PRELIMINARY RESULTS OF MINERALOGY AND PETROLOGY OF THE COZZETTE INTERVAL (DEPTH 7871 - 7957 ft) DRILL CORE MWX-1

by

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INTRODUCTION

Sandia National Laboratories is conducting and directing the Multi-Well Experiment (MWX) core analysis program as part of the Western Gas Sands Project for the Department of Energy's Unconventional Gas Sands Program. Sandia National Laboratories will carry out sample selection, sample distribution, prioritization of analyses, distribution of data, and coordination of interagency analyses. The U.S.G.S., along with Sandia, will provide interpretation of analytical results. A sedimentological model of the Mesa Verde Group at the Multi-Well site will be published by J.C. Lorenze (Sandia).

The Petrology Laboratory of Bendix Field Engineering Corporation is providing routine mineralogic and petrologic analyses of MWX core samples and interpretations, as detailed in this report. These are preliminary results to be used primarily for characterization of the general mineralogy and textures of an interval so that variations in mineralogic trends can be delineated. This report is the second of fifteen which will present the results of petrologic analyses of the fifteen intervals to be submitted from drill holes MWX-1 and 2. Included here are mineralogic and petrologic data from the Cozzette Interval of drill hole MWX-1.

PROCEDURES

SAMPLE PREPARATION

Sixteen samples were submitted from the Cozzette Interval which extends from hole depths of 7871 ft to 7957 ft. The samples were received on April 2, 1982 and consisted of eleven whole plug samples and five end-chips of plugs which were sent to Core Laboratories, Inc., Denver, Colorado, for

routine core analysis. (The five end-chips were duplicates of five of the whole plug samples and were used only for comparisons).

Thin section preparation, thin section analysis, clay mineral analysis and other X-ray diffraction analyses were done as described for the Coastal Interval, MWX-1.

RESULTS

LITHOLOGY

The overall rock type of the Cozzette Interval is subarkose, according to classification by Folk, (1980). The samples are generally very fine sand-sized, feldspar- and lithic-rich quartz sandstones. Detrital grains are well-sorted, angular to subrounded and very fine sand-sized grading to fine sand-sized at the bottom of the interval. These sandstones are well indurated with concavo-convex and sutured grain contacts. Criteria used for picking changes in lithology (for detailed description) were: grain size, bedding characteristics and carbonate content.

Interval 7871.2 to 7896.7 ft

The top third of the Cozzette Interval is well sorted, very fine sand-sized, and is devoid of bedding. This interval shows a gradual increase in carbonate content toward the bottom.

Sample 7911.5 ft

At this level indistinct horizons of coarser-grained detritus form bedding planes. It is less well sorted than the above samples, but the average grain size remains the same.

Sample 7916.0 ft

The lithologic characteristics of this sample are very similar to those at 7896.7 ft.

Sample 7944.8 ft

This sample shows an increase in the average grain size to nearly fine sand-size, and a decrease in the carbonate content.

Samples 7952.3 and 7957.3 ft

These samples continue the trend of increasing average grain size toward the bottom of the Cozzette Interval. Carbonate disappears entirely at 7952.3 ft and 7957.3 ft.

MINERALOGY

The overall mineralogy of this interval is very similar to that of the Coastal Interval. The major detrital framework consists of quartz, feldspars and rock fragments, including chert. Other detrital minerals include muscovite, biotite, opaques, zircon and tourmaline. Carbonate, clays and limonite are also found.

Quartz occurs generally as equidimensional grains throughout the interval. At 7911.5 ft the grain size of the quartz is quite variable compared to the rest of the Cozzette Interval. Indistinct horizons of relatively coarser quartz grains (up to medium sand-size) and the subparallel orientation of elongate quartz grains form bedding planes.

Quartz is mostly monocrystalline, but a few polycrystalline varieties were observed in most samples. The quartz is fairly clear and rutile inclusions are common. Secondary quartz overgrowths are common throughout the Cozette Interval, but are often difficult to distinguish from some angular detrital quartz.

Plagioclase is the dominant feldspar in this interval. Alteration of the plagioclase ranges from nearly fresh to almost totally altered. Alteration is to clay and sericite. All of the fresher plagioclase displayed polysynthetic twins and altered grains had remnant twin lamellae. Many unidentified

grains composed of sericite and clay may be totally altered plagioclase.

K-feldspar content ranges from very few grains to three percent of the mode. The most common K-feldspar is microcline, but perthite was also observed in some samples. The alteration of K-feldspar was generally slight.

Nearly all of the rock fragments are mudstones, claystones and a few carbonate clasts. Also a few are highly altered, but may be volcanics and metamorphics. There is an increase in relative abundance of rock fragments at sample depths 7911.5 ft, 7944.8 ft, 7052.3 ft and 7957.3 ft. The last two samples contain relatively clear claystone fragments while most of the fragments uphole are limonitized. Some of these claystone fragments could represent totally altered plagioclase grains. Chert was found in all of the samples.

The predominant carbonate mineral is dolomite, while calcite is rarely present. Dolomite occurs as irregular patches and rhombohedral grains. Carbonate is fairly abundant throughout the Cozzette Interval, but disappears completely at the bottom.

In most of the samples containing dolomite there is textural evidence supporting dolomite replacement of quartz. Subhedral to euhedral rhombs as well as irregular patches of dolomite are surrounded by interlocking quartz grains.

Detrital opaques as well as framboidal pyrite, limonite and carbonaceous(?) material are present in the Cozzette Interval. Limonite and pyrite are more common in the upper portion of the interval (7871.2 ft through 7944.8 ft) than in the lower portion. Framboidal pyrite (or cubic aggregates of pyrite) is common at 7911.5 ft and 7893.7 ft. Carbonaceous(?) material occurs as small patches and thin stringers in the upper part of the interval.

CLAY MINERALOGY

Clay minerals identified by X-ray diffraction include an illite-montmorillonite mixed layer clay, kaolinite and chlorite. Illite, without interstratified montmorillonite, may also be present in some samples (7944.8 ft and 7957.4 ft).

In general the air dried X-ray diffraction patterns for the clay minerals showed major [001] peaks at approximately 14.4 Å, 10.6 Å and 7.2 Å. Upon glycolation the 14.4 Å peak did not shift in any of the clay patterns. This indicates the presence of chlorite rather than montmorillonite. The 10.6 Å peak shifted to 10.1 Å with a pronounced step at about 11.5 Å. This step indicates illite with small amounts of interstratified montmorillonite with some detree of ordered interstratification. Clay samples at 7944.8 ft and 7957.4 ft did not show a shift in the [001] illite peak.

X-ray diffraction patterns of the clays heated to 330°C confirmed the presence of chlorite and interstratified montmorillonite with the illite. The 14.4 Å peak remained and the stepped illite peak collapsed to 10.1 Å. The 7.2 Å kaolinite peak remained unchanged. Upon heating to 550°C the 7.2 Å kaolinite peak collapsed leaving a small second order chlorite peak.

