PACIFICORP - ENERGY WEST MINING COMPANY
ANNUAL REPORTS 1995

PACIFICORP

ENERGY WEST MINING COMPANY

ANNUAL REPORTS

1995

DEER CREEK MINE ACT/015/018

COTTONWOOD/WILBERG MINE ACT/015/019

DES BEE DOVE MINE ACT/015/017

TRAIL MOUNTAIN MINE ACT/015/009

COAL MINING AND RECLAMATION OPERATIONS FOR 1995

(Must be submitted to the Division by April 2, 1996)

State of Utah
Department of Natural Resources
Division of Oil, Gas and Mining
3 Triad Center, Suite 350
355 West North Temple
Salt Lake City, Utah 84180-1203
(801) 538-5340

RECEIVED
MAR 29 1996
DIV OF OIL, GAS & MINING

Permittee: PacifiCorp

Mine Name: Deer Creek Mine

Mailing Address: Box 310, Huntington, Utah 84528

Company Representative: Val Payne

Resident Agent: Val Payne

Permit Number: ACT/015/018

MSHA ID Number: 42-00121

Date of Initial Permanent Program Permit: February 7, 1986

Date of Permit Renewal: February 6, 1996

Quantity of Coal Mined (tonnage) 1995: 4,142,192.5

Attach Updated Mine Sequence Map(s) showing mine development through December 31, 1995. (Same as Lease Royalty Payment Map and/or MSHA Progress Map)

All monitoring activities during the report period to be submitted with this report (including, but not limited to):

A. General

1. **Discuss anomalies, missing data and monitoring changes made throughout the year.**
2. **Summarize any corrective actions and the results that may have occurred during the year.**

B. Water Monitoring Data:
Groundwater Summary

1. **Mine Discharge**
    a. **Summarize the total annual discharge from mine water discharge points and**

COAL MINING AND RECLAMATION OPERATIONS FOR 1995

(Must be submitted to the Division by April 2, 1996)

State of Utah
Department of Natural Resources
Division of Oil, Gas and Mining
3 Triad Center, Suite 350
355 West North Temple
Salt Lake City, Utah 84180-1203
(801) 538-5340

Permittee: PacifiCorp

Mine Name: Cottonwood/Wilberg Mine

Mailing Address: Box 310, Huntington, Utah 84528

Company Representative: Val Payne

Resident Agent: Val Payne

Permit Number: ACT/015/019

MSHA ID Number: Wilberg 42-00080 Cottonwood 42-01944

Date of Initial Permanent Program Permit: July 6, 1984

Date of Permit Renewal: July 6, 1994

Quantity of Coal Mined (tonnage) 1995: 2,155,356.0

Attach Updated Mine Sequence Map(s) showing mine development through December 31, 1995. (Same as Lease Royalty Payment Map and/or MSHA Progress Map)

All monitoring activities during the report period to be submitted with this report (including, but not limited to):

A. General

1. **Discuss anomalies, missing data and monitoring changes made throughout the year.**
2. **Summarize any corrective actions and the results that may have occurred during the year.**

B. Water Monitoring Data:
Groundwater Summary

1. **Mine Discharge**
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COAL MINING AND RECLAMATION OPERATIONS FOR 1995

(Must be submitted to the Division by April 2, 1996)

State of Utah
Department of Natural Resources
Division of Oil, Gas and Mining
3 Triad Center, Suite 350
355 West North Temple
Salt Lake City, Utah 84180-1203
(801) 538-5340

Permittee: PacifiCorp

Mine Name: Des Bee Dove

Mailing Address: Box 310, Huntington, Utah 84528

Company Representative: Val Payne

Resident Agent: Val Payne

Permit Number: ACT/015/017

MSHA ID Number: Deseret 42-00988, Beehive 42-00082, Little Dove 42-01393

Date of Initial Permanent Program Permit: August 29, 1985

Date of Permit Renewal: September 7, 1995

Quantity of Coal Mined (tonnage) 1995: -0-

Attach Updated Mine Sequence Map(s) showing mine development through December 31, 1995. (Same as Lease Royalty Payment Map and/or MSHA Progress Map)

All monitoring activities during the report period to be submitted with this report (including, but not limited to):

A. General

1. **Discuss anomalies, missing data and monitoring changes made throughout the year.**
2. **Summarize any corrective actions and the results that may have occurred during the year.**

B. Water Monitoring Data:
Groundwater Summary

1. **Mine Discharge**
   a. **Summarize the total annual discharge from mine water discharge points and**

COAL MINING AND RECLAMATION OPERATIONS FOR 1995

(Must be submitted to the Division by April 2, 1996)

State of Utah
Department of Natural Resources
Division of Oil, Gas and Mining
3 Triad Center, Suite 350
355 West North Temple
Salt Lake City, Utah 84180-1203
(801) 538-5340

Permittee: PacifiCorp

Mine Name: Trail Mountain

Mailing Address: Box 310, Huntington, Utah 84528

Company Representative: Val Payne

Resident Agent: Val Payne

Permit Number: ACT/015/009

MSHA ID Number: 42-01211

Date of Initial Permanent Program Permit: May 11, 1978

Date of Permit Renewal: February 21, 1995

Quantity of Coal Mined (tonnage) 1995: 1,362,793.8

Attach Updated Mine Sequence Map(s) showing mine development through December 31, 1995.
(Same as Lease Royalty Payment Map and/or MSHA Progress Map)

All monitoring activities during the report period to be submitted with this report (including, but not limited to):

A. General

1. **Discuss anomalies, missing data and monitoring changes made throughout the year.**
2. **Summarize any corrective actions and the results that may have occurred during the year.**

B. Water Monitoring Data:
Groundwater Summary

1. **Mine Discharge**
   a. **Summarize the total annual discharge from mine water discharge points and**

SECTIONS A AND B

WATER MONITORING DATA

See: **ANNUAL HYDROLOGIC MONITORING REPORT EAST MOUNTAIN PROPERTY 1995**

SECTION C

SUBSIDENCE MONITORING REPORT

See: **ANNUAL SUBSIDENCE MONITORING REPORT EAST MOUNTAIN PROPERTY 1995**

SECTION D

VEGETATION MONITORING

See: **VEGETATION MONITORING OF THE COTTONWOOD/ WILBERG, DES BEE DOVE, DEER CREEK, TRAIL MOUNTAIN AND COTTONWOOD FAN PORTAL AREAS 1995**

SECTION D: VEGETATION DATA OR REVEGETATION SUCCESS MONITORING

1. See enclosed report (Mt. Nebo Scientific)

2. See enclosed report (Mt. Nebo Scientific)

3. See enclosed report (Mt. Nebo Scientific)

4. During the fall of 1995 and winter of 1995/1996, the following areas were seeded:

   COTTONWOOD MINE

   A. Berm #4 at the Cottonwood Waste Rock Facility was seeded and covered with curlex blanket. (Final Reclamation)

   B. Trail Mountain Mine soil piles at the Old Cottonwood Waste Rock Facility were seeded and covered with curlex blanket.

   DEER CREEK MINE

   A. Rilda Canyon Topsoil Pile and sides of Fan Pad Access Road were seeded and covered with curlex blanket. (Interim Reclamation)

SECTION E

IMPOUNDMENT CERTIFICATION

ANNUAL ENGINEERING REPORT
DEER CREEK SEDIMENT POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

Top of Dam Elevation	**7235.00**
Toe of Dam Elevation	**7217.14**
Spillway Crest Elevation	**7232.03**
Total Storage Capacity	**12.51 ac.ft.**
Sediment Storage Capacity	**3.11 ac.ft.**
Control Points	**1-7235.54**
	2-7235.50
	3-7235.64
	4-7235.98

Operational data:

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-30-95	**Frozen**	**7223.68**	**No Change**
2nd Quarter 6-29-95	**0.60**	**7219.18**	**No Change**
3rd Quarter 9-26-95	**1.03**	**7220.97**	**No Change**
4th Quarter 11-29-95	**Frozen**	**7223.27**	**No Change**

INSPECTION:
Visual inspections were made during each quarter, no stability problems or other concerns were found.

ANNUAL ENGINEERING REPORT
DES BEE DOVE SEDIMENT POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

Top of Dam Elevation	6775.00
Toe of Dam Elevation	6756.00
Spillway Crest Elevation	6771.80
Total Storage Capacity	19.80 ac.ft.
Sediment Storage Capacity	2.00 ac.ft.
Control Points	0+00 - 6775.20
	0+85 - 6775.00
	1+25 - 6775.20
	1+65 - 6775.40

Operational data:

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-29-95	0.0	6756.57	No Change
2nd Quarter 6-29-95	0.0	6756.67	No Change
3rd Quarter 10-3-95	0.0	6756.67	No Change
4th Quarter 12-5-95	0.0	6756.67	No Change

INSPECTION:

Visual inspections were made during each quarter, no stability problems or other concerns were found.

ANNUAL ENGINEERING REPORT
COTTONWOOD SEDIMENT POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

NORTH POND (#1)

Design data:

Top of Dam Elevation	7368.30
Toe of Dam Elevation	7345.20
Spillway Crest Elevation	7365.00
Total Storage Capacity	2.15 ac.ft.
Sediment Storage Capacity	0.90 ac.ft.
Control Points	1-7367.81 B.M.

Operational data: North Pond cleaned lst and 4th Quarters. New x-sections of North Pond in 4th Quarter while cleaned and exposed. Dam berm raised during 4th Quarter.

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-29-95	0.0 Cleaned	7356.00	No Change
2nd Quarter 6-29-95	0.0	7357.39	No Change
3rd Quarter 9-27-95	0.64	7358.01	No Change
4th Quarter 12-29-95	0.0 Cleaned	7354.53	7368.3 Dam Berm

SOUTH POND (#2)

Design data:

Top of Dam Elevation	7339.92
Toe of Dam Elevation	7317.00
Spillway Crest Elevation	7335.00
Total Storage Capacity	1.88 ac.ft.
Sediment Storage Capacity	0.30 ac.ft.
Control Points	7336.56 B.M.

Operational data: Raised dam height during 4th Quarter

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-29-95	0.00	7330.30	No Change
2nd Quarter 6-29-95	0.00	7330.30	No Change
3rd Quarter 9-27-95	0.00	7329.17	No Change
4th Quarter 12-29-95	Frozen	7329.17	No Change

INSPECTION:

Visual inspections were made during each quarter, no stability problems or other concerns were found.

North Pond was cleaned of sediment during lst and 4th Quarters, 1995.

ANNUAL ENGINEERING REPORT
TRAIL MOUNTAIN SEDIMENT POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

Total Storage Capacity	**2.12 ac.ft.**
Sediment Storage Capacity	**0.282 ac.ft.**

Operational data: **Pond cleaning started during 4th Quarter 1995, completed into lst Quarter, 1996.**

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-29-95	0.00	7181.80	No Change
2nd Quarter 6-29-95	0.00	7182.50	No Change
3rd Quarter 9-28-95	0.358	7188.2	No Change
4th Quarter 12-27-95	Cleaning Pond	No Water	No Change

Inspection:

Visual inspections were made, no stability problems or other concern were found.

ANNUAL ENGINEERING REPORT
COTTONWOOD EXPLORATION SITE SEDIMENT PONDS
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

	SEDIMENT CAPACITY	TOTAL CAPACITY
North Basin	.047 ac.ft.	.107 ac.ft.
Center Basin	.115 ac.ft.	.511 ac.ft.
TOTAL	.245 ac.ft.	.696 ac.ft.

Operational data:

ACCUMULATED SEDIMENT (AC.FT.)

	NORTH #1	SOUTH #2
1st Quarter 3-29-95	0.0	0.0
2nd Quarter 6-29-95	0.0	.050
3rd Quarter 9-29-95	0.0	.050
4th Quarter 11-29-95	0.0	.050

WATER ELEVATION

	NORTH #1	SOUTH #2
1st Quarter	Dry	Dry
2nd Quarter	Dry	Dry
3rd Quarter	Dry	Approx. 5" Water 7219.20
4th Quarter	Dry	Dry

Inspection:

Visual inspections were made during each quarter, no stability problems or other concerns were found.

ANNUAL ENGINEERING REPORT
COTTONWOOD WASTE ROCK DETENTION POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

Top of Dam Elevation	6772.00
Toe of Dam Elevation	6755.00
Spillway Crest Elevation	6770.00
Total Storage Capacity	4.58 ac.ft.
Sediment Storage Capacity	1.65 ac.ft.
Control Points	0+00 6770.0
	0+30 6772.0
	0+67 6772.0
	1+05 6772.0

Operational data:

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-29-95	0.0	6756.00	No Change
2nd Quarter 6-29-95	0.0	6756.00	No Change
3rd Quarter 9-27-95	0.0	6755.62	No Change
4th Quarter 11-29-95	0.0	6755.66	No Change

Inspection:

Visual inspections were made during each quarter, no stability problems or other concerns were found.

ANNUAL ENGINEERING REPORT
DEER CREEK WASTE ROCK DETENTION POND
1995

This report is submitted as required by Federal and State regulations:

R645-301-514.300
30 CFR 77.216-4
30 CFR 817.49

Design data:

Top of Dam Elevation	6319.00
Toe of Dam Elevation	6311.20
Spillway Crest Elevation	6317.30
Total Storage Capacity	4.64 ac.ft.
Sediment Storage Capacity	2.90 ac.ft.
Control Points	1. 6313.70
	2. 6326.10
	3. 6326.80

Operational data:

	ACCUMULATED SEDIMENT	WATER ELEVATION	CONTROL POINT ELEVATION
1st Quarter 3-30-95	0.0	Dry	No Change
2nd Quarter 6-29-95	0.0	Dry	No Change
3rd Quarter 9-29-95	0.0	6309.70	No Change
4th Quarter 11-29-95	0.0	Dry	No Change

Inspection:

Visual inspections were made during each quarter, no stability problems or other concerns were found.

ENGINEERS STATEMENT:

I do hereby certify that the 1995 Annual Engineering Reports for the Sedimentation Structures for the Deer Creek, Cottonwood/Wilberg, Des Bee Dove Mines, Cottonwood Exploration Site and the Trail Mountain Mine are true and correct to the best of my knowledge and belief.

1/5/96

John Christensen **Date**
PE # 165651

LICENSED PROFESSIONAL ENGINEER
JOHN CHRISTENSEN
No. 165651
STATE OF UTAH

SECTION F

REFUSE DATA

SECTION F: REFUSE, ROOF, FLOOR AND MID-SEAM DATA

1. Samples were collected at the Cottonwood/Wilberg/Des-Bee-Dove Waste Rock Storage Facility, Cottonwood Mine, Deer Creek Waste Rock Storage Facility, Deer Creek Mine.

2. Samples were collected in accordance with procedures outlined in the Cottonwood/Wilberg Waste Rock Storage Facility Volume, Chapter II, pages 2-12.1 through 2-12.2 and the Deer Creek Waste Rock Storage Facility Volume, Chapter VII, pages 7-4 through 7-5.

   Waste rock soil samples were collected in accordance with the Cottonwood Permit, Appendix VII, page 13.

   Coal:Rock ratio samples were collected in accordance with procedures outlined in the Cottonwood/Wilberg Waste Rock Storage Facility Volume, Chapter II, pages 2-13 and 2-14.

3. Please refer to the attached laboratory analyses. All parameters were analyzed according to the Division's **"GUIDELINES FOR MANAGEMENT OF TOPSOIL AND OVERBURDEN"** (Refuse, Roof, Floor, and Mid-Seam) or the **"TITLE V COAL PROGRAM POLICY FOR DISPOSAL OF SEDIMENT POND WASTE"**.

4. All analyzed parameters fall in the "acceptable" range of the Division's guidelines with the exception of the following:

LAB NO.	LOCATION	UNACCEPTABLE PARAMETER
COTTONWOOD MINE		
119474	CTW0695	SAR
119475	CTW0795	SAR
129066	CTW1795	pH
*119910	CTW0895	TOT. ORGANIC CARBON
* 31502	CTW0196	SAR
TRAIL MOUNTAIN MINE		
* 31503	CTW0296	TOT. ORGANIC CARBON
DEER CREEK MINE		
**31506	DCO496	TOT. ORGANIC CARBON

The refuse/sediment pond material will be covered by 4' of suitable material for the vegetative root zone.

