0533	0.5613	0.8274	0.6889
MO	-0.15868	-0.07517	0.75133	-0.23169	0.59532	-0.30737	-0.19161	0.24255	0.03684	0.13557	0.71402	0.32195	-0.62784	1.00000	-0.54055	0.23555	0.52742	0.32666
	0.7074	0.8596	0.0316	0.5809	0.1195	0.4590	0.6494	0.5627	0.9310	0.7489	0.0466	0.4368	0.0956	0.0000	0.1666	0.5744	0.1792	0.4297
AG	-0.24048	-0.30933	-0.13549	0.58156	0.09669	0.31394	0.78063	0.17733	0.50038	-0.28321	-0.28115	-0.72065	0.69974	-0.54055	1.00000	0.00065	-0.40514	-0.24685
	0.5662	0.4559	0.7491	0.1305	0.8198	0.4489	0.0222	0.6744	0.2066	0.4967	0.5000	0.0437	0.0533	0.1666	0.0000	0.9988	0.3194	0.5556
CA	0.40213	0.68648	0.20958	0.57265	0.73171	0.62010	-0.30246	0.69114	-0.25430	0.20933	0.37092	0.40447	0.24344	0.23555	0.00065	1.00000	0.77963	0.60407
	0.3233	0.0601	0.6184	0.1379	0.0391	0.1010	0.4665	0.0577	0.5433	0.6188	0.3657	0.3203	0.5613	0.5744	0.9988	0.0000	0.0225	0.1127
SR	0.03452	0.76212	0.18866	0.23293	0.62101	0.52425	-0.62364	0.70155	-0.32623	0.05374	0.37448	0.76526	-0.09260	0.52742	-0.40514	0.77963	1.00000	0.89888
	0.9353	0.0279	0.6546	0.5788	0.1003	0.1823	0.0985	0.0525	0.4303	0.8994	0.3607	0.0269	0.8274	0.1792	0.3194	0.0225	0.0000	0.0024
MG	-0.23956	0.74996	0.03174	0.36073	0.53712	0.72215	-0.60760	0.72238	-0.13585	-0.04745	0.24860	0.67315	0.16909	0.32666	-0.24685	0.60407	0.89888	1.00000
	0.5677	0.0321	0.9405	0.3800	0.1698	0.0431	0.1101	0.0430	0.7484	0.9112	0.5527	0.0673	0.6889	0.4297	0.5556	0.1127	0.0024	0.0000

APPENDIX D

FACTOR ANALYSIS

FACTOR ANALYSIS OF LOW URANIUM CHERT-----NORMALIZED DATA BY LOG TRANSFORMATION

ROTATION METHOD: VARIMAX

	1	2	3	4	5	6	7
EIGENVALUES	7.041928	2.516572	1.230482	0.986920	0.580261	0.439499	0.143062
PORTION	0.542	0.194	0.095	0.076	0.045	0.034	0.011
CUM PORTION	0.542	0.735	0.830	0.906	0.950	0.984	0.995

	8	9	10	11	12	13
EIGENVALUES	0.061278	0.000000	0.000000	0.000000	-0.000000	-0.000000
PORTION	0.005	0.000	0.000	0.000	-0.000	-0.000
CUM PORTION	1.000	1.000	1.000	1.000	1.000	1.000

ROTATED FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3
RESID	-0.96106	0.01970	0.10038
U	0.39839	0.64158	0.15426
FE	0.14989	0.95760	0.08663
ZN	-0.05443	0.95149	-0.13850
PB	0.56369	0.62841	0.06690
CD	0.80088	0.25113	-0.09013
MN	0.80780	0.38210	-0.03456
SR	0.91285	0.25171	-0.03201
CO	-0.08597	0.22491	0.88464
MO	0.21093	0.74820	0.37004
V	0.48196	0.74447	0.10463
CA	0.97164	0.14764	-0.03681
MG	0.38387	0.64929	-0.58630

FACTOR ANALYSIS OF LOW URANIUM LIMESTONE-----NORMALIZED DATA BY LOG TRANSFORMATION

INITIAL FACTOR METHOD: PRINCIPAL AXIS

	1	2	3	4	5	6	7
EIGENVALUES	6.075539	3.144761	1.691937	1.297461	0.554817	0.157946	0.077539
PORTION	0.467	0.242	0.130	0.100	0.043	0.012	0.006
CUM PORTION	0.467	0.709	0.839	0.939	0.982	0.994	1.000

	8	9	10	11	12	13
EIGENVALUES	0.000000	0.000000	0.000000	0.000000	-0.000000	-0.000000
PORTION	0.000	0.000	0.000	0.000	-0.000	-0.000
CUM PORTION	1.000	1.000	1.000	1.000	1.000	1.000