Several trends in the clay mineralogy, corresponding to the minor lithology changes discussed earlier, were observed. In the upper part of the Cozzette Interval (7871.2 ft to 7896.7 ft) the illite/montmorillonite mixed-layer clay is the dominant clay mineral. Kaolinite comprises a major portion of the clay fraction at 7871.2 ft, but gradually decreases to a minor constituent to 7896.7 ft (See Chart 1). A trace of chlorite occurs throughout this interval. At 7911.5 ft kaolinite is the major clay mineral with the illite/montmorillonite mixed-layer clay occurring in a moderate amount (See Chart 2). Chlorite also occurs in this sample in minor amounts. At 7915.8 ft

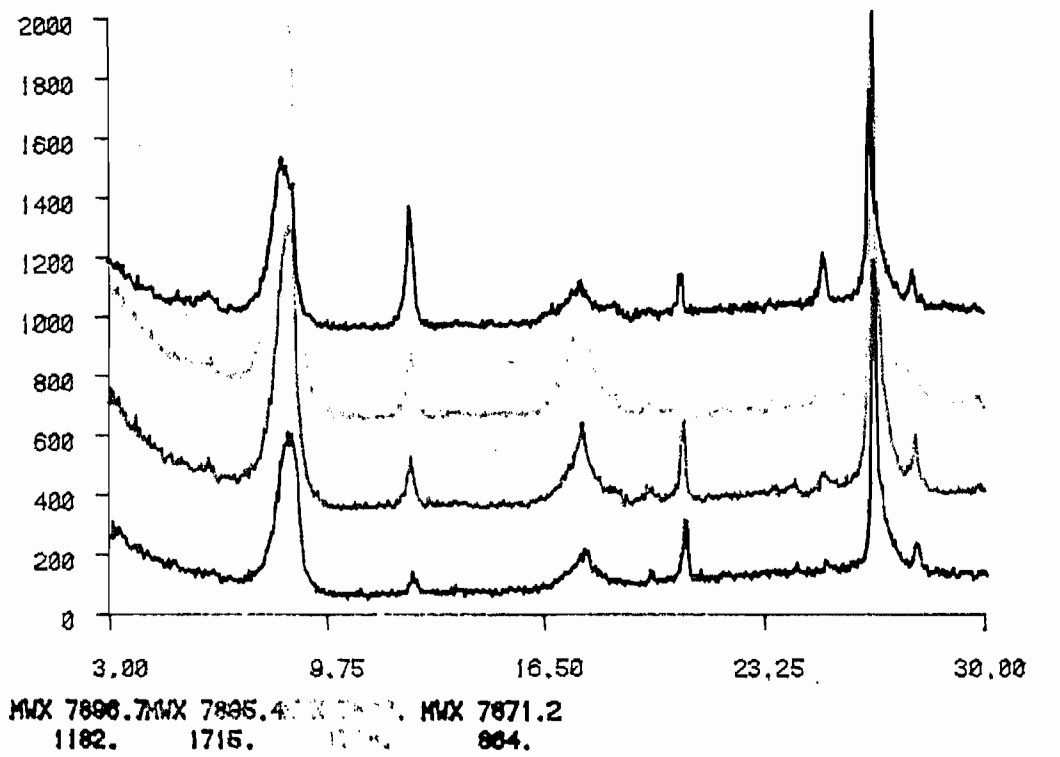


Chart 1. X-ray diffraction patterns of air-dried clay showing the decreasing kaolinite (7.2 Å, 12.3°2θ) in the upper one-third of the Cozzette Interval. Sample depths for each pattern are written left to right starting at the bottom of the interval.

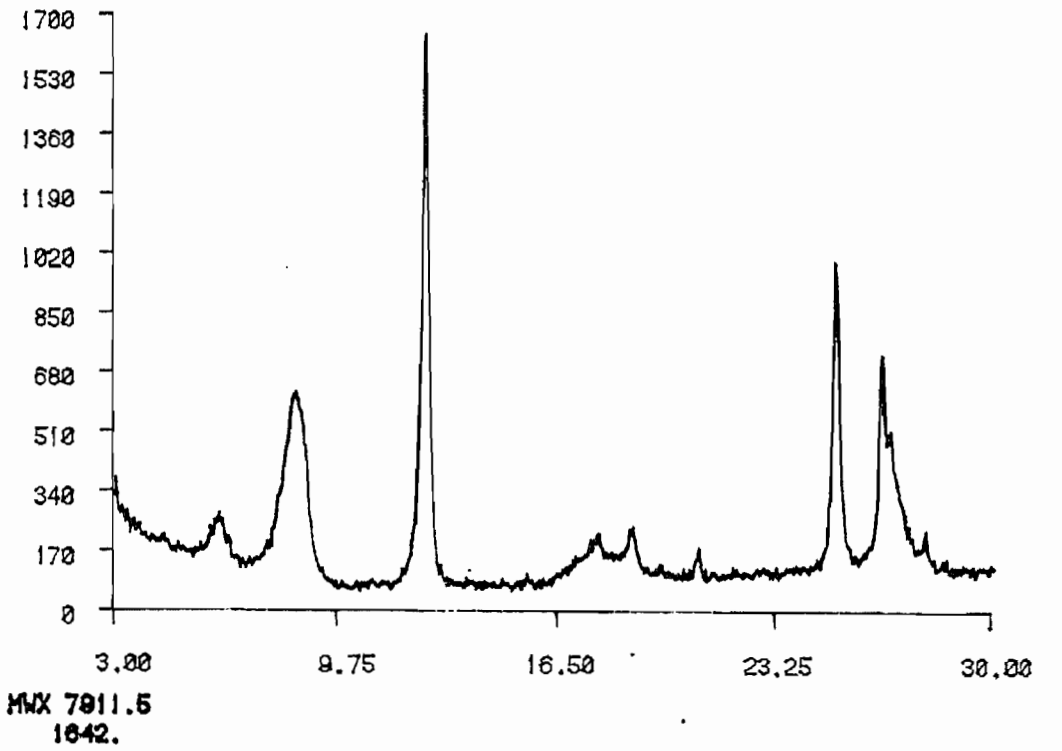


Chart 2. X-ray diffraction pattern of air-dried clay at 7911.5 ft. At this depth kaolinite is the dominant clay mineral.

the ratio of kaolinite to the illite/montmorillonite mixed-layer clay is very similar to the ratio at 7871.2 ft. The chlorite content is also similar. The illite/montmorillonite mixed-layer clay remains dominant through the bottom of the interval. As mentioned previously, illite without the interstratified montmorillonite could be present at 7944.8 ft and 7957.4 ft. Results of clay mineral results are in Appendix D.

Clay minerals occur as interstitial patches, along grain boundaries, lining pore spaces, filling pore throats and as rounded clasts. Many of the clasts and patches may be distorted, totally altered feldspars and rock fragments. Kaolinite generally occurs as authigenic pore filling. Chlorite, when coating detrital quartz grains, inhibits the formation of secondary quartz overgrowths.