*   Sediment pond samples
**   In-mine sample

F\MISC\1995\95REFUSE.RPT

COTTONWOOD MINE

REFUSE DATA

Inter-Mountain Laboratories, Inc.
1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

March 28, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
— 119472	CTW0495		7.1	2.04	5.71	3.21	9.83	4.65	87.2	10.0	2.8	SAND	0.93	<0.02
— 119473	CTW0595		7.4	2.36	4.08	3.21	14.2	7.43	85.2	10.0	4.8	LOAMY SAND		
— 119474	CTW0695		7.3	4.58	5.69	3.69	32.6	15.1	86.0	9.2	4.8	LOAMY SAND		
— 119475	CTW0795		7.5	10.7	24.6	11.8	80.6	18.9	44.2	38.0	17.8	LOAM	1.37	0.04
119476	DC0195		7.3	7.88	32.4	24.3	29.0	5.44	75.2	15.0	9.8	SANDY LOAM		
119477	DC0295		7.1	3.76	27.6	7.11	8.55	2.05	84.4	10.0	5.6	LOAMY SAND	0.76	0.02
119478	DC0395		7.4	4.62	28.6	11.8	12.0	2.66	78.4	14.0	7.6	LOAMY SAND		
119479	DC0495		7.3	5.93	30.1	18.3	16.5	3.35	70.4	19.0	10.6	SANDY LOAM	1.30	0.02

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

March 28, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
119475	CTW0795		7.5	10.7	24.6	11.8	80.6	18.9	44.2	38.0	17.8	LOAM	1.37	0.04
119481	119475(DUP)		7.5	10.8	24.6	11.9	80.5	18.8	46.4	36.0	17.6	LOAM	1.14	0.04

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Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color

Lab No.	Location	Color
119472	CTW0495	Gley N2.5/ Black *
119473	CTW0595	5Y 2.5/1 Black
119474	CTW0695	2.5Y 2.5/1 Black
119475/481	CTW0795	5Y 2.5/1 Black
119476	DC0195	2.5Y 2.5/1 Black
119477	DC0295	2.5Y 2.5/1 Black
119478	DC0395	5Y 3/1 Very Dark Gray
119479	DC0495	5y 3/1 Very Dark Gray

* The Gley chart was the closest I could get to describing this sample which looked, by all appearances, to be coal.

Inter-Mountain Laboratories, Inc.
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Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD

M-- 24, 1995

Lab No.	Location	Depths feet	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
— 120513	CTW1195	0.0-0.0	7.6	2.34	5.96	13.4	7.99	2.57	74.6	16.8	8.6	SANDY LOAM	0.21	<0.02
— 120514	CTW1295	0.0-0.0	7.0	2.17	4.72	6.22	10.4	4.44	69.6	20.8	9.6	SANDY LOAM	0.59	0.02
— 120515	CTW1395	0.0-0.0	7.7	0.49	0.89	0.60	3.15	3.66	85.6	12.8	1.6	LOAMY SAND	0.84	<0.02
— 120516	CTW1495	0.0-0.0	8.6	3.75	12.1	6.53	19.7	6.46	48.6	36.8	14.6	LOAM	1.03	<0.02

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Inter·Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD

" ·ember 7, 1995

Lab No.	Location	Depths feet	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
129065	CTW1695	0.0-0.0	7.4	6.48	33.7	23.2	17.2	3.22	78.2	14.8	7.0	LOAMY SAND	0.96	0.02
129066	CTW1795	0.0-0.0	9.1	8.86	22.9	4.54	57.7	15.6	64.2	23.8	12.0	SANDY LOAM	0.67	<0.02
129067	CTW1895	0.0-0.0	7.7	0.46	1.31	0.97	1.98	1.86	86.2	10.8	3.0	LOAMY SAND	1.08	<0.02
129068	CTW1995	0.0-0.0	7.5	4.67	13.2	13.1	24.8	6.85	84.2	11.8	4.0	LOAMY SAND	1.55	0.02

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Inter-Mountain Laboratories, Inc.
1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
(FINES)

November 3, 1995

Lab No.	Location	Depths	Sand %	Silt %	Clay %	Texture
129065	CTW1695		45.2	42.2	12.6	LOAM
129066	CTW1795		45.2	38.2	16.6	LOAM
129067	CTW1895			NO FINES		
129068	CTW1995		63.2	28.2	8.6	SANDY LOAM

Inter·Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color

Lab No.	Location	Color
129065	CTW1695	2.5Y 3/1 Very Dark Gray
129066	CTW1795	10YR 4/2 Dark Grayish Brown
129067	CTW1895	Gley 2.5/1 Black
129068	CTW1995	Gley 2.5/1 Black

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color - fines

Lab No.	Location	Color
129065	CTW1695	2.5Y 4/1 Dark Gray
129066	CTW1795	2.5Y 3/1 Very Dark Gray
129067	CTW1895	Gley 2.5/1 Black
129068	CTW1995	Gley 2.5/1 Black

COTTONWOOD MINE

SEDIMENT POND DATA

Inter-Mountain Laboratories, Inc.
1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

[illegible] 25, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Saturation %	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture
119910	CTW0895		7.4	8.87	35.4	8.45	8.79	68.7	23.4	72.0	21.0	7.0	SANDY LOAM

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter·Mountain Laboratories, Inc.

1633 Terra Avenue | Sheridan, Wyoming 82801 | Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

[illegible] 25, 1995

Lab No.	Location	Depths	Total Organic Carbon %	Total Sulfur %	T.S. AB t/1000t	Neut. Pot. t/1000t	T.S. ABP t/1000t	Sulfate Sulfur %	Pyritic Sulfur %	Organic Sulfur %	PyrS AB t/1000t	PyrS ABP t/1000t
119910	CTW0895		61.5	0.64	20.0	117.	97.4					

Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neut. Pot.= Neutralization Potential

iml

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

A· ' 25, 1995

Lab No.	Location	Depths	Total P ppm	Total K ppm	Boron ppm	Avail Na meq/100g	Exch Na meq/100g	CEC meq/100g	ESP	Chloride PE meq/l
119910	CTW0895		<0.01	1550.	1.13	4.49	2.06	4.86	42.3	28.5

Abbreviations for extractants: PE= Saturated Paste Extract, H2OSol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.
1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

A[illegible] 25, 1995

Lab No.	Location	Depths	Total Cadmium ppm	Total Copper ppm	Total Chromium ppm	Total Lead ppm	Total Molybdenum ppm	Total Nickel ppm	Total Selenium ppm	Total Iron ppm	Total Manganese ppm	Total Zinc ppm	Total Kjeldahl Nitrogen %
119910	CTW0895		<0.01	7.50	12.0	6.00	<0.05	5.00	1.50	5600.	86.5	17.0	0.93

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ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

A[illegible] 25, 1995

Lab No.	Location	Depths	Total Calcium ppm	Total Sodium ppm
119910	CTW0895		29950.	3140.

1160 Research Drive
Bozeman, Montana 59715

QUALITY ASSURANCE / QUALITY CONTROL

Inter-Mountain Laboratories, Inc.

1160 Research Drive
Bozeman, Montana 59715

TOXICITY CHARACTERISTIC LEACHING PROCEDURE - TCLP
TRACE METAL CONCENTRATION

Client:	ENERGY WEST MINING COMPANY		
Sample ID:	CTW0895	Date Reported:	04/08/95
Project ID:	Sheridan	Date Sampled:	04/04/95
Laboratory ID:	B952820	Date Received:	04/05/95
Sample Matrix:	Soil	Date Extracted TCLP:	04/06/95
		Date Analyzed:	04/07/95

Parameter	Sample Result	PQL	Regulatory Level	Units
Arsenic	ND	0.2	5.0	mg/L
Barium	ND	5	100.0	mg/L
Cadmium	ND	0.05	1.0	mg/L
Chromium	ND	0.05	5.0	mg/L
Lead	ND	0.2	5.0	mg/L
Mercury	ND	0.001	0.2	mg/L
Selenium	ND	0.2	1.0	mg/L
Silver	ND	0.01	1.0	mg/L

ND-Parameter not detected at stated Practical Quantitation limit (PQL).

Reference: Toxicity Characteristic Leaching Procedure , Final Rule, Federal Register, 40 CFR 261-302. Part V, EPA Vol 55, No. 126, June 29, 1990

Method 3010: Acid Digestion of Aqueous Samples and Extracts for Total Metals, SW-846, September, 1986.

Method 6010: Inductively Coupled Plasma-Atomic Emission Spectroscopy, SW-846, September, 1990.

Method 7470: Mercury in Liquid Waste (Manual Cold-Vapor Technique), SW-846, September 1986.

Analyst ____________

Reviewed ____________

[illegible]ntermountain Laboratories, Inc.
1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

[illegible] WEST MINING COMPANY
HUNTINGTON, UTAH
ATTN: COTTONWOOD
[illegible] NORTH POND SEDIMENT

DATE SAMPLED: 2-12-96
March 22, 1996

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Saturation %	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture
31502	CTW0196		7.5	9.41	41.3	2[illegible]	[illegible]	61	13.1	54.0	20.6	[illegible]	SANDY LOAM
31503	CTW0296		7.1	8.61	51.7	[illegible]	[illegible]	53	11.7	56.0	29.0	[illegible]	[illegible]M

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Te. (307) 672-3945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH END SEDIMENT

ATE SAMPLED: 2-12-96
arch 22, 1996

ab No.	Location	Depths	Total Organic Carbon %	Total Sulfur %	T.S. AB t/1000t	Neut. Pot. t/1000t	T.S. ABP t/1000t	Sulfate Sulfur %	Pyritic Sulfur %	Organic Sulfur %	PyrS AB t/1000t	PyrS ABP t/1000t	P ppm	Boron ppm
31502	CTW0196		32.5	0.28	8.75	237.	228.						2.32	1.68
31503	CTW0296		52.2	0.57	17.8	135.	117.						2.05	2.59

TO: 801 653 2479

FROM:KONICA FAX

breviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neut. Pot.= Neutralization Potential

InterMountain Laboratories Inc.
33 Terra Avenue Sheridan, Wyoming 8280 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH POND SEDIMENT

ATE SAMPLED: 2-29
arch 22, 1996

ab No.	Location	Depths	Total Potassium ppm	Total Sodium ppm	Avail Na meq/100g	Exch Na meq/100g	Chloride PE meq/l	Total Calcium ppm	Total Cadmium ppm	Total Copper ppm	Total Chromium ppm	Total Lead ppm	Total Molybdenum ppm	Total Nickel ppm	Total Cobalt ppm
13502	CTW0196		5000.	7010.0	4.10	1.6	25.5	73500.	<0.0	10.5	27.5	<0.0	0.50	12.0	3.00
1503	CTW0296		5200.	6100.0	3.96	1 1	27.5	36000.	<0.01	11.9	28.8	<0.01	2.49	13.4	3.50

breviations for Extracts: PE= Saturated Paste Extract, H2OSol= water soluble, AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
iscellaneous Abbreviation SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.
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ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH POND SEDIMENT

ATE SAMPLED: 2-12-96
arch 22, 1996

b No.	Location	Depths	Total Selenium ppm	Total Iron ppm	Total Manganese ppm	Total Zinc ppm	Total Kjeldahl Nitrogen %
1502	CTW0396		1.00	7900.	143.	31.5	0.40
1503	CTW0296		1.44	9150.	91.5	42.3	0.62

COTTONWOOD MINE

ROOF, FLOOR AND MID-SEAM DATA

Samples of the roof, floor and mid-seam have been collected for the Cottonwood Mine. Energy West has not received the analytical results. Results will be included in the 1996 Annual Report. Future sampling of the roof, floor and mid-seam of the Cottonwood Mine will not occur.

COTTONWOOD MINE

COAL:ROCK RATIO DATA

Waste Rock Site
Cottonwood Mine
09/21/95
Annual Sampling
Sampled by Tom Lloyd

	Ash	Weight (lbs)	Weighted Ash % Rock
Fines	44.1	253.3	13.6
Coal	12.8	182.0	2.8
Rock	100.0	385.3	47.0
Total		820.5	63.4

Total Coal	36.6
Total Rock	63.4

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • TEL: 708-953-9300 FAX: 708-953-9306
SINCE 1908
Member of the SGS Group (Société Générale de Surveillance)

PLEASE ADDRESS ALL CORRESPONDENCE TO:
P.O. BOX 1020, HUNTINGTON, UT 84528
TEL: (801) 653-2311
FAX: (801) 653-2436

September 20, 1995

PACIFICORP FIELD OFFICE
P.O. Box 1005
Huntington UT 84528

Sample identification by

COTTONWOOD COAL
WASTE ROCK SITE
1 BARREL
ROCK-CHUNK

Kind of sample reported to us

Sample taken at

Sample taken by PacifiCorp

Date sampled September 13, 1995

Date received September 13, 1995

Analysis report no. 59-184615

Sample Analysis

ROCK- 385.25 LBS.

PACIFICORP
SEP 20 1995
FIELD OFFICE

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, Huntington Laboratory

COMMERCIAL TESTING & ENGINEERING CO.
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FAX: (801) 653-2436

September 20, 1995

PACIFICORP FIELD OFFICE
P.O. Box 1005
Huntington UT 84528

Sample identification by

Kind of sample reported to us

COTTONWOOD COAL
WASTE ROCK SITE
1 BARREL
253.25 LBS. CHUNK FINES

Sample taken at

Sample taken by PacifiCorp

Date sampled September 13, 1995

Date received September 13, 1995

Analysis report no. 59-184616

ASH ANALYSIS

AS RECEIVED

%Ash	44.08

PACIFICORP
SEP 20 1995
FIELD OFFICE

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, Huntington Laboratory

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • TEL: 708-953-9300 FAX: 708-953-9306
Member of the SGS Group (Société Générale de Surveillance)

PLEASE ADDRESS ALL CORRESPONDENCE TO:
P.O. BOX 1020, HUNTINGTON, UT 84528
TEL: (801) 653-2311
FAX: (801) 653-2436

September 20, 1995

PACIFICORP FIELD OFFICE
P.O. Box 1005
Huntington UT 84528

Sample identification by

Kind of sample reported to us

COTTONWOOD COAL
WASTE ROCK SITE
1 BARREL
182.0 LBS. CHUNK COAL

Sample taken at

Sample taken by PacifiCorp

Date sampled September 13, 1995

Date received September 13, 1995

Analysis report no. 59-184614

ASH ANALYSIS

AS RECEIVED

%Ash	12.84

PACIFICORP
SEP 20 1995
FIELD OFFICE

Post-it™ brand fax transmittal memo 7671	# of pages ▸ 3
To Jon Lloyd	From
Co.	Co.
Dept.	Phone #
Fax #	Fax #

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Larry Stout
Manager, Huntington Laboratory

DEER CREEK MINE

REFUSE DATA

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue | Sheridan, Wyoming 82801 | Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

March 28, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
119472	CTW0495		7.1	2.04	5.71	3.21	9.83	4.65	87.2	10.0	2.8	SAND	0.93	<0.02
119473	CTW0595		7.4	2.36	4.08	3.21	14.2	7.43	85.2	10.0	4.8	LOAMY SAND		
119474	CTW0695		7.3	4.58	5.69	3.69	32.6	15.1	86.0	9.2	4.8	LOAMY SAND		
119475	CTW0795		7.5	10.7	24.6	11.8	80.6	18.9	44.2	38.0	17.8	LOAM	1.37	0.04
119476	DC0195		7.3	7.88	32.4	24.3	29.0	5.44	75.2	15.0	9.8	SANDY LOAM		
119477	DC0295		7.1	3.76	27.6	7.11	8.55	2.05	84.4	10.0	5.6	LOAMY SAND	0.76	0.02
119478	DC0395		7.4	4.62	28.6	11.8	12.0	2.66	78.4	14.0	7.6	LOAMY SAND		
119479	DC0495		7.3	5.93	30.1	18.3	16.5	3.35	70.4	19.0	10.6	SANDY LOAM	1.30	0.02

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

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ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH

March 28, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
119475	CTW0795		7.5	10.7	24.6	11.8	80.6	18.9	44.2	38.0	17.8	LOAM	1.37	0.04
119481	119475(DUP)		7.5	10.8	24.6	11.9	80.5	18.8	46.4	36.0	17.6	LOAM	1.14	0.04

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color

Lab No.	Location	Color
119472	CTW0495	Gley N2.5/ Black *
119473	CTW0595	5Y 2.5/1 Black
119474	CTW0695	2.5Y 2.5/1 Black
119475/481	CTW0795	5Y 2.5/1 Black
119476	DC0195	2.5Y 2.5/1 Black
119477	DC0295	2.5Y 2.5/1 Black
119478	DC0395	5Y 3/1 Very Dark Gray
119479	DC0495	5y 3/1 Very Dark Gray

* The Gley chart was the closest I could get to describing this sample which looked, by all appearances, to be coal.

Inter·Mountain Laboratories, Inc.