3 FACTORS WILL BE RETAINED.

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3
RESID	-0.92522	-0.12514	-0.01850
U	-0.46886	0.29713	0.63251
FE	0.57084	-0.68935	-0.38852
ZN	0.29015	-0.74921	-0.43933
PB	0.74922	-0.35411	0.02567
CD	0.82250	0.54821	-0.12883
MN	0.92899	0.26672	0.09605
SR	0.53654	0.76483	0.03188
CO	0.75917	-0.54617	0.27960
MO	-0.02249	0.65213	-0.63859
V	0.78140	0.01115	0.35643
CA	0.90715	0.35955	-0.14301
MG	0.43652	-0.26322	0.53535

FACTOR ANALYSIS OF LOW URANIUM SANDSTONE-----NORMALIZED DATA BY LOG TRANSFORMATION

INITIAL FACTOR METHOD: PRINCIPAL AXIS

	1	2	3	4	5	6	7	8	9
EIGENVALUES	4.585399	1.130211	1.097418	0.929388	0.470358	0.364690	0.233674	0.121931	0.066930
PORTION	0.509	0.126	0.122	0.103	0.052	0.041	0.026	0.014	0.007
CUM PORTION	0.509	0.635	0.757	0.860	0.913	0.953	0.979	0.993	1.000

3 FACTORS WILL BE RETAINED.

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3
RESID	-0.83372	0.31228	0.00373
FE	0.70107	0.57277	-0.08902
CU	0.39280	-0.25417	-0.04357
ZN	0.71461	0.38674	-0.41209
MN	0.85375	-0.31673	-0.09879
SR	0.90118	-0.16832	-0.07045
CO	0.54545	-0.25846	0.70164
V	0.45180	0.54315	0.61919
MG	0.83139	-6.04E-05	-0.16540

FACTOR ANALYSIS OF LOW URANIUM SHALE-----NORMALIZED DATA BY LOG TRANSFORMATION

ROTATION METHOD: VARIMAX

	1	2	3	4	5	6	7	8
EIGENVALUES	4.870196	1.143610	0.790566	0.458327	0.318762	0.276727	0.115730	0.026080
PORTION	0.609	0.143	0.099	0.057	0.040	0.035	0.014	0.003
CUM PORTION	0.609	0.752	0.851	0.908	0.948	0.932	0.997	1.000

ROTATED FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3
RESID	-0.72503	-0.38916	-0.39321
FE	0.29277	0.91820	-0.04680
CU	0.42178	0.06229	0.85567
MN	0.39236	0.65956	0.49190
SR	0.77361	0.34422	0.19938
AG	0.87855	0.02132	0.17006
CA	0.64588	0.70135	0.12703
MG	-0.09993	0.71260	0.54393

FACTOR ANALYSIS OF HIGH URANIUM SHALE-----NORMALIZED DATA BY LOG TRANSFORMATION

INITIAL FACTOR METHOD: PRINCIPAL AXIS

	1	2	3	4	5	6	7
EIGENVALUES	5.167364	3.632786	1.998641	1.108087	0.649699	0.327705	0.115717
PORTION	0.397	0.279	0.154	0.085	0.050	0.025	0.009
CUM PORTION	0.397	0.677	0.831	0.916	0.966	0.991	1.000

	8	9	10	11	12	13
EIGENVALUES	0.000000	0.000000	0.000000	-0.000000	-0.000000	-0.000000
PORTION	0.000	0.000	0.000	-0.000	-0.000	-0.000
CUM PORTION	1.000	1.000	1.000	1.000	1.000	1.000

3 FACTORS WILL BE RETAINED.

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3
U	0.88061	-0.26515	-0.37967
CU	0.61054	0.25984	0.69328
ZN	0.50636	0.83220	-0.01101
PB	0.80848	0.45060	-0.33249
CD	0.75301	0.26472	0.27400
MN	-0.59873	0.67060	0.25735
CR	0.16820	-0.44724	0.06320
CO	-0.30083	0.74491	0.32675
MO	0.18255	-0.37586	0.88343
V	0.28745	0.83906	-0.41255
TI	0.63672	-0.68319	-0.11660
CA	0.85662	0.10480	0.19432
MG	0.89980	-0.04078	0.09557

VITA 2

Marvin Milton Abbott

Candidate for the Degree of Master of

Master of Science

Thesis: A BASIC EVALUATION OF THE URANIUM POTENTIAL OF THE MORRISON FORMATION OF NORTHWESTERN CIMARRON COUNTY, OKLAHOMA, AND ADJOINING AREAS OF NEW MEXICO AND COLORADO

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