PORE SPACE

Porosity in the Cozzette Interval is dominated by microporosity in clay-filled intergranular pore space, as was the case in the Coastal Interval. Clay-filled pore throats, open voids and microporosity in altered feldspar also contribute to the porosity.

In the finer-grained samples intergranular pore space tends to be very small and of irregular shape with very thin pore throats (See Photo 1). In the coarser-grained samples (7952.3 ft and 7957.3 ft) the size of the pore space is greatly increased (See Photo 2). The percent pore space also tends to increase with grain size. However at 7911.5 ft the percent porosity is significantly greater than in any of the other samples. Porosity in this sample is dominated by many small irregularly shaped pores and pore throats (See Photo 3).

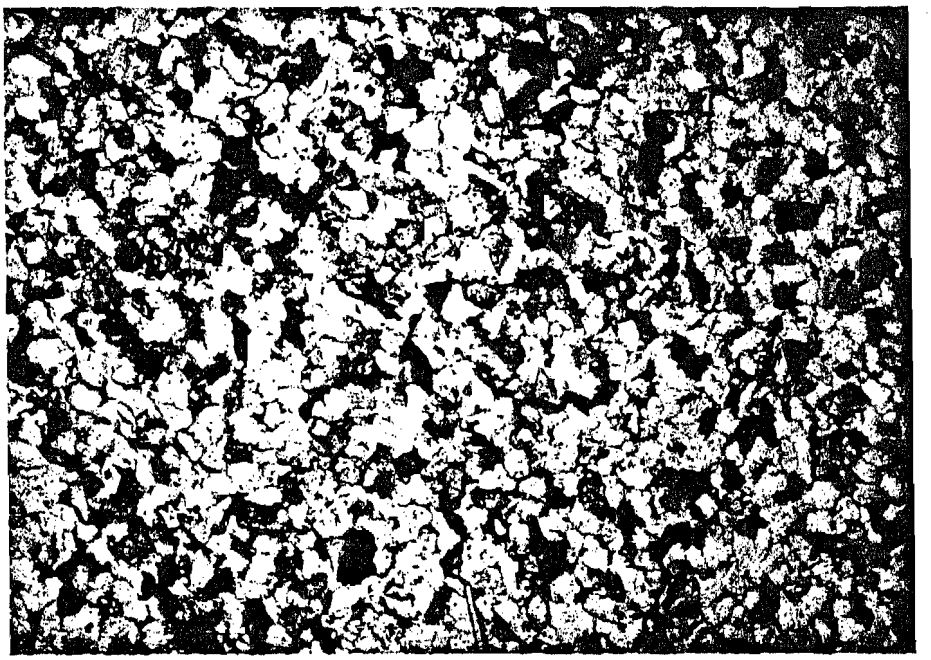


Photo 1. Blue impregnated areas show small irregular pores. 7883.3 ft. Plane polarized light.

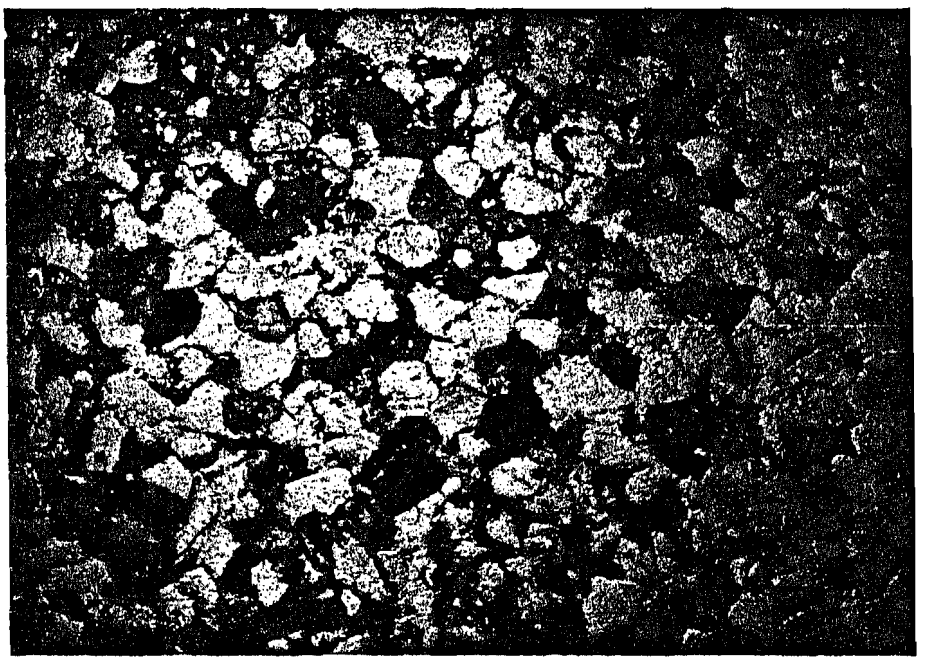


Photo 2. Pores are much larger in this coarser grained sample. 7957.4 ft. Plane polarized light.

Photo 3. Numerous very small irregular shaped pores and pore throats. 7911.5 ft. Plane polarized light.

Randomly oriented and loosely packed clays are usually well impregnated with blue epoxy. Pore space and pore throats containing clay minerals which occur as tightly stacked books show relatively little, if any, impregnation. This is more evident in the coarser grained samples as the grain size of the clay minerals also tends to increase in these samples.

Some pore spaces which are void of clay also contain dolomite and quartz. Two samples 7916.0 ft and 7957.3 ft contain pores which may be filled with a zeolite mineral (negative relief, low birefringence), however no zeolite minerals were detected using X-ray diffraction.

CHIP/PLUG COMPARISONS

Thin sections of core plug end-chips and those taken near the center of whole plugs were compared in order to determine if coring effects were more evident in the end-chips. No significant lithologic differences were observed. Excessive fracturing which might have been expected near the edge of the core was not evident.

PARAGENESIS

A general diagenetic sequence for the Cozzette Interval is interpreted as an early(?) carbonate stage; feldspar alteration; formation of chlorite; formation of authigenic quartz overgrowths; authigenic clays, and dolomitization of a later calcite(?). Most of these events probably overlap, with some occurring simultaneously.

The presence of an early carbonate (calcite?) could not be adequately determined. Dolomite replacement of quartz and other minerals makes the identification of an early carbonate stage difficult. The only evidence of the early carbonate is the entrapment of carbonate (calcite?) under secondary quartz overgrowths (See Photo 4).

Photo 4. Carbonate (calcite?) trapped under secondary quartz overgrowths. 7944.8 ft. Crossed polarizers.

Alteration of feldspars probably started very early in the sequence and continued throughout. Some of the clay minerals were probably present during deposition, however most were formed by the alteration of feldspars and breakdown of rock fragments. Clay trapped under quartz overgrowths is evidence for detrital clay or early alteration of feldspars.