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ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK

N--ember 7, 1995

Lab No.	Location	Depths feet	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Boron ppm	Selenium ppm
129063	DC0895	0.0-0.0	7.7	5.41	12.6	18.1	27.2	6.95	46.2	36.8	17.0	LOAM	0.52	0.02
129064	DC0995	0.0-0.0	7.3	5.70	29.6	15.0	20.5	4.34	72.2	16.8	11.0	SANDY LOAM	1.24	0.04

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Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK
(FINES)

November 3, 1995

Lab No.	Location	Depths	Sand %	Silt %	Clay %	Texture
129063	DC0895		34.2	46.2	19.6	LOAM
129064	DC0995		44.2	38.2	17.6	LOAM

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color

Lab No.	Location	Color
129063	DC0895	10YR 5/3 Brown
129064	DC0995	2.5Y 3/1 Very Dark Gray

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color - fines

Lab No.	Location	Color
129063	DC0895	10YR 4.5/3 Brown
129064	DC0995	10YR 3/1 Very Dark Gray

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK

November 14, 1995

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Carbonate %
129061	DC0695		7.3	13.7	40.1	29.9	81.0	13.7	66.2	20.8	13.0	SANDY LOAM	12.2
129062	DC0795		7.7	7.47	23.0	21.5	46.8	9.93	67.2	21.8	11.0	SANDY LOAM	12.6

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Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK

November 14, 1995

Lab No.	Location	Depths	Total Organic Carbon %	Total Sulfur %	T.S. AB t/1000t	Neut. Pot. t/1000t	T.S. ABP t/1000t	Sulfate Sulfur %	Pyritic Sulfur %	Organic Sulfur %	PyrS AB t/1000t	PyrS ABP t/1000t	Boron ppm	Selenium ppm
129061	DC0695		41.9	0.50	15.6	134.	118.						1.58	0.10
129062	DC0795		46.3	0.37	11.6	139.	128.						0.77	0.04

Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neut. Pot.= Neutralization Potential

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color

Lab No.	Location	Color
129061	DC0695	2.5Y 3/1 Very Dark Gray
129062	DC0795	5Y 3/1 Very Dark Gray

Inter·Mountain Laboratories, Inc.
1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK
(FINES)

November 3, 1995

Lab No.	Location	Depths	Sand %	Silt %	Clay %	Texture
129061	DC0695		46.2	36.2	17.6	LOAM
129062	DC0795		50.2	34.2	15.6	LOAM

1633 Terra Avenue
Sheridan, Wyoming 82801

Energy West
Munsell Color - fines

Lab No.	Location	Color
129061	DC0695	2.5Y 3/1 Very Dark Gray
129062	DC0795	10YR 2/1 Black

DEER CREEK MINE

ROOF, FLOOR AND MID-SEAM DATA

iml

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK/COTTONWOOD

DATE SAMPLED: 2-8-96, 2-12-96
March 22, 1996

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture	Carbonate %
31504	DC0296		7.7	0.75	2.58	2.85	1.62	0.98	53.0	27.0	20.0	SANDY CLAY LOAM	0.5
31505	DC0396		7.9	0.41	0.99	0.77	2.29	2.43	63.0	15.0	22.0	SANDY CLAY LOAM	4.0
31506	DC0496		7.1	1.05	6.56	4.03	1.43	0.62	88.0	6.0	6.0	SAND	1.3
31507	DC0596		7.6	0.34	1.35	1.32	0.58	0.50	79.0	13.0	8.0	LOAMY SAND	13.5
31508	DC0696		8.1	0.31	0.99	1.46	0.53	0.49	88.0	5.0	7.0	LOAMY SAND	20.6

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

iml

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue Sheridan, Wyoming 82801 Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: DEER CREEK/COTTONWOOD

DATE SAMPLED: 2-8-96, 2-12-96
March 22, 1996

Lab No.	Location	Depths	Total Organic Carbon %	Total Sulfur %	T.S. AB t/1000t	Neut. Pot. t/1000t	T.S. ABP t/1000t	Sulfate Sulfur %	Pyritic Sulfur %	Organic Sulfur %	PyrS AB t/1000t	PyrS ABP t/1000t	Boron ppm	Selenium ppm
31504	DC0296		5.1	0.36	5.00	5.81	0.81						0.38	0.08
31505	DC0396		16.4	0.13	4.06	44.4	40.3						0.43	0.04
31506	DC0496		91.3	0.85	26.6	14.1	-12.5	<0.01	0.23	0.64	7.19	6.89	0.39	<0.02
31507	DC0596		1.5	<0.01	0.00	128.	128.						0.04	<0.02
31508	DC0696		0.6	0.01	0.31	213.	213.						0.02	<0.02

Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur,
Neut. Pot.= Neutralization Potential

TRAIL MOUNTAIN MINE

SEDIMENT POND DATA

Intermountain Laboratories, Inc.

1633 Terra Avenue

Sheridan, Wyoming 82801

Tel. (307) 672-8945

KENNECOTT WEST MINING COMPANY
HUNTINGTON, UTAH
FOR: COTTONWOOD
NORTH POND SEDIMENT
Trail Mtn Pond

DATE SAMPLED: 2-12-96
March 22, 1996

Lab No.	Location	Depths	pH	EC mmhos/cm @ 25°C	Saturation %	Calcium meq/l	Magnesium meq/l	Sodium meq/l	SAR	Sand %	Silt %	Clay %	Texture
31502	CTW0196		7.5	9.41	41.3	2.J	[illegible]	61	13.1	54.0	28.0	[illegible]	SANDY LOAM
31503	CTW0296 Trail		7.1	8.61	52.7	29	[illegible]	5.9	11.7	56.0	29.0	[illegible]	[illegible]AM

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

Inter-Mountain Laboratories, Inc.
1633 Terra Avenue Sheridan, Wyoming 82801 Te. (307) 672-3945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH END SEDIMENT
Trail Mtn. Pond

ATE SAMPLED: 2-12-96
arch 22, 1996

ab No.	Location	Depths	Total Organic Carbon %	Total Sulfur %	T.S. AB t/1000t	Neut. Pot. t/1000t	T.S. ABP t/1000t	Sulfate Sulfur %	Pyritic Sulfur %	Organic Sulfur %	PyrS AB t/1000t	PyrS ABP t/1000t	P ppm	Boron ppm
31502	CTW0196		32.5	0.28	8.75	237.	228.						2.12	1.68
31503	CTW0296 Trail		52.2	0.57	17.8	135.	117.						2.05	2.59

breviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur,
Neut. Pot.= Neutralization Potential

MAR 25 1996 2:05PM FROM: KONICA FAX TO: 801 653 2470 P.04

InterMountain Laboratories Inc.

:33 Terra Avenue Sheridan, Wyoming 8280' Tel. (307) 6728945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH POND SEDIMENT
Trail Mtn. Pond

ATE SAMPLED: 2-29
arch 22, 1996

ab No.	Locatio	Depths	Total Potassium ppm	Total Sodium ppm	Avail Na meq/100g	Exch Na meq/100g	Chloride PE meq/l	Total Calcium ppm	Total Cadmium ppm	Total Copper ppm	Total Chromium ppm	Total Lead ppm	Total Molybdenum ppm	Total Nickel ppm	Total Cobalt ppm
13502	CTW0196		5000.	7010.0	4.10	1.6[illegible]	25.5	73500.	<0.0[illegible]	16.5	27.5	<0.0[illegible]	0.50	12.0	3.00
1503	CTW0296 Trail		5200.	6100.0	3.96	1 1[illegible]	27.5	36000.	<0.01	11.9	28.8	<0.01	2.49	13.4	3.50

breviations for extracts: PE= Saturated Paste Extract, H2OSol= water soluble, AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
iscellaneous Abbreviation SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage, Exch= Exchangeable, Avail= Available

FROM:KONICA FAX TO: 801 653 2479 MAR 25, 1996 2:06PM P.05

iml

Inter-Mountain Laboratories, Inc.

1633 Terra Avenue
Sheridan, Wyoming 82801
Tel. (307) 672-8945

ENERGY WEST MINING COMPANY
HUNTINGTON, UTAH
MINE: COTTONWOOD
SITE: NORTH POND SEDIMENT
Trail Mtn. Pond sed.

TE SAMPLED: 2-12-96
rch 22, 1996

b No.	Location	Depths	Total Selenium ppm	Total Iron ppm	Total Manganese ppm	Total Zinc ppm	Total Kjeldahl Nitrogen %
1502	CTW0396		1.00	7900.	143.	31.5	0.40
1503	CTW0296		1.44	9150.	91.5	42.3	0.62

SECTION G

REPORT OF OFFICERS

PacifiCorp Directors
1996

Name	Position	Address
Kathryn A. Braun	Director	8105 Irvine Center Drive Irvine, CA 92718
Frederick W. Buckman	Director	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
C. Todd Conover	Director	101 First Street, Suite 670 Los Altos, CA 94022
Richard C. Edgley	Director	50 East North Temple Salt Lake City, UT 84501
Nolan E. Karras	Director	4695 South 1900 West, #3 Roy, UT 84607
Keith R. McKennon	Chairman	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
Robert G. Miller	Director	P O Box 42121 Portland, Oregon 97242
Verl R. Topham	Director	201 South Main, Site 2300 Salt Lake City, UT 84140
Don M. Wheeler	Director	4901 West 2100 South Salt Lake City, Utah 84120
Nancy Wilgenbusch	Director	Marylhurst College Marylhurst, OR 97036
Peter I. Wold	Director	P O Box 114 Casper, WY 92602

PacifiCorp Officers
1996

Name	Position	Address
Frederick W. Buckman	President and CEO	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
John A. Bohling	Senior Vice President	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
Shelley R. Faigle	Senior Vice President	920 SW Sixth Avenue, Suite 1500 Portland, OR 97204
Paul G. Lorenzini	Senior Vice President	920 SW Sixth Avenue, Suite l500 Portland, OR 97204
John E. Mooney	Senior Vice President	201 South Main, Suite 2300 Salt Lake City, UT 84140
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Daniel L. Spalding	Senior Vice President	Level 3, 77 Southbank Blvd. Southbank, Victoria 3006 Australia
Dennis P. Steinberg	Senior Vice President	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
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Sally A. Nofziger	Vice President and Corporate Secretary	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
William C. Brauer	Vice President	201 South Main, 2300 OUC Salt Lake City, Utah 84140
Thomas J. Forsgren	Vice President	201 South Main, 2300 OUC Salt Lake City, Utah 84140
J. Brett Harvey	Vice President	201 South Main, 2300 OUC Salt Lake City, Utah 84140

1996 PacifiCorp officers - cont.

Michael C. Henderson	Vice President	825 NE Multnomah, Suite 775 Portland, Oregon 97232
David P. Hoffman	Vice President	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
Thomas J. Imeson	Vice President	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
Robert F. Lanz	Vice President	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
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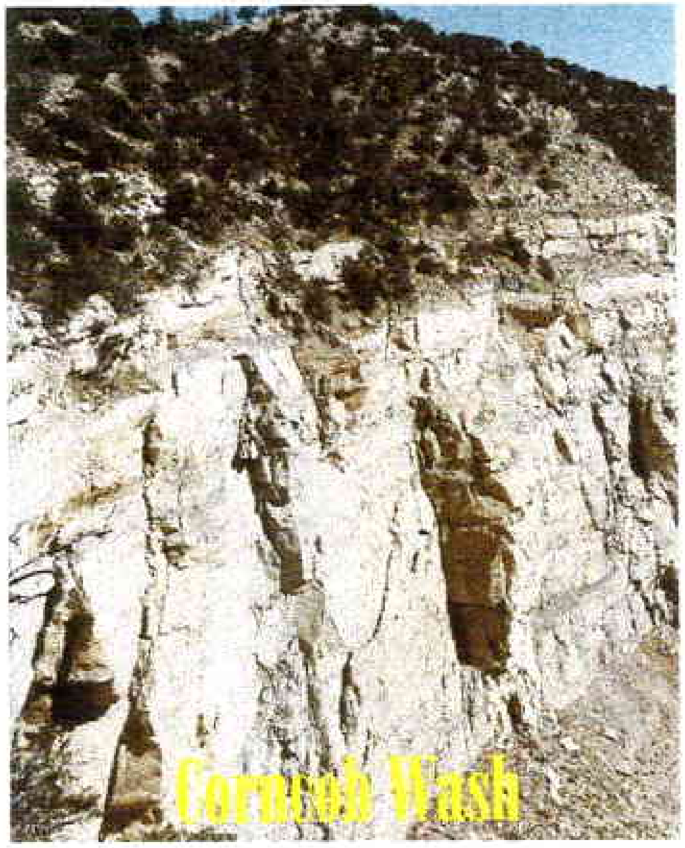
Paul N. Pechersky	Vice President	920 SW Sixth, Suite 1500 Portland, OR 97204
Michael J. Pittman	Vice President	920 SW Sixth Avenue, Suite 1100 Portland, OR 97204
Ernest E. Wessman	Vice President	201 South Main, Suite 2100 Salt Lake City, Utah 84101
Richard D. Westerberg	Vice President	2484 Washington Blvd., Suite 400 Ogden, UT 84401
William E. Peressini	Treasurer	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116
Jacqueline S. Bell	Controller	700 NE Multnomah, Suite 700 Portland, OR 97232-4116
Lenore M. Martin	Assistant Secretary	700 NE Multnomah, Suite 700 Portland, OR 97232-4116
Marsha E. Carroll	Assistant Secretary	700 NE Multnomah, Suite 700 Portland, OR 97232-4116

1996 PacifiCorp officers - cont.

John Detjens III	Assistant Secretary	700 NE Multnomah, Suite 950 Portland, OR 97232-4116
C. K. Ferguson	Assistant Secretary	825 NE Multnomah, Suite 570 Portland, OR 97232
John M. Schweitzer	Assistant Secetary	700 NE Multnomah, Suite 950 Portland, OR 97232
H. Arnold Wagner	Controller and Assistant Secretary	201 South Main, Suite 700 Salt Lake City, UT 84140
John F. Fryer	Assistant Treasurer	700 NE Multnomah, Suite 1600 Portland, OR 97232
John R. Stageberg	Assistant Treasurer	700 NE Multnomah, Suite 1600 Portland, OR 97232
Bruce N. Williams	Assistant Treasurer	700 NE Multnomah, Suite 1600 Portland, OR 97232-4116

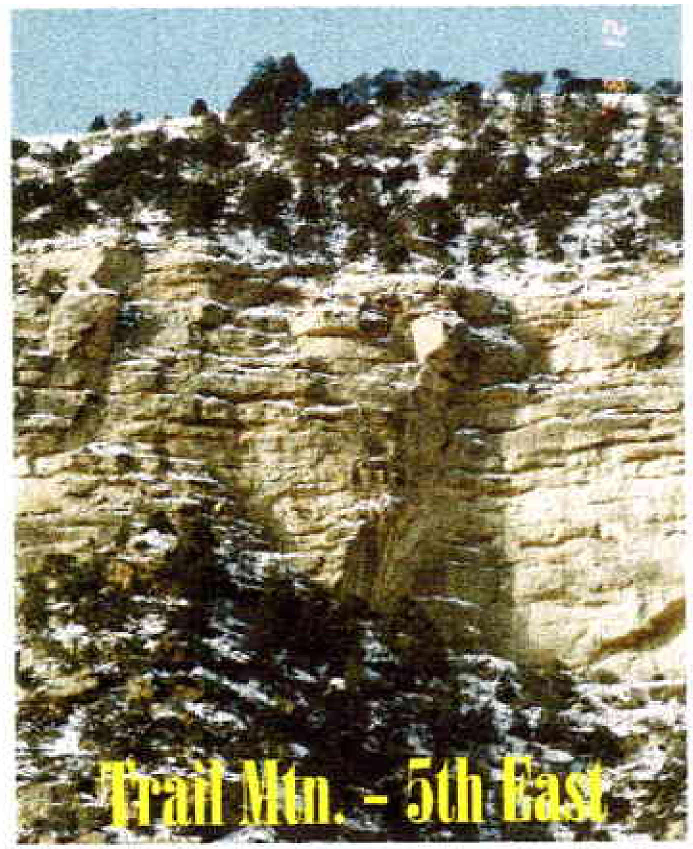


Energy West Mining Co.

A Subsidiary of PacifiCorp

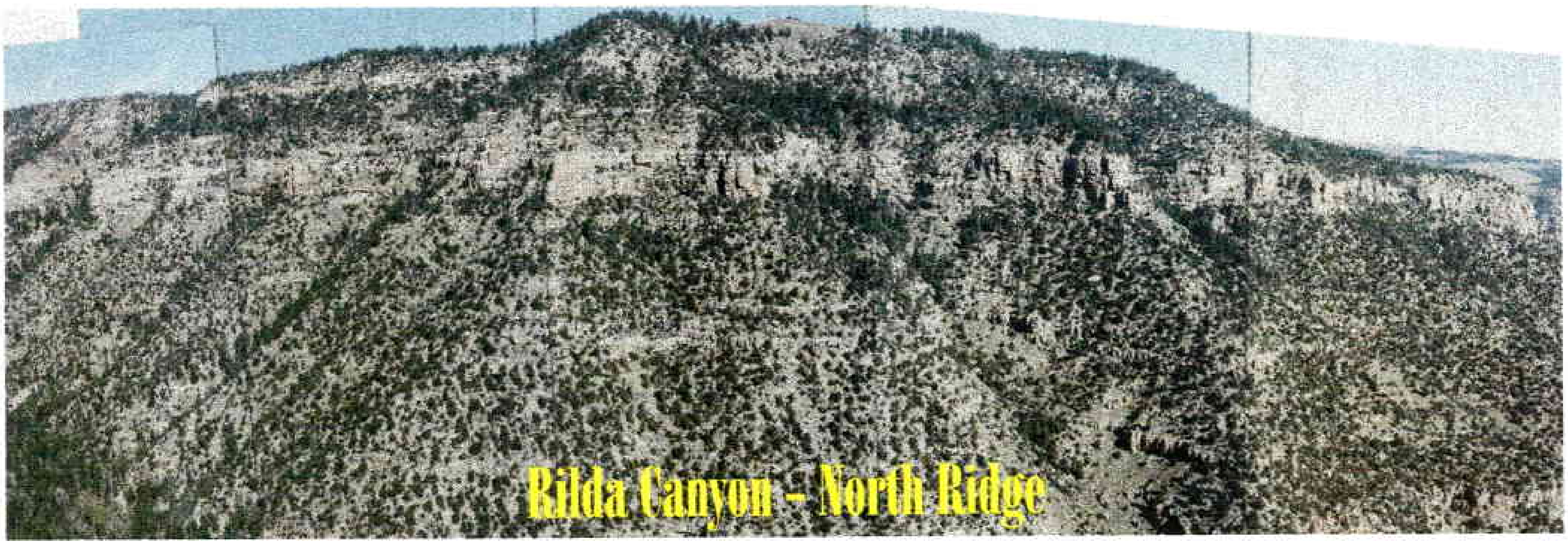
STATUS REPORT

February 1998



☆ Assessment of Surface Impacts to the Castlegate Sandstone Escarpment from Full Extraction Reserve Recovery

☆ Overview of Castlegate Sandstone Escarpment Geotechnical Model Evaluation



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Energy West Mining Co.

Energy West Mining Co.

STATUS REPORT

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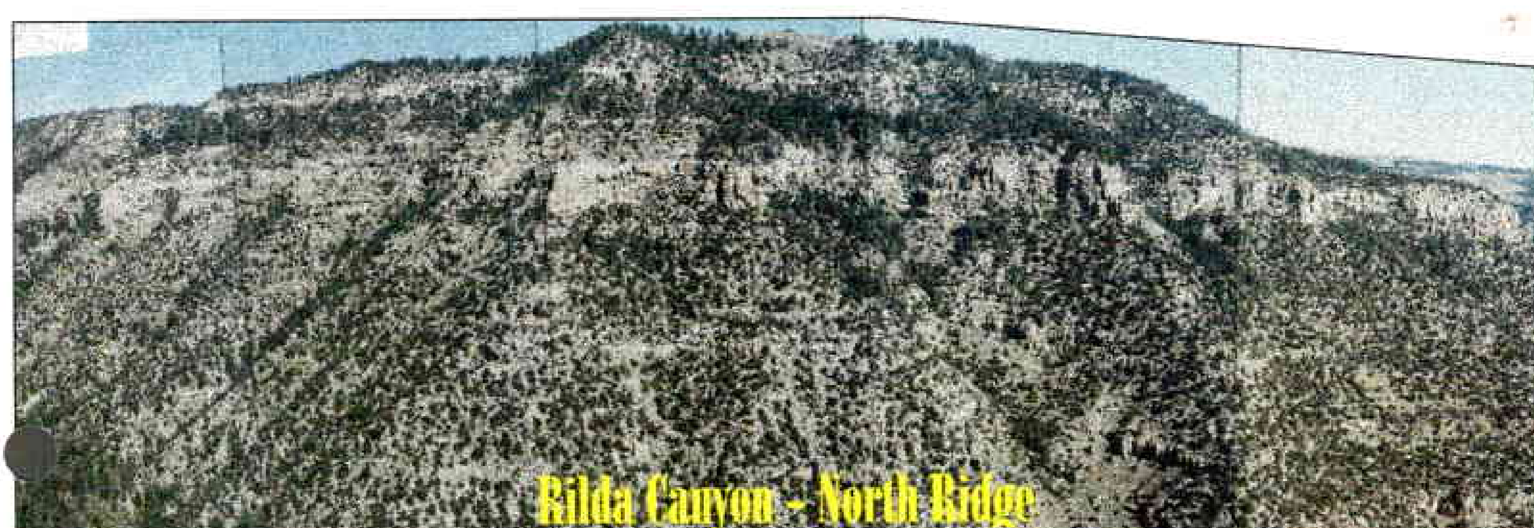


Table of Contents

STATUS REPORT - FEBRUARY 1998:

✯ ***Assessment of Surface Impacts to the Castlegate Sandstone Escarpment From Full Extraction Reserve Recovery***

✯ ***Overview of Castlegate Sandstone Escarpment Geotechnical Evaluation***

Since early 1985, PacifiCorp has been actively predicting, modeling, and documenting full-extraction longwall mining as it relates to the Castlegate Sandstone escarpment. Numerical models were developed from field observations from PacifiCorp's Cottonwood Mine as mining beneath the Castlegate Sandstone escarpment was conducted in Newberry and Concob Wash in an effort to back analyze and predict escarpment failure. The 2-D numerical models developed from these test section studies (i.e. USBM, Seegmiller, University of Utah) were for the most part, inconclusive and incomplete.

The extension of the 5th East longwall panel at PacifiCorp's Trail Mountain Mine has allowed for an additional test section which provides a case in which only one longwall panel is extracted from beneath the Castlegate escarpment. In addition to this field test section, a geotechncal project was initiated with an independent consultant (Maleki Technologies).

The scope of the current Castlegate Sandstone escarpment evaluation project is as follows:

☆ Back analyze existing data from Newberry Canyon and Corncob Wash studies (i.e. field survey data, geologic/litholgic data, mining orientation/sequence, previous 2-D model development by previous researchers (USBM, Seegmiller, U of U), and summarize conclusions;

☆ Selection of a separate study area within the existing Newberry Canyon/Corncob Wash test section areas. Development of an independent/updated 2-D finite element model that provides conclusive escarpment failure results when compared to the post mining field data.

☆ Development of a separate (simplified) "risk/failure" mathematical probability model (through the use of regression analyses) based upon geotechnical/geological survey parameters of the separate study area selected from the Newberry Canyon/Corncob Wash test sections with regard to the independently developed 2-D finite element model. Evaluation of this model with regard to conclusive escarpment failure results as compared to the post mining field data.

☆ Selection of the "best fit" model from the above referenced trial models and simulation of the full-extraction mining of the Trail Mountain Mine 5th East longwall panel and associated Castlegate Sandstone escarpment failure. Recalibration of the model(s) to fit the field results of the Trail Mountain 5th East longwall test area.

☆ Evaluation of the existing Colorado Rock Simulation Program (CRSP) with regard to modeling and prediction of rockfalls from escarpment failures down the existing outslopes below the Castlegate Sandstone escarpment. Recalibrate program to " best fit" available field data from all escarpment test study areas.

☆ Summarize and present project findings to the applicable Federal and State regulatory agencies. Specifically, address modeling of the southern portion of the Castlegate Sandstone escarpment in the North Rilda Canyon Area prior to pre-mining environmental analysis of potential impacts from full-extraction longwall mining within the immediate area of the Castlegate Sandstone escarpment in the North Rilda Canyon Area.

This report is a compilation of the data collected and compiled during 1997, including geotechnical and environmental information. The following reports are included as outlined below:

Report 1: ***ASSESSMENT OF SURFACE IMPACT TO THE CASTLEGATE SANDSTONE ESCARPMENT FROM FULL-EXTRACTRACTION RESERVE RECOVERY OF THE 5TH EAST LONGWALL PANEL; FEDERAL LEASE U-64375; TRAIL MOUNTAIN MINE; EMERY COUNTY, UTAH***

Reference Data:

- Appendix A: Prism Survey Data
- Appendix B: CRSP Data
- Maps:
  - Drawing # 1705D Trail Mountain Mine: Escarpment Modeling Study 1997
  - Drawing # TMS1721A Trail Mountain Mine: Escarpment Study Cross Section
  - Drawing # TMS1711C Trail Mountain Mine: Escarpment Study 5th East Talus Cross Section
  - Drawing: Prism Stand and Mounting Plate
- Photos:
  - Trail Mountain Mine: 5th East Castlegate Escarpment Study Area - 9/96
  - Trail Mountain Mine: 5th East Castlegate Escarpment Study Area - 12/96

Report 2: ***CASTLEGATE SANDSTONE CLIFF STABILITY TRAIL MOUNTAIN - 5th EAST***

(Comparison to East Mountain - Newberry Canyon 6th & 7th EAST)

Reference Data:

Appendix A:	Research Paper: Fluvial Sedimentology of the Upper Cretaceous Castlegate Sandstone, Book Cliffs, Utah
Appendix B:	East Mountain Joint Mapping Data
Appendix C:	Trail Mountain Joint Mapping Data
Maps:	Drawing # KS1703D Cottonwood Mine: Escarpment Modeling Study 1997 Drawing # TMS1705D Trail Mountain Mine: Escarpment Modeling Study 1997 Drawing # CE10790EM Joint Mapping - Castlegate Sandstone Cliff Stability Rilda Canyon Area

Report 3 ***SURFACE RESOURCE IMPACT ASSESSMENT ASSOCIATED WITH MINING BENEATH THE CASTLEGATE SANDSTONE ESCARPMENT TRAIL MOUNTAIN - 5TH EAST***

Reference Data:

Appendix A:	Cultural Resource Evaluation of an Escarpment & Talus Zone at the Entrance to Cottonwood Canyon in Emery County, Utah.
Appendix B:	Environmental Assessment for PacifiCorp dba Utah Power & Light Right-of-Way Application UTU-70447, EA No. 067-95-1 1.
Maps:	Drawing # TMS1705D Trail Mountain Mine: Escarpment Modeling Study 1997 Drawing # TMS1721A Trail Mountain Mine: Escarpment Study Cross Section
Photos	Trail Mountain Mine: 5th East Castlegate Escarpment Study Area - 12/96

Report 4: ***MALEKI TECHNOLOGIES - TECHNICAL APPROACH: ESCARPMENT STUDY***

Report 5: ✤ ***CORNCOB WASH JOINT MEASUREMENTS AND SURFACE OBSERVATIONS***
✤ ***METHODOLOGY OF CASTLEGATE COMPARISON STUDIES***

Reference Data:

Appendix A:	Corncob Wash Joint Measurement Data	
Appendix B:	Corncob Wash Cell Modeling Data	
Appendix C:	Rilda Canyon Cell Modeling Data	
Maps:	Drawing # KS1743D Cottonwood Mine: Escarpment Modeling Study Corncob Wash Jointing	
	Drawing # KS1744D Deer Creek Mine: Escarpment Modeling Study Rilda Canyon Jointing	

Report 6: ***NORTH RILDA LEASE AREA - VEGETATION SURVEY AND EVALUATION SEPTEMBER 1997***

Reference Data:

Maps: Drawing # DS1741C Deer Creek Mine: North Rilda Area Vegetation Map

Report 7: ***ASSESSMENT OF SPOTTED BAT (Euderma maculatum) AND TOWNSEND'S BIG-EARED BAT (Corynorhinus townsendii) IN THE PROPOSED NORTH RILDA LEASE AREA, MANTI LASAL NATIONAL FOREST, EMERY COUNTY, UTAH***

Reference Data:

Maps: Drawing # DS1697C Deer Creek Mine: North Rilda Area Bat Survey Information

Report 8: ***CULTURAL RESOURCES EVALUATION OF ESCARPMENTS IN THE RILDA CANYON LOCALITY OF EMERY COUNTY, UTAH***

Report 9: ***VISUAL ASSESEMENT OF NORTH RILDA ESCARPMENT***

Reference Data:

Maps: Drawing # DS1745D Rilda Canyon View of Castlegate Sandstone Outcrop From State Highway 31

<u>Report 10:</u> ***EAST MOUNTAIN RAPTOR NESTING & HABITAT DATA***

Reference Data:

Appendix A:	East Mountain Raptor Nest Data
Maps:	<u>Drawing #</u> GENS1746D East Mountain Property: Raptor Nesting Location & Habitat Map

ASSESSMENT OF SURFACE IMPACT TO THE CASTLEGATE SANDSTONE ESCARPMENT FROM FULL-EXTRACTRACTION RESERVE RECOVERY OF THE 5TH EAST LONGWALL PANEL, FEDERAL LEASE U-64375, TRAIL MOUNTAIN MINE; EMERY COUNTY, UTAH

INTRODUCTION/BACKGROUND

In early 1996, PacifiCorp applied for an extension of 4th and 5th East longwall panels in the southeastern portion of Federal Lease U-64375. This proposed extension to the east, of approximately 720 feet (setup face location) from the original plan (Proposed Trail Mountain Mine R2P2; submitted to BLM 12/94), was necessary to provide a test section to evaluate surface impacts due to undermining the Castlegate Sandstone escarpment and to maximize the economic recovery of the coal reserves within the existing Federal Lease boundary. With the proposed extension of the 4th and 5th East longwall panels it was estimated that an additional recovery of approximately 430,000 tons of coal was possible.

A "Mine Permit / Lease Stipulation Modification" approval was required from State and Federal regulatory agencies to allow mining of the proposed test section to occur.

Per the current Federal Coal Lease Agreement (U-64375):

"The following stipulations pertain to the lessee responsibility for mining operations on the lease area and on adjacent areas as may be specifically designated on National Forest Service lands...

> 13. Except at specifically approved locations, underground mining operations shall be conducted in such a manner so as to prevent surface subsidence that would: (1) cause the creation of hazardous conditions such as potential escarpment failure and landslides, (2) cause damage to existing surface structures, or (3) damage or alter the flow of perennial streams. The Lessee shall provide specific measures for the protection of escarpments, and determine corrective measures to assure that hazardous conditions are not created."

Pursuant to the above referenced stipulation, PacifiCorp's original plan addressed the protection of the Castlegate Sandstone escarpment with an underground escarpment protective barrier. From exploration drilling and surface mapping, a seam elevation was established. Using a 15-degree "angle-of-draw" between the coal seam being mined (Hiawatha) and the surface feature to be protected (Castlegate Sandstone escarpment), a protective barrier was calculated and implemented. This is consistent with the setup entry locations of the Trail Mountain Mine 2nd East and 3rd East longwall panels (see Drawing # TMS1705D).

During agency review and discussions of PacifiCorp's proposed R2P2 for the Trail Mountain Mine, it became evident that protection of the Castlegate Sandstone escarpment greatly affected the maximization of economic coal recovery from within the lease boundary. It was estimated that an additional 430,000 tons of reserves could be economically recovered by extending the proposed 4th East and 5th East longwall panels approximately 720 feet to the east, under the Castlegate Sandstone escarpment.

From the review and discussions referenced above, it became evident that limited documented field information exists to model and evaluate the degree of impact on the escarpment from full extraction longwall mining. As a result of these various discussions, it was proposed and approved that a trial/evaluation test section be established in the immediate area of the 4th East and 5th East longwall panels to monitor and document the impacts of full extraction mining to the Castlegate Sandstone escarpment and to address the "significance" of what potential impact escarpment failure has on surface features and adjoining public lands.

Before approval can be given to undermine the Castlegate Sandstone escarpment, an environmental assessment by the surface resource management agency (USFS in this particular case) must be conducted. The following issues are to be addressed with regard to the escarpment and the significance of surface impact within the subject area:

Potential impact to public health and safety.
Potential visual impacts with regard to local and regional scenic resources.
Potential impact to threatened, endangered, or sensitive wildlife and plant species.
Potential impact to archeological or heritage resources.
Potential surface and sub-surface hydrological impacts.

Additional site-specific issues must also be addressed. The environmental concerns resulting from the failure of the Castlegate Sandstone escarpment in the vicinity of the 5th East longwall panel have been addressed in the reports titled: **An Assessment of Actual Impacts to Surface Resources Associated with Mining Beneath the Castlegate Sandstone, Trail Mountain - 5th East** and **Environmental Accessway and Undermining of Escarpment, Trail Mountain Mine, Trail Mountain Mine, Emery County, Utah**. These reports demonstrate that the actual impacts were minimal and less than the projected impacts.

In February 1996, PacifiCorp submitted a report on the potential surface impacts to the Castlegate Sandstone escarpment from the proposed full-extraction reserve recovery of the 4th East and 5th East longwall panels. This report included comparisons with previous escarpment study areas at PacifiCorp's Cottonwood Mine in Newberry Canyon and Corncob Wash. Computer simulations of rockfalls in Newberry Canyon and potential rockfall events in Cottonwood Canyon were conducted utilizing the Colorado Rockfall Simulation Program (CRSP). Based on these analyses, it was concluded that it was very unlikely that any debris associated with escarpment failure could pose any danger to public health or safety. Further, it was concluded that the formation of a debris field or talus zone, resulting from the failure of the Castlegate Sandstone escarpment, would occupy less than 5 acres. Prior to the extraction of the 5th East longwall panel, perimeter signs [warning of potential rock fall hazards] were established in the vicinity of the panel extension area along State Road 29 in Straight Canyon and County Road 00506 in Cottonwood Canyon to insure public safety.