Secondary quartz overgrowths on detrital quartz grains occur throughout the Cozzette Interval. The lack of quartz overgrowths on detrital quartz grains coated by chlorite is evidence that chlorite preceded the formation of the secondary overgrowths. Authigenic development of kaolinite probably followed or occurred simultaneously with these overgrowths.

It seems unlikely that the dolomite which is pervasive in most of the samples is primary, therefore, it is suggested that it is probably replacement of a later stage calcite. The occurrence of this late stage calcite could not be easily positioned in the diagenetic sequence. Complete dolomitization of the calcite and replacement of other authigenic and detrital minerals obscures all the evidence for this calcite stage.

SUMMARY

The Cozzette Interval consists of generally very fine-grained sandstones with minimal mineralogic variations except for the distinct lack of carbonate minerals at the bottom of the Interval. As in the Coastal Interval, permeability appears to be controlled more by clay mineral morphology in pores and pore throats rather than by compaction and overgrowths. A more extensive study of the relationship of pore space and pore filling material is suggested to fully understand porosity and permeability controls in these sandstones.

BIBLIOGRAPHY

Folk, R.L., 1980, Petrology of Sedimentary Rocks (2d ed.): Austin, Texas, Hemphill Publishing Company, 184 p.

APPENDIX A

SUMMARY OF RESULTS
COZZETTE INTERVAL

Depth ft	Rock Name	Mean Grain Size mm	% Pore Space	% Carbonate	Clay Analysis (by XRD)
7871.2	Subarkose	0.06	7	5	X
7883.3	Subarkose	0.06	11	6	-
7890.4	Subarkose	0.06	6	10	X
7893.7	Subarkose	0.06	7	9	-
7895.4	Calc. Subarkose	0.07	13	13	X
7896.7	Calc. Subarkose	0.07	9	14	X
7911.5	Subarkose	0.07	18	10	X
7916.0	Calc. Subarkose	0.07	7	15	X
7944.8	Subarkose	0.11	11	4	X
7952.3	Sublitharenite	0.12	13	-	X
7957.3	Subarkose	0.13	15	-	X

APPENDIX B
PRIORITY INTERVALS AND
THE TENTATIVE DATES OF COMPLETION
(IN ORDER OF PRIORITY) FOR
MINERALOGY AND PETROLOGY ANALYSES

Priority	Depth	Well	Interval	Tentative Completion Date
1	6345-6580	MWX-1	Coastal	06/30/82
2	7817-7900	MWX-1	Cozzette	06/30/82
3	7832-8141	MWX-2	Corcoran & Cozzette	07/30/82
4	5690-5870	MWX-1	Fracture Zone	09/15/82
5	7080-7390	MWX-2	Paludal	11/05/82
6	6400-6580	MWX-2	Coastal	11/28/83
7	4840-4960	MWX-1	High Fluvial I	12/31/82
8	4180-4400	MWX-1	Top	02/07/83
9	5690-5870	MWX-2	Fracture Zone	02/28/83
10	4490-4840	MWX-1	High Fluvial II	04/28/83
11	4960-5300	MWX-1	Mid Fluvial I	06/13/83
12	5300-5690	MWX-1	Mid Fluvial II	08/08/83
13	5870-6345	MWX-1	Low Fluvial	09/23/83
14	6580-6830	MWX-1	Bottom Fluvial	10/18/83
15	4880-4950	MWX-2	High Fluvial I	11/18/83

APPENDIX C
PETROGRAPHIC DATA SHEETS

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7871.2
INTERVAL: Cozzette

Petrologist: M. L. Dixon
Date: May 27, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.06
Grain Size Range (mm): 0.02 - 0.13

% Pore Space: 7
Sorting (est.): Well Sorted
Angularity (est.): SA to SR

GENERAL DESCRIPTION: Well indurated; grain contacts are concavo-convex and to a lesser degree sutured; some evidence of carbonate replacement of quartz; porosity is dominated by microporosity in intergranular clays and pore throats; a few open voids are also present.

COMPOSITION	%	COMMENTS
Quartz	60	Mostly monocrystalline; few polycrystalling; rutile inclusions in some
K-feldspar	1	Microcline and perthite
Plagioclase	6	Nearly fresh to almost totally altered
Chert	2	
Lithics	2	Claystones
Authigenic Minerals		
Silica O. gr.	7	
Calcite	tr	Very fine patches associated with dolomite
Dolomite	5	Dolomite/calcite ratios visually estimated; rarely twinned
Muscovite	tr	Contorted
Biotite	tr	Contorted
Opaques	1	Detrital grains and globular masses which may be alteration product
Accessory Minerals		
Zircon	tr	
Tourmaline	tr	
Other	tr	Limonitic clay coating some grains
Unknown	tr	Thin stringers of carbonaceous material?
Voids w/o Clay	1	
Voids w/Clay	6	
Clay Minerals	9	Intergranular patches
Kaolinite (By XRD)	Mod	
Chlorite (By XRD)	tr	Angular quartz grains in contact with chlorite have no overgrowths
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7883.3
INTERVAL: Cozzette

Petrologist: M. L. Dixon
Date: May 27, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.06
Grain Size Range (mm): 0.03 - 0.10

% Pore Space: 11
Sorting (est.): Well Sorted
Angularity (est.): SA to SR

GENERAL DESCRIPTION: Mineralogically and texturally similar to the previous sample (MWX-7871.2); porosity is dominated by clay-filled intergranular pores and pore throats. Few open pores were observed.

COMPOSITION	%	COMMENTS
Quartz	60	
K-feldspar	1	
Plagioclase	4	Many replaced by carbonate
Chert	3	
Lithics	1	Claystones and carbonate clasts
Authigenic Minerals		
Silica O. gr.	5	
Calcite	tr	
Dolomite	6	Dolomite/calcite ratio by visual estimate. Twinned.
Muscovite	tr	
Biotite	tr	Altered to chlorite
Opaques	tr	
Accessory Minerals		
Zircon	tr	
Tourmaline	tr	
Apatite	tr	
Voids w/o Clay	tr	
Voids w/Clay	11	Illite patches, clay clasts, and pore throats
Clay Minerals	7	Should be similar to previous sample
Kaolinite (Optically)	tr	Pore filling
Chlorite (Optically)	tr	After biotite
Mixed Layer (Optically)	Dom	Intergranular patches (mixed layer assumed)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7890.4
INTERVAL: Cozzette

Petrologist: M. L. Dixon
Date: May 27, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.06
Grain Size Range (mm): 0.02 - 0.10

% Pore Space: 6
Sorting (est.): Well Sorted
Angularity (est.): SR to SA

GENERAL DESCRIPTION: Mineralogically and texturally similar to previous samples; distinct decrease in kaolinite (XRD effects); porosity dominated by clay-filled pores and to a lesser degree open voids; very few pore throats observed; distinct decrease in pore space from previous sample.