On April 25th, 1996, the USFWS (United States Fish and Wildlife Service) concluded that the discovery of active Peregrine Falcon inhabitance (a Federal protected species) in the vicinity of the proposed extension of the 4th and 5th East longwall panels precluded the extension of the 4th East longwall panel due to the time required to obtain the necessary permits. Therefore, the 4th East longwall panel was developed as originally planned with the exception that the 4th East gateroads were developed to cross-cut #66 in anticipation of subsequent agency approval to extend the 5th East longwall panel (refer to Drawing #TMS1705D Trail Mountain Mine Escarpment Study 1997).

On September 20th, 1996 it was proposed that the 5th East longwall setup and bleeder entries be combined into a single 2-entry development at cross-cut #65 (see Figure 1). This proposal was based upon site-specific conditions such as depth of cover, geological conditions, and stable ground conditions experienced in previous panels. This proposal eliminated the 350 ft. barrier pillar, which was originally designed to protect the 5th East longwall panel bleeder entries. The proposed configuration was subsequently approved and provided an additional 350 ft. of longwall panel extraction. Under this scenario, the 5th East longwall setup face was extended approximately 1,055 ft. to the East of the original longwall panel setup face location. Longwall retreat mining of the 5th East panel began on October 29th, 1996 and was completed on March 15th, 1997. The 1,055 ft. extension of the 5th East longwall allowed for the additional recovery of approximately 286,000 tons of coal.

Prior to 5th East longwall panel retreat, three (3) surface survey prisms were established [as shown in Figure 1]. During longwall retreat, field survey data was obtained from these prism locations. Subsequent to longwall panel extraction, all subsidence monitoring data were summarized and plotted. Surface impacts were noted and evaluated, and a back analysis of the failed Castlegate Sandstone escarpment debris field was compared against data from the Colorado Rockfall Simulation Program. The details of which are presented in the remainder of this report.

IMPACT ASSESSMENT

Geological data, prior to longwall mining, was collected in the vicinity of the 5th East longwall panel on the orientation and spacing of the joint systems of the Castlegate Sandstone escarpment (see Drawing # TMS1705D).

Prior to longwall mining, survey prisms were located on the surface of the Castlegate Sandstone escarpment in the vicinity of the 5th East longwall panel to monitor subsidence. Subsidence monitoring was conducted using standard surveying practices. Survey measurements were conducted utilizing a Topcon GTS-4 total station and Lietz triple prisms mounted on 2 in. diameter steel pipes, 4 ft. in length (see Drawing # PRISM). A total of three prisms were anchored to the tops of the cliffs in the vicinity of the 5th East longwall panel. A permanent control station (EC-2) was established from which all prism units were visible. Elevation control on EC-2 was not established, therefore it was assigned an elevation of 0.00 ft. Elevation readings on the prisms represent the difference in elevation from a particular prism and EC-2.

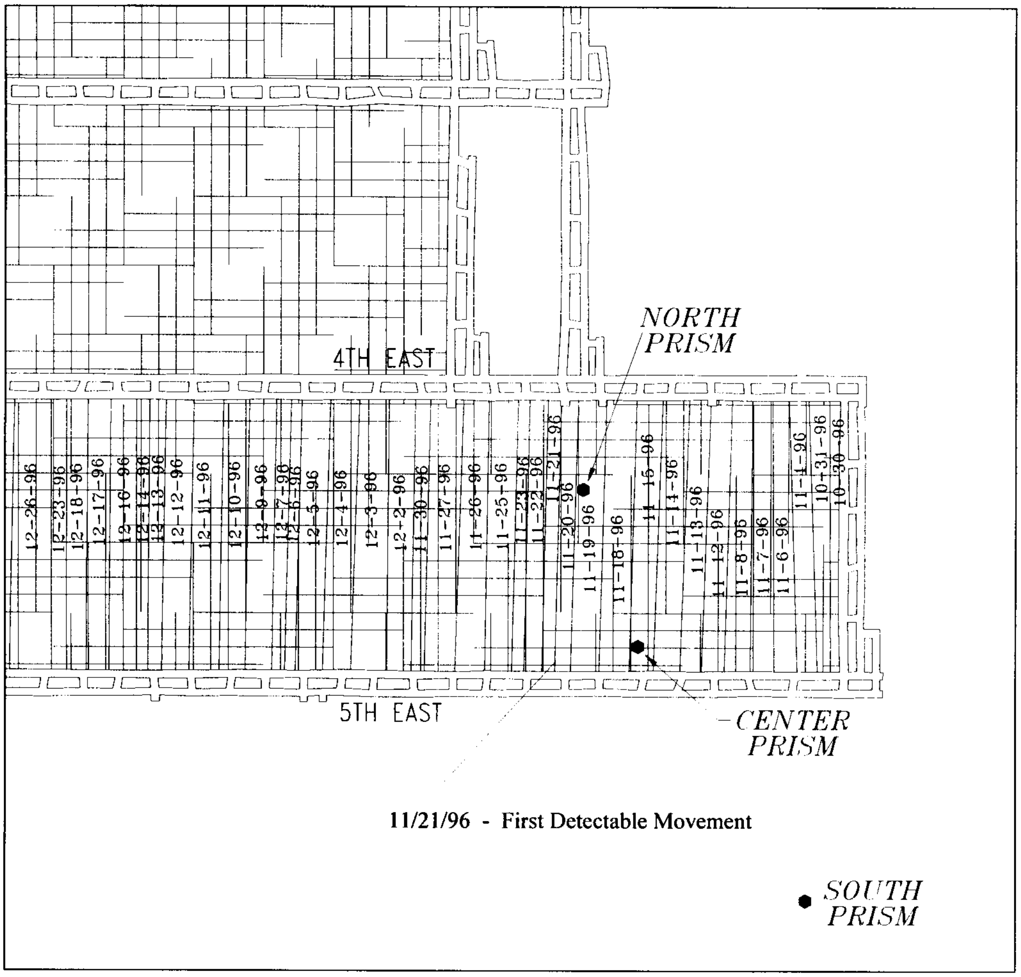


Figure 1. Survey Prism Locations and 5th East Extraction Timing

Survey observations began on October 11th, 1996. Three (3) readings were taken on each of the prisms prior to longwall mining. The averages of these pre-mining readings were used to establish initial prism location and survey accuracy. Photo #1 presents a panoramic view of the Escarpment in the vicinity of the 5th East longwall panel prior to mining.

Monitoring of the prisms during the winter months was adversely affected by extreme weather conditions resulting in ice and fog coating the prisms and making survey instrument set-up difficult. The effect of weather conditions can be observed in the survey data and associated plots presented in Appendix A. The first detectable movement was recorded on the north prism on November 21st, 1996 at which time the longwall had retreated 780 ft. from the set-up face. Failure of the Castlegate Sandstone escarpment was observed on November 27th, 1996 at which time the longwall had retreated 1,097 ft. from the set-up face. The position of the 5th East longwall face was adjacent to the setup face of the 4th East longwall panel when failure of the escarpment occurred. It was at this point where the cave generated from extraction of the 5th East longwall panel met with the cave from the 4th East longwall panel (see Figure 1). A cross section of the slope through the major failure and debris zone is shown in Drawing # TMS1711C. All prism movement was essentially complete by December 20th, 1996. Table 1 presents summary survey data as of June 25th, 1997.

Table 1. Summary Subsidence Monitoring of Castlegate Sandstone Escarpment in the Vicinity of 5th East Longwall Panel.

Prism	Net Change Easting	Net Change Northing	Net Change Vertical (ft.)
South	No detectable change	No detectable change	No detectable change
Center	- 0.277	+ 0.524	- 0.410
North	+ 1.366	- 0.305	- 3.273

The major zone of Castlegate Sandstone escarpment failure (see Photo #2) is approximately 200 ft. in height and 239 ft. in width which accounted for approximately 33,500 yd^3 of debris which was deposited over a 3.5 acre area. Direct field observation has revealed minor (2 - 4 inches in width) tension cracks, running north-south, on the slopes just to the south of the major failure zone and just below the Castlegate Sandstone escarpment. The existence of these cracks indicate foundation failure as the most likely mode of failure of the Castlegate Sandstone escarpment.

Colorado Rockfall Simulation Program

The Colorado Department of Transportation with the help of the Colorado Geological Survey and the Colorado School of Mines wrote the Colorado Rockfall Simulation Program (CRSP) 3.0a. CRSP is based on field observations and data collected from studies of video taped rockfalls. It was initially designed as a tool for the location and design of rockfall mitigation structures. This program uses the slope profile, rebound and friction characteristics of the slope, and the rotational energy of the rocks to simulate rocks tumbling down a slope. Empirically derived functions for velocity, friction, and slope material properties are used to model the dynamic interaction of the rock and the slope. The statistical variation observed among rockfalls is modeled by randomly varying the angle at which the rock impacts the slope within limits set by rock diameter and slope roughness.

Rocks do not simply slide down a slope, they travel down a slope with a combination of free fall, bouncing and rolling. This program tries to model rockfall during all of these modes of travel.

Slope inclination and length are the most important factors in determining the behavior of rockfalls because they define zones of acceleration. Slope inclination and length are input into CRSP by dividing the slope into straight line segments called cells. These cells are entered into the program using the beginning and ending coordinates of each line segment.

Second in importance to determining rockfall behavior are the surface irregularities on the slope. These irregularities alter the angle that a rock impacts the slope. CRSP models surface irregularities by randomly varying the slope angle between zero and a maximum value which is controlled by the rock size and the surface roughness. The maximum random angle is:

$$\theta_{max} = \tan^{-1}(S_{max}/R)$$

where:

θ_{max}= the maximum possible variation in the slope angle.

S_{max} = the perpendicular variation of the slope as measured along a slope distance equal to the radius of the rock.

R= radius of the rock.

Other items that affect the behavior of a rock traveling down a slope are the material properties of the slope. These properties affect the behavior of a rock rebounding from the surface. CRSP uses two material properties to model rockfall behavior; the coefficient of restitution (R_n) and the tangential coefficient of frictional resistance (R_t). These coefficients measure the conservation of kinetic energy after a rock impacts the slope. R_n is a measure of the degree of elasticity in a collision normal to the slope, and R_t is a measure of the frictional resistance to movement parallel to the slope.

Some general assumptions used in development of the program are:

- This is a two dimensional analysis, therefore, the profile should follow the most probable rock path, as established by field investigation.

- Rock size and shape remain constant. Therefore, the rock does not break apart as it travels down the slope.

Based upon field observations, rock shape was observed to be cylindrical rather than spherical in nature. Thus, modeling was carried on rocks that were more of a block shape. Three different rock sizes were analyzed; 3 ft. x 3 ft. cylinder, 5 ft. x 5 ft. cylinder, and 10 ft. x 10 ft. cylinder. The program assumes that all rocks remain intact as they travel down the slope.

GENERAL DISCUSSION OF PROGRAM INPUT

Input parameters are site-specific and depend on field observations of the chosen rockfall path from the Castlegate Sandstone escarpment to features of concern (roads and streams). The parameters that need to be determined are the rock size, the cell boundaries or slope profile, the surface roughness, the tangential coefficient, and the normal coefficient.

Rock sizes are usually determined by using the largest rocks found at the base of the rockfall path that can be identified as having fallen from the source area. The rock size or sizes can then be used later in determining the surface roughness.

Cell boundaries are selected where either a change in slope or a change in slope material occurs. In this case, changes in material resulted in changes in slope, therefore, distinct breaks in the slope inclination were used as cell boundaries.

The surface roughness (S) is the perpendicular variation of the slope as measured parallel to the dip of the slope along a distance equal to the radius of the rock. The surface roughness is not always the value for the largest bump on the slope, or an average variation in the slope, rather it is the value of the largest variation that occurs with some frequency. Surface roughness is also a function of rock size, such that different size rocks may posses different surface roughness for the same slope profile. The tangential coefficient was determined from Table 2. The normal coefficient was determined from Table 3.

Table 2: Tangential Coefficient for Various Slope Conditions

Tangential	
.87-.92	Smooth hard surfaces such as pavement or smooth bedrock surfaces.
.83-.87	Most bedrock surfaces and talus with no vegetation.
.82-.85	Most talus slopes with some low vegetation.
.80-.83	Vegetated talus slopes and soil slopes with scarce vegetation.
.78-.82	Brush covered soil slope.

Table 3: Normal Coefficient for Various Slope Conditions

Normal Coefficient R_n	Description of Slope
.37-.42	Smooth hard surfaces and paving.
.33-.37	Most bedrock and boulder fields.
.30-.33	Talus and firm soil slopes.
.28-.30	Soft soil slopes.

BACK ANALYSIS OF ESCARPMENT FAILURE UTILIZING CRSP 3.0a

PacifiCorp has conducted a theoretical escarpment failure back analysis of the Trail Mountain Mine Castlegate Sandstone escarpment test study area, utilizing field observations. Computer simulations of the slope failure were completed utilizing CRSP version 3.0a. Every effort was made to accurately represent the resultant slope(s) at Trail Mountain through technical engineering assumptions and data input files.

The results of the evaluation contained in this report discuss the simulation of mining induced surface influence on the Castlegate Sandstone escarpment above the extension of the 5th East longwall panel at the Trail Mountain Mine.

CRSP models rockfall behavior by dropping a specific number of rocks, all of the same size and shape, from a zone above the slope. For all modeled cross-sections, this zone was entered as the major area of failure, which was from an elevation of 8,200 ft. to 8,000 ft. This best accounts for the majority of Castlegate Sandstone escarpment failure.

Surface roughness varied from 1.0 to 8.5 feet. The material makeup of the slope varied from very competent sandstone outcrops to moderately vegetated rocky soils. The tangential coefficient therefore varied from 0.87 to 0.82 with 0.82 being the most commonly used coefficient. The normal coefficient varied from 0.37 to 0.33 with a value of 0.33 being used most frequently. For specific values assigned to each cross-section, see Drawing # TMS1721A.

Due to the inaccessibility of the debris field, it was not possible to determine an accurate size distribution of the material, which made it to the bottom portion of the debris field. For this reason, three different rock sizes were modeled in the back analysis of the Trail Mountain Castlegate Sandstone escarpment study area; 3 ft. x 3 ft., 5 ft. x 5 ft., and 10 ft. x 10 ft. cylindrical shaped rocks were modeled.

PROGRAM RESULTS

The most significant parameter outside of rock size is surface roughness, which may vary depending upon rock size. By adjusting this parameter for a particular size rock, while keeping all other variables constant, allows one to fit the program output to the observed field data.

For this analyses a surface roughness of 5.0 for 3 ft. x 3 ft. and 5 ft. x 5 ft. cylindrical rocks produced results consistent with field observations. In order to produce results consistent with field observation for 10 ft. x 10 ft. cylindrical rocks, the surface roughness had to be increased to 8.5. Detailed input/output data from the program are provided in Appendix B.

Although it is possible to produce results consistent with field observations by adjusting surface roughness factors for given rock sizes, it should be noted that very large material in excess of 20 ft. x 15 ft. can be seen near the upper portion of the failure (Photo #2). Surface roughness required to contain this material in close proximity to the failure would be in excess of reasonable values.

Two explanations for the presence of such large boulders in the upper portion of the debris field may be:

- The mode of failure (foundation failure) did not lead to toppling of rock from higher elevations, instead the material may have slid downslope limiting the initial amount of potential energy available for the rock to roll down the slope.

✢ The existence of small ledges just below the failure (see Photo #1) helped contain some of the failure material in the areas above those ledges. These ledges are not evident on the slope profile due to the fact that the slope profile was constructed from a topographic map that contained 80 ft. contour intervals (best information available).

OVERVIEW OF CASTLEGATE SANDSTONE ESCARPMENT GEOTECHNICAL MODEL EVALUATION

Since early 1985, PacifiCorp has been actively predicting, modeling, and documenting full-extraction longwall mining as it relates to the Castlegate Sandstone escarpment. Numerical models were developed from field observations from PacifiCorp's Cottonwood Mine as mining beneath the Castlegate Sandstone escarpment was conducted in Newberry and Corncob Wash in an effort to back analyze and predict escarpment failure. The 2-D numerical models developed from these test section studies (i.e. USBM, Seegmiller, University of Utah) were for the most part, inconclusive and incomplete.

The extension of the 5th East longwall panel at PacifiCorp's Trail Mountain mine has allowed for an additional test section which provides a case in which only one east-west oriented longwall panel is extracted from beneath the north-south running Castlegate Sandstone escarpment. In addition to this field test section, a geotechnical project was initiated with an independent consultant (Maleki Technologies).

The scope of the current Castlegate Sandstone escarpment evaluation project is as follows:

✢ Back analyze existing data from Newberry Canyon and Corncob Wash studies (i.e. field survey data, geologic/litholgic data, mining orientation/sequence, previous 2-D model development by previous researchers (USBM, Seegmiller, U of U), and summarize conclusions).

✢ Selection of a separate study area within the existing Newberry Canyon/Corncob Wash test section areas. Development of an independent/updated 2-D finite element model that provides conclusive escarpment failure results when compared to the post mining field data.

✢ Development of a separate (simplified) "risk/failure" mathematical probability model (through the use of regression analyses) based upon geotechnical/geological survey parameters of the separate study area selected from the Newberry Canyon/Corncob Wash test sections with regard to the independently developed 2-D finite element model. Evaluation of this model with regard to conclusive escarpment failure results as compared to the post mining field data.

✢ Selection of the "best fit" model from the above referenced trial models and simulation of the full-extraction mining of the Trail Mountain Mine 5th East longwall panel and associated Castlegate Sandstone escarpment failure. Recalibration of the model(s) to fit the field results of the Trail Mountain 5th East longwall test area.

+ Evaluation of the existing CRSP with regard to modeling and prediction of rockfalls from escarpment failures down the existing outslopes below the Castlegate Sandstone escarpment. Recalibrate program to " best fit" available field data from all escarpment test study areas.

+ Summarize and present project findings to the applicable Federal and State regulatory agencies. Specifically, address modeling of the southern portion of the Castlegate Sandstone escarpment in the North Rilda Canyon Area prior to pre-mining environmental analysis of potential impacts from full-extraction longwall mining within the immediate area of the Castlegate Sandstone escarpment.

CONCLUSIONS

The failure of the Castlegate Sandstone escarpment in the vicinity of the Trail Mountain Mine 5th East longwall panel was minimal and impacted approximately 3.5 acres which was less than the 5 acres which had been estimated prior to mining. The failure has not endangered public health and safety and currently does not pose a significant threat to public health and safety.

The extension of the 5th East longwall panel underneath the Castlegate Sandstone escarpment resulted in the recovery of an additional 286,000 tons of coal resources that would have been lost had the panel not been extended.

The Colorado Rockfall Simulation Program is a conservative tool for predicting the impact of rock falls from escarpment failure and this should be considered as such for future areas of concern with regard to escarpment failure.

Model development for the prediction of Castlegate Sandstone escarpment failure is currently be undertaken by an independent consultant that was acceptable to the BLM and Forest Service. The results of which, will be provided to the applicable Federal and State regulatory agencies.

REFERENCE DATA:

Appendix A: Prism Survey Data
Appendix B: CRSP Data
Maps:
<u>Drawing #</u> 1705D TRAIL MOUNTAIN MINE: ESCARPMENT MODELING STUDY 1997
<u>Drawing #</u> TMS1721A TRAIL MOUNTAIN MINE: ESCARPMENT STUDY CROSS SECTION
<u>Drawing #</u> TMS1711C TRAIL MOUNTAIN MINE: ESCARPMENT STUDY 5TH EAST TALUS CROSS SECTION
<u>Drawing:</u> PRISM STAND and MOUNTING PLATE

Photos: TRAIL MOUNTAIN MINE: 5TH EAST CASTLEGATE ESCARPMENT STUDY AREA - 9/96
TRAIL MOUNTAIN MINE: 5TH EAST CASTLEGATE ESCARPMENT STUDY AREA - 12/96

North Prism

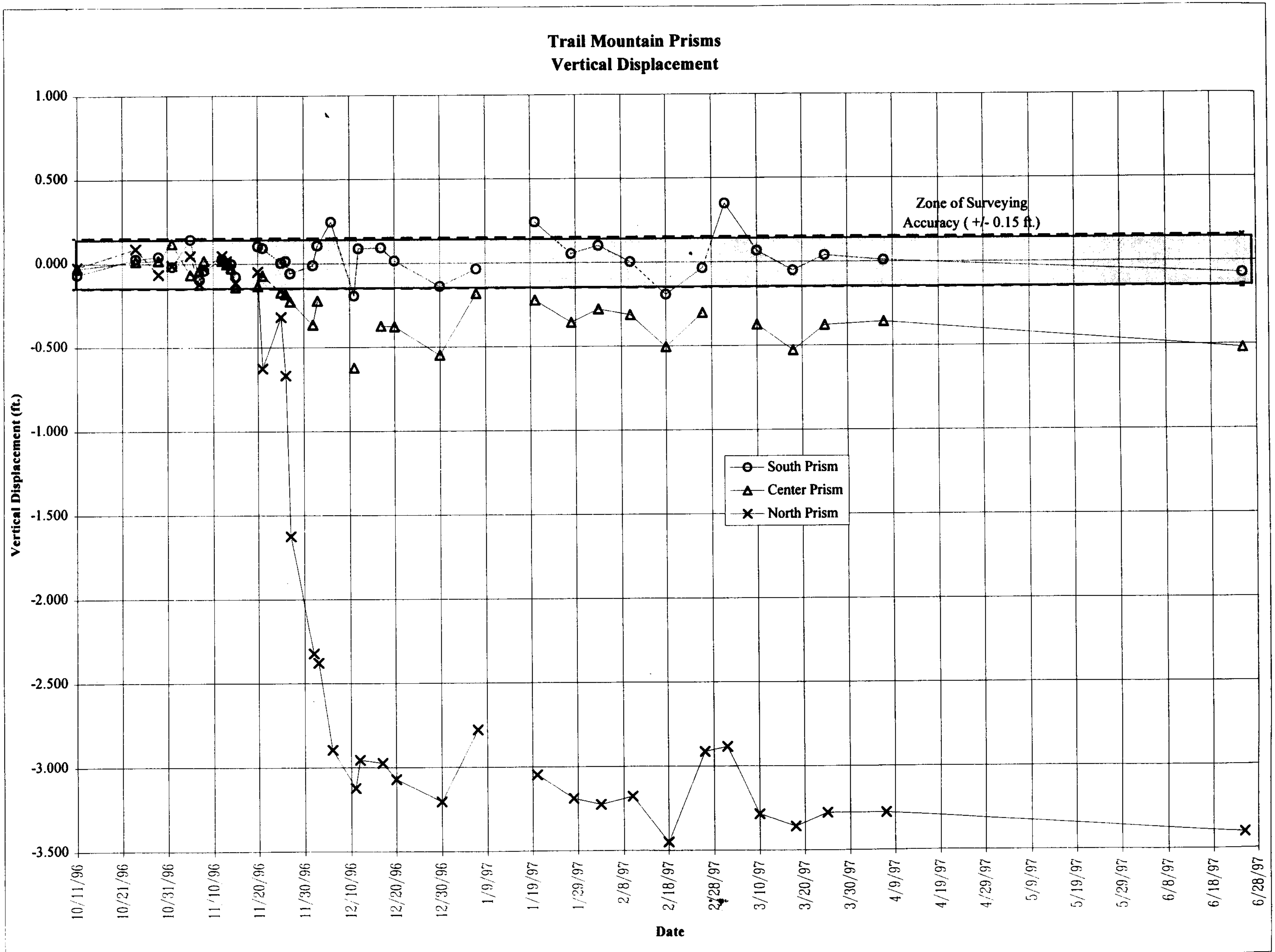
Date	Northing	Easting	Elevation	Differences in Northing	Differences in Easting	Differences in Elevation	Time (days)	Comments
Initial Coords:	**347,394.976**	**2,089,044.179**	**1,595.903**	**0.000**	**0.000**	**0.000**		**Average of first 3 measurements**
10/11/96	347,395.112	2,089,044.093	1,595.880	0.136	-0.086	-0.023	0	
10/24/96	347,394.939	2,089,044.202	1,595.990	-0.037	0.023	0.087	13	
10/29/96	347,394.876	2,089,044.242	1,595.838	-0.100	0.063	-0.065	18	
11/1/96	347,394.890	2,089,044.138	1,595.890	-0.086	-0.041	-0.013	21	
11/5/96	347,395.030	2,089,044.181	1,595.950	0.054	0.002	0.047	25	
11/7/96	347,395.035	2,089,044.340	1,595.780	0.059	0.161	-0.123	27	
11/8/96	347,394.821	2,089,044.187	1,595.875	-0.155	0.008	-0.028	28	
11/12/96	347,394.758	2,089,044.273	1,595.950	-0.218	0.094	0.047	32	
11/13/96	347,394.850	2,089,044.231	1,595.918	-0.126	0.052	0.015	33	
11/14/96	347,395.063	2,089,044.095	1,595.880	0.087	-0.084	-0.023	34	
11/15/96	347,394.936	2,089,044.218	1,595.788	-0.040	0.039	-0.115	35	
11/18/96	347,394.962	2,089,044.209		-0.014	0.030		38	
11/20/96	347,394.938	2,089,044.337	1,595.853	-0.038	0.158	-0.050	40	
11/21/96	347,394.905	2,089,044.308	1,595.278	-0.071	0.129	-0.625	41	
11/25/96	347,394.774	2,089,044.467	1,595.583	-0.202	0.288	-0.320	45	
11/26/96	347,394.248	2,089,045.000	1,595.235	-0.728	0.821	-0.668	46	
11/27/96	347,394.578	2,089,045.792	1,594.278	-0.398	1.613	-1.625	47	
12/2/96	347,394.550	2,089,045.962	1,593.580	-0.426	1.783	-2.323	52	
12/3/96	347,394.550	2,089,046.000	1,593.525	-0.426	1.821	-2.378	53	
12/6/96	347,394.543	2,089,045.940	1,593.008	-0.433	1.761	-2.895	56	
12/11/96	347,394.539	2,089,045.886	1,592.780	-0.437	1.707	-3.123	61	
12/12/96	347,394.690	2,089,045.863	1,592.948	-0.286	1.684	-2.955	62	
12/17/96	347,394.547	2,089,045.859	1,592.930	-0.429	1.680	-2.973	67	
12/20/96	347,394.465	2,089,045.879	1,592.833	-0.511	1.700	-3.070	70	
12/30/96	347,394.456	2,089,045.879	1,592.698	-0.520	1.700	-3.205	80	
1/7/97	347,394.910	2,089,045.721	1,593.125	-0.066	1.542	-2.778	88	Had difficulty keeping survey instrument level.
1/15/97	347,394.355	2,089,045.881		-0.621	1.702		96	Could not read mirrors.
1/20/97	347,394.476	2,089,045.723	1,592.855	-0.500	1.544	-3.048	101	
1/28/97	347,394.599	2,089,045.658	1,592.715	-0.377	1.479	-3.188	109	
2/3/97	347,394.255	2,089,045.792	1,592.678	-0.721	1.613	-3.225	115	
2/10/97	347,394.559	2,089,045.659	1,592.725	-0.417	1.480	-3.178	122	
2/18/97	347,394.597	2,089,045.541	1,592.453	-0.379	1.362	-3.450	130	
2/26/97	347,394.496	2,089,045.811	1,592.990	-0.480	1.632	-2.913	138	
3/3/97	347,394.589	2,089,045.749	1,593.020	-0.387	1.570	-2.883	143	
3/10/97	347,394.517	2,089,045.633	1,592.618	-0.459	1.454	-3.285	150	
3/18/97	347,394.600	2,089,045.569	1,592.545	-0.376	1.390	-3.358	158	
3/25/97	347,394.559	2,089,045.615	1,592.625	-0.417	1.436	-3.278	165	
4/7/97	347,394.671	2,089,045.592	1,592.625	-0.305	1.413	-3.278	178	
6/25/97	347,394.573	2,089,045.645	1,592.500	-0.403	1.466	-3.403	257	

Center Prism

Date	Northing	Easting	Elevation	Differences in Northing	Differences in Easting	Differences in Elevation	Time (days)	Comments
Initial Coords:	**346,971.656**	**2,089,190.948**	**1,565.248**	**0.000**	**0.000**	**0.000**		**Average of first 3 measurements**
10/11/96	346,971.803	2,089,190.872	1,565.218	0.147	-0.076	-0.030	0	
10/24/96	346,971.632	2,089,190.951	1,565.260	-0.024	0.003	0.012	13	
10/29/96	346,971.532	2,089,191.022	1,565.265	-0.124	0.074	0.017	18	
11/1/96	346,971.588	2,089,190.988	1,565.366	-0.068	0.040	0.118	21	
11/5/96	346,971.621	2,089,190.969	1,565.181	-0.035	0.021	-0.067	25	
11/7/96	346,971.673	2,089,190.892	1,565.208	0.017	-0.056	-0.040	27	
11/8/96	346,971.482	2,089,191.030	1,565.265	-0.174	0.082	0.017	28	
11/12/96	346,971.441	2,089,191.107	1,565.265	-0.215	0.159	0.017	32	
11/13/96	346,971.544	2,089,191.061	1,565.245	-0.112	0.113	-0.003	33	
11/14/96	346,971.759	2,089,190.963	1,565.220	0.103	0.015	-0.028	34	
11/15/96	346,971.602	2,089,190.992	1,565.108	-0.054	0.044	-0.140	35	
11/18/96	346,971.694	2,089,191.038		0.038	0.090		38	
11/20/96	346,971.729	2,089,191.060	1,565.113	0.073	0.112	-0.135	40	
11/21/96	346,971.741	2,089,191.053	1,565.175	0.085	0.105	-0.073	41	
11/25/96	346,971.828	2,089,191.072	1,565.075	0.172	0.124	-0.173	45	
11/26/96	346,971.758	2,089,191.430	1,565.065	0.102	0.482	-0.183	46	
11/27/96	346,971.943	2,089,190.980	1,565.020	0.287	0.032	-0.228	47	
12/2/96	346,971.798	2,089,191.029	1,564.883	0.142	0.081	-0.365	52	
12/3/96	346,971.880	2,089,191.039	1,565.025	0.224	0.091	-0.223	53	
12/6/96	346,971.791	2,089,191.091		0.135	0.143		56	
12/11/96	346,971.937	2,089,190.932	1,564.625	0.281	-0.016	-0.623	61	
12/12/96	346,971.911	2,089,190.903		0.255	-0.045		62	
12/17/96	346,971.826	2,089,191.059	1,564.873	0.170	0.111	-0.375	67	
12/20/96	346,971.826	2,089,191.059	1,564.870	0.170	0.111	-0.378	70	
12/30/96	346,971.748	2,089,191.043	1,564.700	0.092	0.095	-0.548	80	
1/7/97	346,972.342	2,089,190.843	1,565.065	0.686	-0.105	-0.183	88	Had difficulty keeping survey instrument level.
1/15/97	346,971.712	2,089,191.086		0.056	0.138		96	Could not read mirrors
1/20/97	346,972.054	2,089,190.982	1,565.025	0.398	0.034	-0.223	101	
1/28/97	346,972.046	2,089,190.914	1,564.892	0.390	-0.034	-0.356	109	
2/3/97	346,971.827	2,089,190.882	1,564.970	0.171	-0.066	-0.278	115	
2/10/97	346,972.060	2,089,190.920	1,564.935	0.404	-0.028	-0.313	122	
2/18/97	346,972.027	2,089,190.882	1,564.743	0.371	-0.066	-0.505	130	
2/26/97	346,972.084	2,089,190.941	1,564.945	0.428	-0.007	-0.303	138	
3/3/97	346,972.213	2,089,190.864		0.557	-0.084		143	
3/10/97	346,971.993	2,089,190.954	1,564.873	0.337	0.006	-0.375	150	
3/18/97	346,972.081	2,089,190.844	1,564.720	0.425	-0.104	-0.528	158	
3/25/97	346,972.148	2,089,191.031	1,564.870	0.492	0.083	-0.378	165	
4/7/97	346,972.180	2,089,190.671	1,564.890	0.524	-0.277	-0.358	178	
6/25/97	346,972.092	2,089,190.936	1,564.728	0.436	-0.012	-0.520	257	