COMPOSITION	%	COMMENTS
Quartz	62	
K-feldspar	1	
Plagioclase	2	
Chert	2	
Lithics	1	
Authigenic Minerals		
Silica O. gr.	5	
Calcite	tr	Very fine patch associated with dolomite
Dolomite	10	Dolomite/calcite ratio by visual estimate. Twinned.
Muscovite	tr	
Biotite	tr	Largely altered to chlorite
Opaques	tr	
Accessory Minerals		
Zircon	tr	
Tourmaline	tr	
Voids w/o Clay	1	
Voids w/Clay	5	
Clay Minerals	10	Common around quartz grains; no epoxy impregnation
Kaolinite (By XRD)	Minor	
Chlorite (By XRD)	tr	Altered detrital biotite
Mixed Layer (By XRD)	Dom	Illite/montmorillonite

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7893.7
INTERVAL: Cozzette

Petrologist: M. L. Dixon
Date: May 27, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.06
Grain Size Range (mm): 0.02 - 0.10

% Pore Space: 7
Sorting (est.): Well Sorted
Angularity (est.): SA to SR

GENERAL DESCRIPTION: Very similar in composition and texture to the previous samples. Pore space dominated by clay-filled pores and to a lesser degree open voids and pore throats.

COMPOSITION	%	COMMENTS
Quartz	58	
K-felspar	1	
Plagioclase	4	
Chert	1	
Lithics	2	
Authigenic Minerals		
Silica O. gr.	5	
Dolomite	9	Visual estimate of calcite stain; twinned
Muscovite	1	
Biotite	tr	
Opaques	1	Aggregates of pyrite cubes
Accessory Minerals		
Tourmaline	tr	
Zircon	tr	
Other	tr	Ferruginous clay common
Voids w/o Clay	1	
Voids w/Clay	6	
Clay Minerals	9	Not included in pore space
Kaolinite (Optically)	Minor	Should be similar to previous sample
Chlorite (Optically)	tr	Should be similar to previous sample
Mixed Layer (Optically)	Dom	Should be similar to previous sample

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7895.4
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: May 28, 1982

Rock Type: Calcareous Subarkose
Mean Grain Size (mm): 0.07
Grain Size Range (mm): 0.2 to 0.02

% Pore Space: 13
Sorting (est.): Well
Angularity (est.): Angular to SR

GENERAL DESCRIPTION: Very similar in composition and texture to previous samples; porosity is dominated by clay-filled intergranular pores and pore throats; few open voids observed; some blue epoxy penetrated under quartz overgrowths.

COMPOSITION	%	COMMENTS
Quartz	56	
K-feldspar	1	
Plagioclase	4	
Chert	tr	
Lithics	2	
Authigenic Minerals		
Silica O. gr.	8	
Calcite	tr	
Dolomite	13	Some twinned
Muscovite	1	
Biotite	tr	
Opaques	1	Irregular patches; few detrital grains; few pyrite framboids
Unknown	tr	Phosphatic blebs?
Voids w/o Clay	1	
Voids w/Clay	12	
Clay Minerals	tr	Not included in pore space
Kaolinite (By XRD)	Minor	
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7896.7
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: May 28, 1982

Rock Type: Calcareous Subarkose
Mean Grain Size (mm): 0.07
Grain Size Range (mm): 0.02 - 0.13

% Pore Space: 9
Sorting (est.): Well
Angularity (est.): Angular to SR

GENERAL DESCRIPTION: Very similar in composition and texture to previous samples; slight increase in amount of opaque minerals; distinct decrease in kaolinite (XRD effects); porosity is dominated by clay-filled voids; few open pores; very few pore thorats observed.

COMPOSITION	%	COMMENTS
Quartz	57	
K-feldspar	tr	
Plagioclase	6	
Chert	tr	
Lithics	1	
Authigenic Minerals		
Silica O. gr.	10	
Calcite	tr	
Dolomite	14	Some twinned
Muscovite	tr	
Biotite	tr	
Opaques	2	Globular patches and possible pyrite framboids
Accessory Minerals		
Zircon	tr	
Tourmaline	tr	
Other	tr	
Unknown	tr	
Voids w/o Clay	1	
Voids w/Clay	8	
Clay Minerals	1	Not included in pore space
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)
Kaolinite (By XRD)	tr	

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7911.5
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: May 28, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.07
Grain Size Range (mm): 0.03 - 0.30

% Pore Space: 18
Sorting (est.): Moderate
Angularity (est.): Angular to SR

GENERAL DESCRIPTION: Well indurated; elongate indistinct horizons of coarser quartz and subparallel orientation of elongate grains form thin beds; grain contacts are concavo-convex or sutured; porosity is dominated by many small clay-filled voids and pore throats; very few open pores observed.

COMPOSITION	%	COMMENTS
Quartz	50	Mostly monocrystalline; thin horizons of coarser grains
K-feldspar	tr	Microcline
Plagioclase	7	Nearly fresh to almost totally altered
Chert	2	
Lithics	4	Mostly mudstone possibly some volcanics
Authigenic Minerals		
Silica O. gr.	3	
Calicte	tr	
Dolomite	10	Some twinned
Silica Cement	tr	Microcrystalline and fibrous habit
Muscovite	tr	
Biotite	tr	Altering to chlorite
Opaques	3	Many aggregates of fine-grained cubic pyrite parallel to bedding
Accessory Minerals		
Zircon	tr	
Other	1	Ferruginous clay
Unknown	tr	Jarosite? intergranular patches
Voids w/o Clay	tr	
Voids w/Clay	18	Small irregular intergranular voids and pore throats
Clay Minerals	1	Not included in pore space
Kaolinite (By XRD)	Dom	
Chlorite (By XRD)	Minor	
Mixed Layer (By XRD)	Mod	Illite/montmorillonite (illite dominant)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7916.0
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: May 28, 1982

Rock Type: Calcareous Subarkose
Mean Grain Size (mm): 0.07
Grain Size Range (mm): 0.02 - 0.15

% Pore Space: 7
Sorting (est.): Well
Angularity (est.): Angular to SR

GENERAL DESCRIPTION: Well indurated; grain contacts are concavo-convex and sutured; porosity is dominated by small intergranular clay-filled pores and some pore throats.