South Prism

Date	Northing	Easting	Elevation	Differences in Northing	Differences in Easting	Differences in Elevation	Time (days)	Comments
Initial Coords:	**346,282.388**	**2,089,639.849**	**1,638.777**	**0.000**	**0.000**	**0.000**		**Average of first 3 measurements**
10/11/96	346,282.432	2,089,639.803	1,638.710	0.044	-0.046	-0.067	0	
10/24/96	346,282.397	2,089,639.862	1,638.803	0.009	0.013	0.026	13	
10/29/96	346,282.336	2,089,639.881	1,638.818	-0.052	0.032	0.041	18	
11/1/96	346,282.328	2,089,639.858	1,638.758	-0.060	0.009	-0.019	21	
11/5/96	346,282.391	2,089,639.884	1,638.920	0.003	0.035	0.143	25	
11/7/96	346,282.348	2,089,639.880	1,638.680	-0.040	0.031	-0.097	27	
11/8/96	346,282.120	2,089,640.026	1,638.735	-0.268	0.177	-0.042	28	
11/12/96	346,282.153	2,089,640.117	1,638.805	-0.235	0.268	0.028	32	
11/13/96	346,282.311	2,089,639.910	1,638.783	-0.077	0.061	0.006	33	
11/14/96	346,282.429	2,089,639.856	1,638.775	0.041	0.007	-0.002	34	
11/15/96	346,282.360	2,089,639.865	1,638.700	-0.028	0.016	-0.077	35	
11/18/96	346,282.380	2,089,639.928		-0.008	0.079		38	
11/20/96	346,282.427	2,089,639.867	1,638.880	0.039	0.018	0.103	40	
11/21/96	346,282.435	2,089,639.904	1,638.868	0.047	0.055	0.091	41	
11/25/96	346,282.342	2,089,639.902	1,638.780	-0.046	0.053	0.003	45	
11/26/96	346,282.395	2,089,639.819	1,638.790	0.007	-0.030	0.013	46	
11/27/96	346,282.414	2,089,639.727	1,638.718	0.026	-0.122	-0.059	47	
12/2/96	346,282.207	2,089,639.938	1,638.765	-0.181	0.089	-0.012	52	
12/3/96	346,282.323	2,089,639.936	1,638.883	-0.065	0.087	0.106	53	
12/6/96	346,282.239	2,089,639.916	1,639.023	-0.149	0.067	0.246	56	
12/11/96	346,282.239	2,089,639.916	1,638.583	-0.149	0.067	-0.194	61	
12/12/96	346,282.500	2,089,639.834	1,638.865	0.112	-0.015	0.088	62	
12/17/96	346,282.325	2,089,639.897	1,638.868	-0.063	0.048	0.091	67	
12/20/96	346,282.212	2,089,639.985	1,638.790	-0.176	0.136	0.013	70	
12/30/96	346,282.211	2,089,639.942	1,638.638	-0.177	0.093	-0.139	80	
1/7/97	346,282.374	2,089,639.783	1,638.740	-0.014	-0.066	-0.037	88	Had difficulty keeping survey instrument level.
1/15/97	346,282.043	2,089,640.097		-0.345	0.248		96	Could not read mirrors
1/20/97	346,282.421	2,089,639.917	1,639.020	0.033	0.068	0.243	101	
1/28/97	346,282.365	2,089,639.856	1,638.830	-0.023	0.007	0.053	109	
2/3/97	346,282.247	2,089,639.952	1,638.878	-0.141	0.103	0.101	115	
2/10/97	346,282.360	2,089,639.837	1,638.780	-0.028	-0.012	0.003	122	
2/18/97	346,282.164	2,089,639.919	1,638.585	-0.224	0.070	-0.192	130	
2/26/97	346,282.268	2,089,639.934	1,638.740	-0.120	0.085	-0.037	138	
3/3/97	346,282.767	2,089,639.661	1,639.125	0.379	-0.188	0.348	143	
3/10/97	346,282.352	2,089,639.927	1,638.843	-0.036	0.078	0.066	150	
3/18/97	346,282.357	2,089,639.847	1,638.725	-0.031	-0.002	-0.052	158	
3/25/97	346,282.381	2,089,639.859	1,638.815	-0.007	0.010	0.038	165	
4/7/97	346,282.485	2,089,639.776	1,638.785	0.097	-0.073	0.008	178	
6/25/97	346,282.434	2,089,639.847	1,638.703	0.046	-0.002	-0.074	257	



Trail Mountain Prisms
Vertical Displacement
1.000
0.500
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
-3.500
Vertical Displacement (ft.)
Zone of Surveying Accuracy (+/- 0.15 ft.)
South Prism
Center Prism
North Prism
10/11/96
10/21/96
10/31/96
11/10/96
11/20/96
11/30/96
12/10/96
12/20/96
12/30/96
1/9/97
1/19/97
1/29/97
2/8/97
2/18/97
2/28/97
3/10/97
3/20/97
3/30/97
4/9/97
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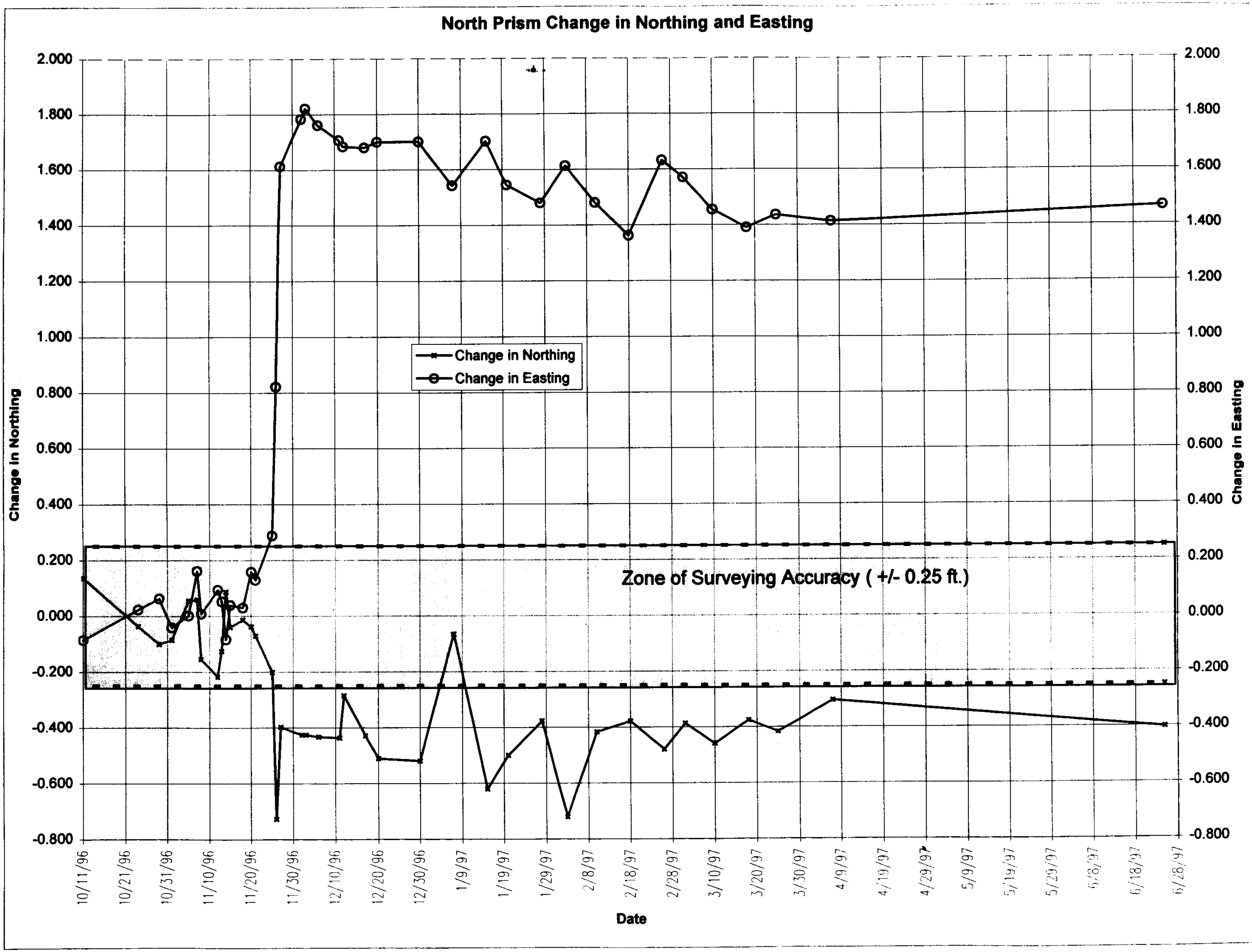
6/18/97
6/28/97
Date



North Prism Change in Northing and Easting
Change in Northing
Change in Easting
Change in Northing
Change in Easting
Zone of Surveying Accuracy (+/- 0.25 ft.)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
-0.200
-0.400
-0.600
-0.800
10/11/96
10/21/96
10/31/96
11/10/96
11/20/96
11/30/96
12/10/96
12/20/96
12/30/96
1/9/97
1/19/97
1/29/97
2/8/97
2/18/97
2/28/97
3/10/97
3/20/97
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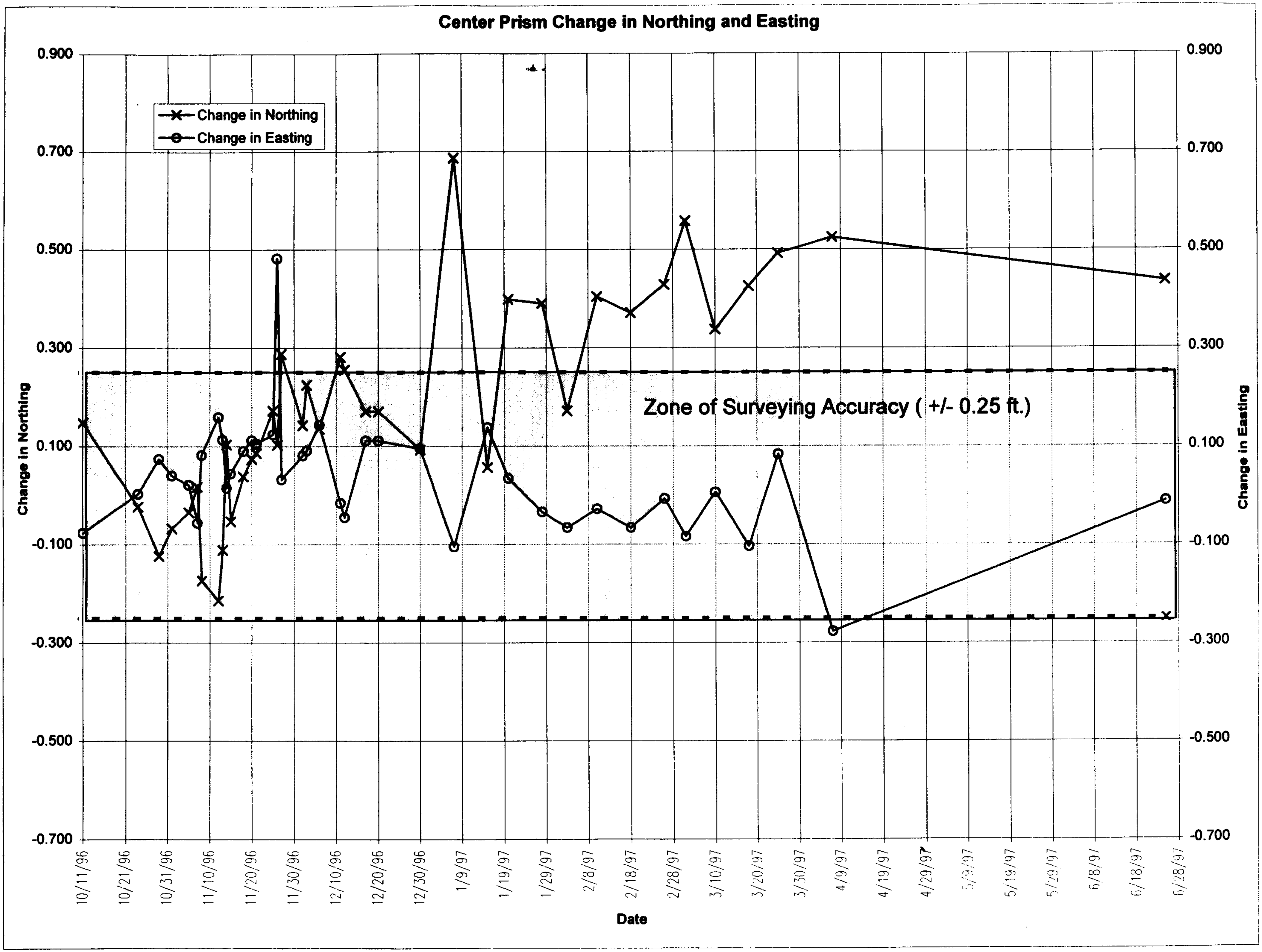
Date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Change in Easting
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0.500
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0.100
-0.100
-0.300
-0.500
-0.700
10/11/96
10/21/96
10/31/96
11/10/96
11/20/96
11/30/96
12/10/96
12/20/96
12/30/96
1/9/97
1/19/97
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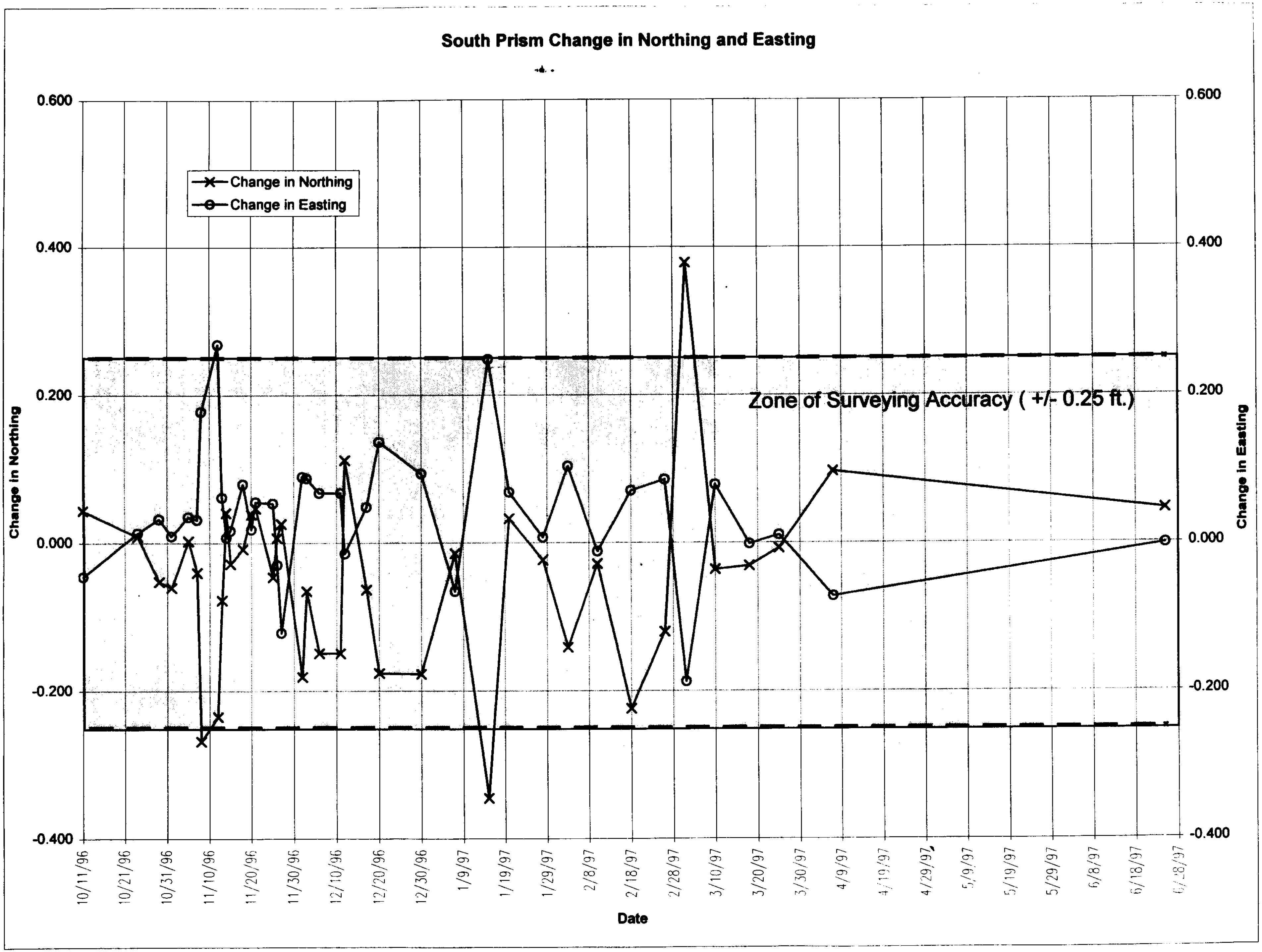
6/28/97
Date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Change in Northing
Change in Easting
Zone of Surveying Accuracy (+/- 0.25 ft.)
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0.400
0.200
0.000
-0.200
-0.400
Change in Northing
Change in Easting
10/11/96
10/21/96
10/31/96
11/10/96
11/20/96
11/30/96
12/10/96
12/20/96
12/30/96
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5/19/97
5/29/97
6/8/97
6/18/97
Date

CRSP Input for Trail Mountain 5th East Escarpment Study Area

Cross Section A

3 ft. Cylindrical Boulder

TMFINAL.DAT

ROCK STATISTICS

3519 lbs CYLINDRICAL ROCK 3 ft BY 3 ft

NUMBER OF CELLS	10
NUMBER OF ROCKS	500

ANALYSIS POSITION	1270.0 ft
INITIAL Y ZONE	8000.0 ft TO 8200.0 ft

INITIAL X VELOCITY	1.0 ft/sec
INITIAL Y VELOCITY	-1.0 ft/sec

CELL DATA TABLE

TMFINAL.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

CELL#	SURFACE ROUGHNESS	TANGENTIAL COEFFICIENT	NORM. COEF. RESTITUTION	BEGINNING X,Y	ENDING X,Y
1	5.00	.85	.35	0.0 ,8480.0	300.0 ,8400.0
2	5.00	.85	.35	300.0 ,8400.0	450.0 ,8320.0
3	1.00	.87	.37	450.0 ,8320.0	570.0 ,8240.0
4	1.00	.87	.37	570.0 ,8240.0	625.0 ,8080.0
5	1.00	.87	.37	625.0 ,8080.0	650.0 ,8000.0
6	5.00	.82	.33	650.0 ,8000.0	730.0 ,7920.0
7	5.00	.82	.33	730.0 ,7920.0	830.0 ,7840.0
8	5.00	.82	.33	830.0 ,7840.0	950.0 ,7760.0
9	5.00	.82	.33	950.0 ,7760.0	1270.0 ,7680.0
10	5.00	.82	.33	1270.0 ,7680.0	1400.0 ,7600.0