COMPOSITION	%	COMMENTS
Quartz	59	Mostly monocrystalline
K-feldspar	tr	Microcline
Plagioclase	2	Nearly fresh to almost totally altered
Chert	1	
Lithics	2	Mudstones
Authigenic Minerals		
Silica O. gr.	5	
Calcite	tr	
Dolomite	15	Some twinned
Muscovite	tr	
Biotite	tr	Altering to chlorite
Opaques	2	Aggregates of pyrite cubes
Accessory Minerals		
Zircon	tr	
Tourmaline	tr	
Other	1	Ferruginous clay
Unknown	1	Totally altered feldspars?
Voids w/o Clay	tr	
Voids w/Clay	7	
Clay Minerals	3	Not included in pore space
Kaolinite (By XRD)	Mod	Pore filling; authigenic
Chlorite (By XRD)	tr	Intergranular patches
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7944.8 | Petrologist: M. O. Eatough
INTERVAL: Cozzette | Date: June 1, 1982

Rock Type: Subarkose | % Pore Space: 11
Mean Grain Size (mm): 0.11 | Sorting (est.): Well
Grain Size Range (mm): 0.03 - 0.30 | Angularity (est.): A to SR

GENERAL DESCRIPTION: Well indurated; concavo-convex and sutured grain contacts; distinct drop in carbonate and increase in grain size; porosity is dominated by clay-filled pores and a few open pores and pore throats.

COMPOSITION	%	COMMENTS
Quartz	58	Mostly monocrystalline; some rutilated grains
K-feldspar	3	Microcline
Plagioclase	4	Nearly fresh to almost totally altered
Chert	3	
Lithics	4	Mudstones; possibly some metamorphic fragments
Authigenic Minerals		
Silica O. gr.	3	Carbonate under a few grains
Calcite	tr	
Dolomite	4	Some twinned
Muscovite	1	Contorted around detrital grains
Biotite	tr	Altering to ferruginous clay and chlorite
Opaques	1	Pyrite? aggregates
Accessory Minerals		
Zircon	tr	
Other	1	Ferruginous clay with pyrite? aggregates
Unknown	5	Probably totally sericitized plagioclase or clay clasts
Voids w/o Clay	1	
Voids w/Clay	10	
Clay Minerals	2	Not included in pore space
Kaolinite (By XRD)	Minor	Authigenic
Chlorite (By XRD)	tr	Irregular patches and biotite alteration
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7952.3
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: June 1, 1982

Rock Type: Sublitharenite
Mean Grain Size (mm): 0.12
Grain Size Range (mm): 0.05 - 0.35

% Pore Space: 13
Sorting (est.): Moderate to Well
Angularity (est.): A to SR

GENERAL DESCRIPTION: Well indurated; concavo-convex grain contacts; deformation of grains due to compaction appears to be less than in most previous samples; distinct absence of carbonate. Porosity is dominated by well impregnated clay-filled pores and pore throats. Very few open pores.

COMPOSITION	%	COMMENTS
Quartz	69	Mostly monocrystalline; few metamorphic
K-feldspar	1	Microcline
Plagioclase	5	Many bent twins; nearly fresh to almost totally altered
Chert	2	
Lithics	6	Mudstones; some volcanic
Authigenic Minerals		
Silica O. gr.	3	
Muscovite	tr	
Biotite	tr	
Opaques	tr	Intergranular patches; possibly limonite
Accessory Minerals		
Zircon	tr	
Voids w/o Clay	tr	
Voids w/Clay	13	Very well impregnated
Clay Minerals	1	Not included in pore space
Kaolinite (By XRD)	Mod	
Chlorite (By XRD)	tr	
Mixed Layer (By XRD)	Dom	Illite/montmorillonite

MULTI-WELL PETROGRAPHIC ANALYSIS

SAMPLE NO: MWX-7957.3
INTERVAL: Cozzette

Petrologist: M. O. Eatough
Date: June 1, 1982

Rock Type: Subarkose
Mean Grain Size (mm): 0.13
Grain Size Range (mm): 0.03 - 0.35

% Pore Space: 15
Sorting (est.): Moderate to Well
Angularity (est.): A to SR

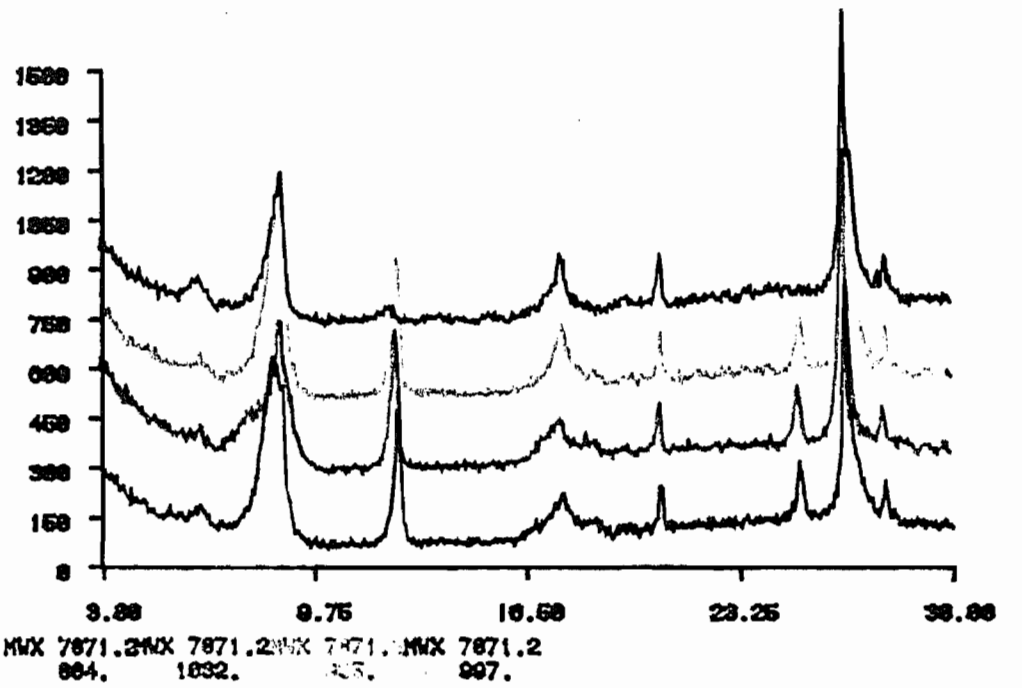
GENERAL DESCRIPTION: Very similar to the previous sample (MWX-7952.4); possilby a little more angular overall. Pore space is dominated by well impregnated clay-filled pores and pore throats. A few open pores observed. Areas where clay shows a random orientation, porosity is higher, and areas where clay has stacked orientation, decreases. Possibly some zeolites in a few pores.

COMPOSITION	%	COMMENTS
Quartz	62	
K-feldspar	2	
Plagioclase	8	
Chert	2	
Lithics	6	
Authigenic Minerals		
Silica O. gr.	3	
Muscovite	tr	
Biotite	tr	
Opaques	tr	
Other	tr	Possibly zeolites in some voids
Voids w/o Clay	1	
Voids w/Clay	14	
Clay Minerals	2	
Kaolinite (By XRD)	Mod	
Chlorite (By XRD)	tr	
Mixed Layer (By XRD)	Dom	Illite/montmorillonite (illite dominant)

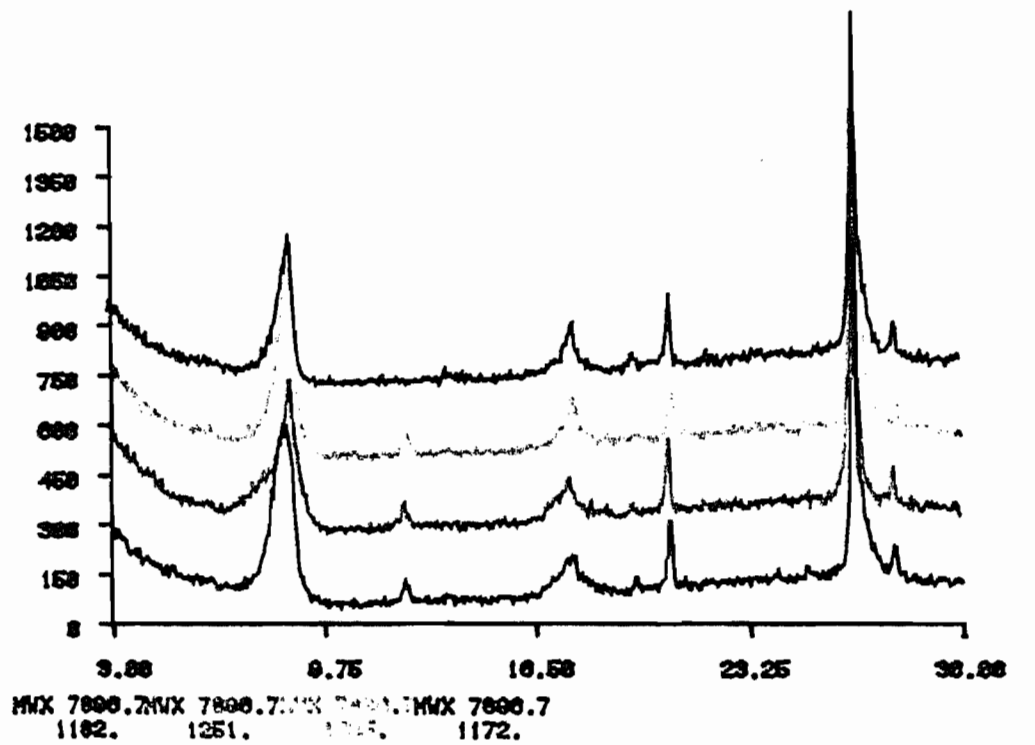
APPENDIX D

X-RAY DIFFRACTION PATTERNS OF CLAY MINERALS

Diffraction patterns from bottom to top are for: Air-dried clay; glycolated clay; clay heated to 330°C; clay heated to 550°C.



BENDIX



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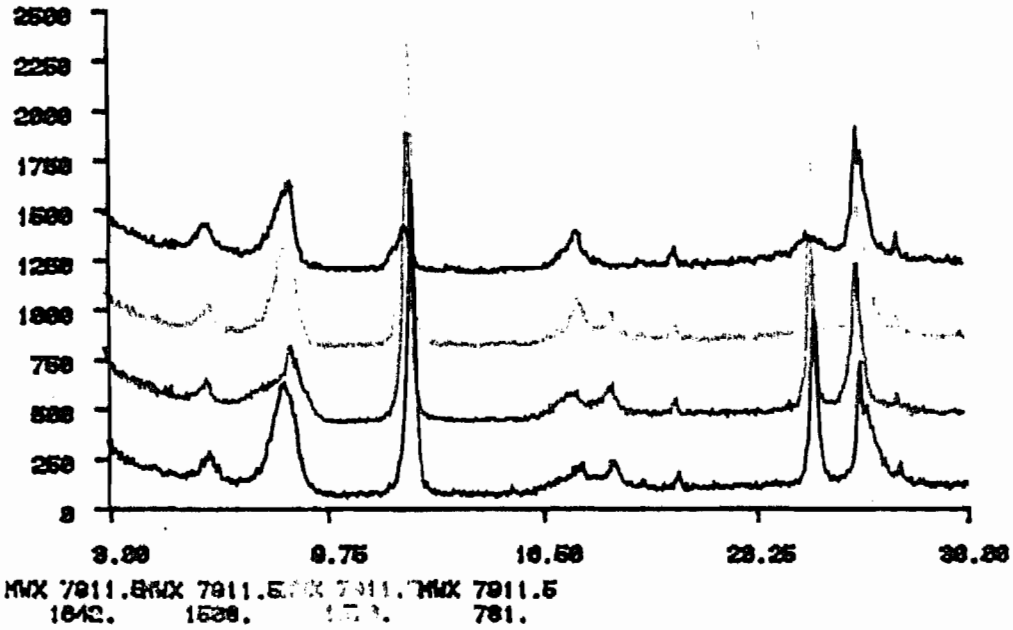

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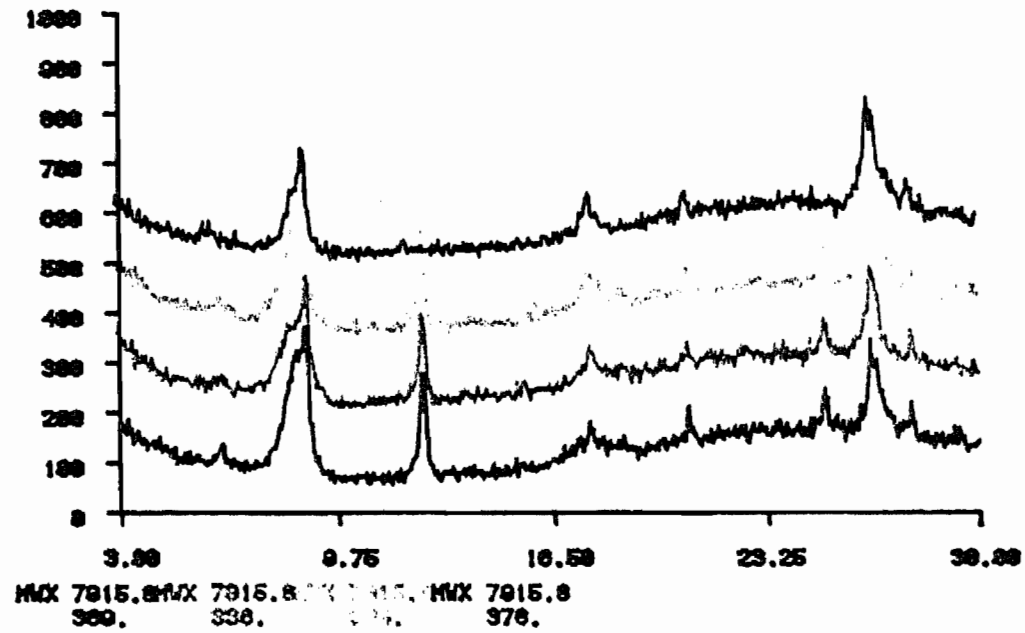

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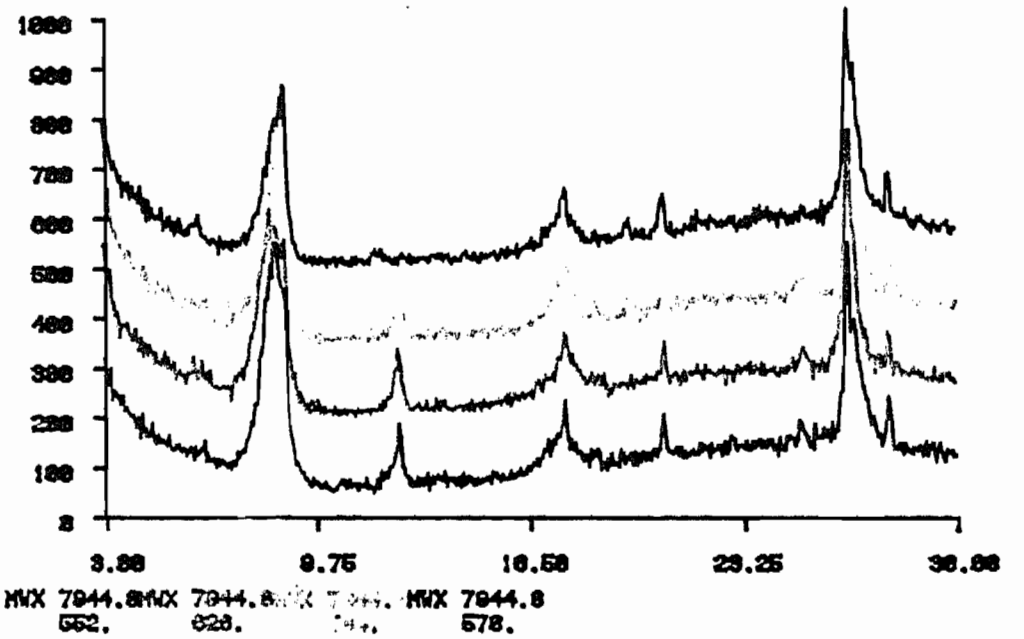
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30.00
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562.
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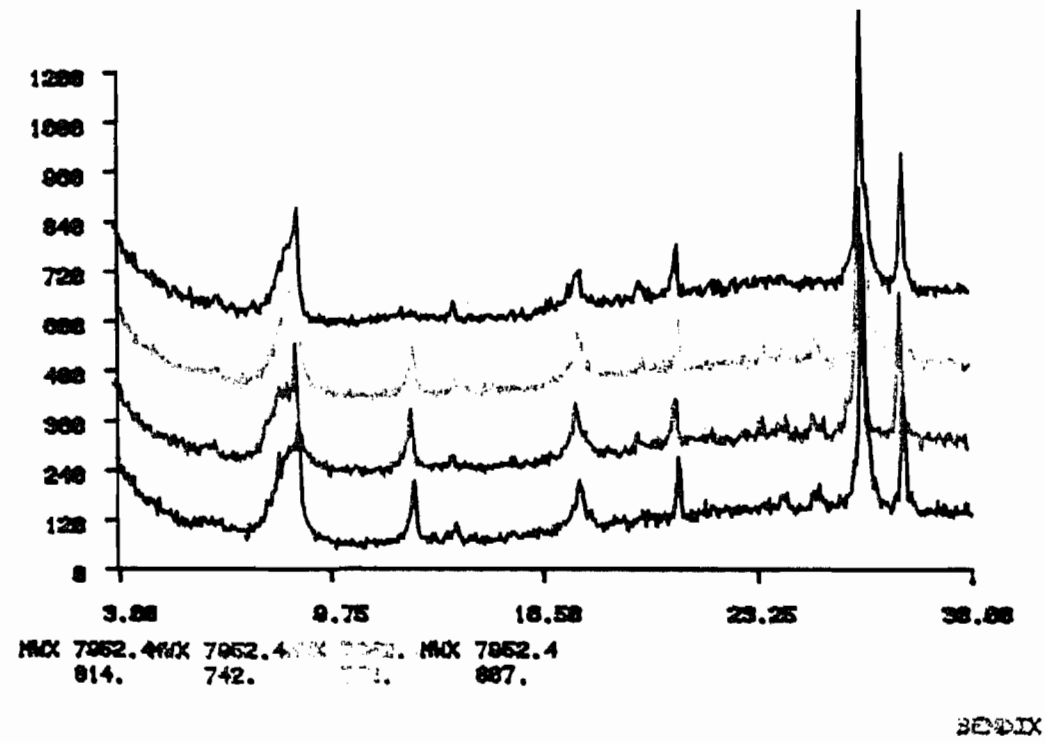
BENDIX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23.25
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MAX 7962.4
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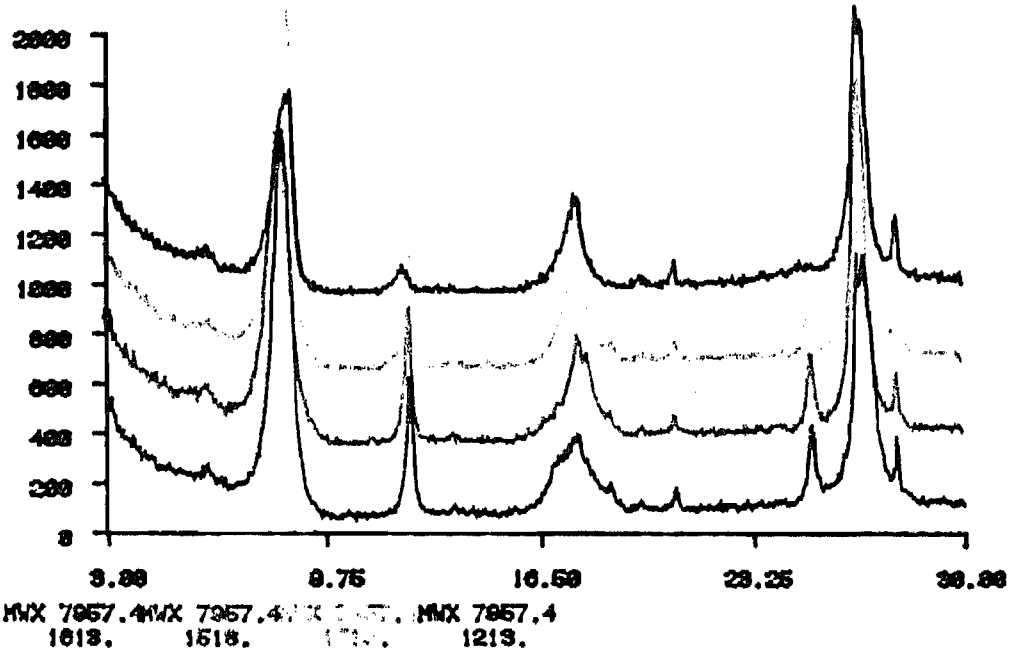
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1516.
MNX 7957.4
1213.

BENDIX