CRSP Output for Trail Mountain 5th East Escarpment Study Area

Cross Section A

3 ft. Cylindrical Boulder

900 ft TO 910 ft	8
910 ft TO 920 ft	10
920 ft TO 930 ft	8
930 ft TO 940 ft	11
940 ft TO 950 ft	6
950 ft TO 960 ft	33
960 ft TO 970 ft	20
970 ft TO 980 ft	16
980 ft TO 990 ft	12
990 ft TO 1000 ft	11
1000 ft TO 1010 ft	6
1010 ft TO 1020 ft	7
1020 ft TO 1030 ft	4
1030 ft TO 1040 ft	3
1040 ft TO 1050 ft	1
1050 ft TO 1060 ft	3
1060 ft TO 1070 ft	2
1080 ft TO 1090 ft	1
1090 ft TO 1100 ft	1
1120 ft TO 1130 ft	1

CELL DATA OUTPUT

TMFINAL.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

DATA COLLECTED AT END OF EACH CELL

CELL #	MAXIMUM VELOCITY (ft/sec)	AVERAGE VELOCITY (ft/sec)	STANDARD DEVIATION VELOCITY	AVERAGE BOUNCE HEIGHT (ft)	MAXIMUM BOUNCE HEIGHT (ft)
1	NO ROCKS PASSED POINT				
2	NO ROCKS PASSED POINT				
3	NO ROCKS PASSED POINT				
4	84	43	16.13	13	43
5	106	56	22.29	20	74
6	87	43	16.50	7	29
7	92	39	18.17	5	26
8	80	35	17.25	4	19
9	NO ROCKS PASSED POINT				
10	NO ROCKS PASSED POINT				

X INTERVAL	ROCKS STOPPED
0 ft TO 10 ft	1
650 ft TO 660 ft	53
660 ft TO 670 ft	20
670 ft TO 680 ft	12
680 ft TO 690 ft	10
690 ft TO 700 ft	3
700 ft TO 710 ft	12
710 ft TO 720 ft	5
720 ft TO 730 ft	6
730 ft TO 740 ft	13
740 ft TO 750 ft	11
750 ft TO 760 ft	12
760 ft TO 770 ft	8
770 ft TO 780 ft	8
780 ft TO 790 ft	15
790 ft TO 800 ft	13
800 ft TO 810 ft	14
810 ft TO 820 ft	10
820 ft TO 830 ft	12
830 ft TO 840 ft	13
840 ft TO 850 ft	12
850 ft TO 860 ft	16
860 ft TO 870 ft	14
870 ft TO 880 ft	12
880 ft TO 890 ft	13
890 ft TO 900 ft	18

CRSP Input for Trail Mountain 5th East Escarpment Study Area

Cross Section A

5 ft. Cylindrical Boulder

TMFINAL.DAT

ROCK STATISTICS

16294 lbs CYLINDRICAL ROCK   5 ft BY 5 ft

NUMBER OF CELLS	10
NUMBER OF ROCKS	500

ANALYSIS POSITION	1270.0 ft
INITIAL Y ZONE	8000.0 ft TO 8200.0 ft

INITIAL X VELOCITY	1.0 ft/sec
INITIAL Y VELOCITY	-1.0 ft/sec

CELL DATA TABLE

TMFINAL.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

CELL#	SURFACE ROUGHNESS	TANGENTIAL COEFFICIENT	NORM. COEF. RESTITUTION	BEGINNING X,Y	ENDING X,Y
1	5.00	.85	.35	0.0 ,8480.0	300.0 ,8400.0
2	5.00	.85	.35	300.0 ,8400.0	450.0 ,8320.0
3	1.00	.87	.37	450.0 ,8320.0	570.0 ,8240.0
4	1.00	.87	.37	570.0 ,8240.0	625.0 ,8080.0
5	1.00	.87	.37	625.0 ,8080.0	650.0 ,8000.0
6	5.00	.82	.33	650.0 ,8000.0	730.0 ,7920.0
7	5.00	.82	.33	730.0 ,7920.0	830.0 ,7840.0
8	5.00	.82	.33	830.0 ,7840.0	950.0 ,7760.0
9	5.00	.82	.33	950.0 ,7760.0	1270.0 ,7680.0
10	5.00	.82	.33	1270.0 ,7680.0	1400.0 ,7600.0

CRSP Output for Trail Mountain 5th East Escarpment Study Area

Cross Section A

5 ft. Cylindrical Boulder

CELL DATA OUTPUT

TMFINAL.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

DATA COLLECTED AT END OF EACH CELL

CELL #	MAXIMUM VELOCITY (ft/sec)	AVERAGE VELOCITY (ft/sec)	STANDARD DEVIATION VELOCITY	AVERAGE BOUNCE HEIGHT (ft)	MAXIMUM BOUNCE HEIGHT (ft)
1	NO ROCKS PASSED POINT				
2	NO ROCKS PASSED POINT				
3	NO ROCKS PASSED POINT				
4	81	47	16.42	9	29
5	106	59	21.32	14	56
6	91	46	18.00	8	30
7	92	39	17.91	5	27
8	91	34	15.92	4	24
9	NO ROCKS PASSED POINT				
10	NO ROCKS PASSED POINT				

X INTERVAL	ROCKS STOPPED
0 ft TO 10 ft	1
650 ft TO 660 ft	15
660 ft TO 670 ft	5
750 ft TO 760 ft	1
770 ft TO 780 ft	3
780 ft TO 790 ft	5
790 ft TO 800 ft	2
800 ft TO 810 ft	3
810 ft TO 820 ft	2
820 ft TO 830 ft	2
830 ft TO 840 ft	11
840 ft TO 850 ft	15
850 ft TO 860 ft	6
860 ft TO 870 ft	7
870 ft TO 880 ft	17
880 ft TO 890 ft	16
890 ft TO 900 ft	11
900 ft TO 910 ft	9
910 ft TO 920 ft	8
920 ft TO 930 ft	15
930 ft TO 940 ft	8
940 ft TO 950 ft	14
950 ft TO 960 ft	61
960 ft TO 970 ft	38
970 ft TO 980 ft	51
980 ft TO 990 ft	42

990 ft	TO 1000 ft	31
1000 ft	TO 1010 ft	20
1010 ft	TO 1020 ft	14
1020 ft	TO 1030 ft	16
1030 ft	TO 1040 ft	11
1040 ft	TO 1050 ft	9
1050 ft	TO 1060 ft	5
1060 ft	TO 1070 ft	8
1070 ft	TO 1080 ft	6
1080 ft	TO 1090 ft	3
1090 ft	TO 1100 ft	2
1100 ft	TO 1110 ft	2
1110 ft	TO 1120 ft	2
1120 ft	TO 1130 ft	1
1130 ft	TO 1140 ft	1
1150 ft	TO 1160 ft	1

CRSP Input for Trail Mountain 5th East Escarpment Study Area

Cross Section A

10 ft. Cylindrical Boulder

TMBIG.DAT

ROCK STATISTICS

130348 lbs CYLINDRICAL ROCK 10 ft BY 10 ft

NUMBER OF CELLS	10
NUMBER OF ROCKS	500

ANALYSIS POSITION	1270.0 ft
INITIAL Y ZONE	8000.0 ft TO 8200.0 ft

INITIAL X VELOCITY	1.0 ft/sec
INITIAL Y VELOCITY	-1.0 ft/sec

CELL DATA TABLE

TMBIG.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

CELL#	SURFACE ROUGHNESS	TANGENTIAL COEFFICIENT	NORM. COEF. RESTITUTION	BEGINNING X,Y	ENDING X,Y
1	8.50	.85	.35	0.0 ,8480.0	300.0 ,8400.0
2	8.50	.85	.35	300.0 ,8400.0	450.0 ,8320.0
3	1.00	.87	.37	450.0 ,8320.0	570.0 ,8240.0
4	1.00	.87	.37	570.0 ,8240.0	625.0 ,8080.0
5	1.00	.87	.37	625.0 ,8080.0	650.0 ,8000.0
6	8.50	.82	.33	650.0 ,8000.0	730.0 ,7920.0
7	8.50	.82	.33	730.0 ,7920.0	830.0 ,7840.0
8	8.50	.82	.33	830.0 ,7840.0	950.0 ,7760.0
9	8.50	.82	.33	950.0 ,7760.0	1270.0 ,7680.0
10	8.50	.82	.33	1270.0 ,7680.0	1400.0 ,7600.0

CRSP Output for Trail Mountain 5th East Escarpment Study Area

Cross Section A

10 ft. Cylindrical Boulder

CELL DATA OUTPUT

TMBIG.DAT

REMARKS: Trail Mountain 5th East Rockfall Cross Section

DATA COLLECTED AT END OF EACH CELL

CELL #	MAXIMUM VELOCITY (ft/sec)	AVERAGE VELOCITY (ft/sec)	STANDARD DEVIATION VELOCITY	AVERAGE BOUNCE HEIGHT (ft)	MAXIMUM BOUNCE HEIGHT (ft)
1	NO ROCKS PASSED POINT				
2	NO ROCKS PASSED POINT				
3	NO ROCKS PASSED POINT				
4	81	49	15.87	4	20
5	106	61	20.64	8	36
6	93	48	17.63	8	31
7	93	41	16.92	6	25
8	89	33	16.39	4	22
9	NO ROCKS PASSED POINT				
10	NO ROCKS PASSED POINT				

X INTERVAL	ROCKS STOPPED
0 ft TO 10 ft	1
650 ft TO 660 ft	7
750 ft TO 760 ft	1
780 ft TO 790 ft	1
800 ft TO 810 ft	1
810 ft TO 820 ft	1
830 ft TO 840 ft	1
840 ft TO 850 ft	2
850 ft TO 860 ft	3
860 ft TO 870 ft	4
870 ft TO 880 ft	4
880 ft TO 890 ft	7
890 ft TO 900 ft	2
900 ft TO 910 ft	5
910 ft TO 920 ft	10
920 ft TO 930 ft	3
930 ft TO 940 ft	3
940 ft TO 950 ft	7
950 ft TO 960 ft	74
960 ft TO 970 ft	65
970 ft TO 980 ft	62
980 ft TO 990 ft	49
990 ft TO 1000 ft	33
1000 ft TO 1010 ft	37
1010 ft TO 1020 ft	20
1020 ft TO 1030 ft	17

1030 ft	TO	1040 ft	12
1040 ft	TO	1050 ft	22
1050 ft	TO	1060 ft	7
1060 ft	TO	1070 ft	5
1070 ft	TO	1080 ft	3
1080 ft	TO	1090 ft	8
1090 ft	TO	1100 ft	8
1100 ft	TO	1110 ft	6
1110 ft	TO	1120 ft	2
1120 ft	TO	1130 ft	3
1140 ft	TO	1150 ft	2
1150 ft	TO	1160 ft	1
1170 ft	TO	1180 ft	1

CASTLEGATE SANDSTONE CLIFF STABILITY
TRAIL MOUNTAIN - 5th EAST

(Comparison to East Mountain - Newberry Canyon 6th & 7th EAST)

INTRODUCTION

PacifiCorp's central Utah coal resources are surrounded by a prominent cliff formed by the massive and resistive Castlegate Sandstone Member of the Mesa Verde Group. Where this cliff has been undermined in the extraction of the coal, it has been demonstrated that the stability of the cliff can be affected. Extensive studies were initiated in 1987 in order to evaluate the possible impacts that underground coal mining might have on the cliffs. The studies included field mapping of joints (orientation and spacing), lithologic review of the surrounding strata, photographic analysis, independent geotechnical evaluation, and environmental monitoring.

STRATIGRAPHY

The Cretaceous Castlegate Sandstone is the upper member of the Mesa Verde Group and overlies the Blackhawk Member unconformably. The Castlegate Sandstone was deposited along the western margin of the Cretaceous Western Interior Seaway. The supply of clastic sediment and rate of deposition were functions of the tectonic activity associated with the Sevier Orogenic Belt located to the west of the Western Interior Seaway. Within the 5th East area the lower contact with the Blackhawk Formation is gradational and variable. Thickness of the Castlegate Sandstone in the southern portion of Trail Mountain ranges from 275 feet to 350 feet (data obtained from surface exploration drill holes and outcrop measurements). The Castlegate Sandstone is comprised predominantly of medium- to fine-grained moderately sorted sandstone having trough cross stratification interbedded with thin, lenticular, discontinuous beds of pebble conglomerate and mudstone. The entire sequence was deposited in a braided stream environment so that none of the individual units is continuous; however, the rapid succession of braided channels forms what appears from a distance to be a massive unit.

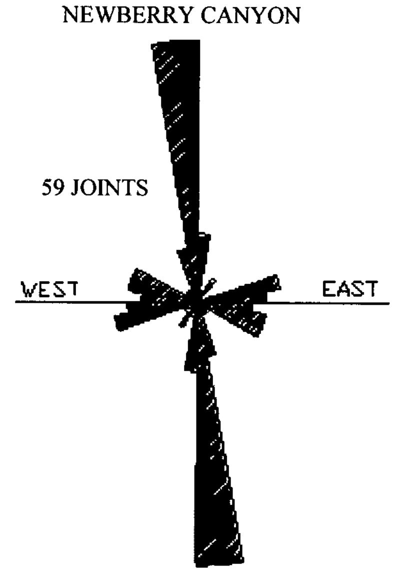
During a detailed stratigraphic review the Castlegate Sandstone was separated into three distinct stratigraphic units. The lower cliff forming unit is dominated by trough crossbedded sandstone of medium- to fine-grained, the middle unit consists of overbank sediments (mudstones) interbedded with channel sandstones, and the upper unit is similar to the lower unit. From observations in Newberry Canyon the presence of the thin lenticular beds of mudstone within the Castlegate Sandstone played an important role in the stability of the cliff. Outcrop mapping of the cliff exposure and data from surface exploration drill holes identified the distribution of mudstone units within the Castlegate Sandstone. The middle unit, consisting of interbedded mudstone and sandstone, is more prevalent on the east side of East Mountain in Newberry Canyon than on the eastern side of Trail Mountain. The mudstone beds present in Newberry Canyon are located 80 to 120 feet down from the top of the Castlegate Sandstone and are 8 to 15 feet in thickness. On outcrop they appear to continue for distances of up to one-fourth of a mile. Inspection of outcrops from Joe's Valley through Cottonwood Canyon and drill holes completed on the southern end of Trail Mountain indicate that the mudstone beds are much less prevalent than in the Newberry Canyon area. Stratigraphic segregation of the Castlegate Sandstone and deposition trends identified concur with research conducted by Chan and Pfaff and reported in the Utah Geological Association Publication 19 (research paper entitled "Fluvial Sedimentology of the Upper Cretaceous Castlegate Sandstone, Book Cliffs, Utah" enclosed for review, see appendix).

DATA COLLECTION - JOINT MAPPING

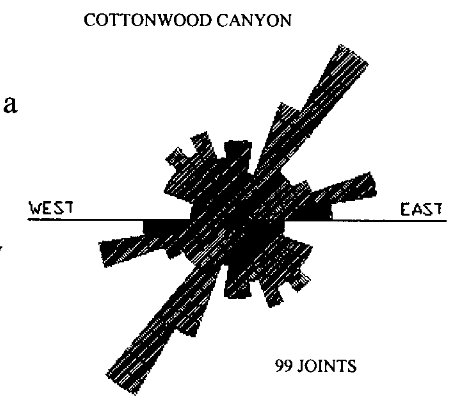
The strata present on East and Trail mountains contain joints or natural fractures induced by tectonic stress. Normally, joints are found as sets of two fractures at nearly right angles to each other. Most of the joints are vertical or near vertical and extend from well below the coal seams through the Flagstaff Limestone present on the highest portions of the plateau. These joints form natural planes of weakness in the Castlegate Sandstone whereby blocks of the sandstone can move vertically or settle near the outcrop. The Castlegate Sandstone is a very competent, massive unit; therefore, where it is exposed on outcrop, it yields to stress only along joints within the rock. This is unlike other formations which crop out on East and Trail mountains such as the North Horn formation, which yields to stress through plastic deformation. Because the joints play an important part in the way that stress is relieved in the Castlegate Sandstone, it is important to map the nature of the joints which are present in the cliff surrounding the coal resources to be mined.

The joints within the Castlegate Sandstone cliff were mapped in detail on the southern end of East Mountain and the southern and southeastern portion of Trail Mountain. The mapping included measuring the location, strike, dip of the joints as well as their spacing and continuity, both horizontally and vertically, and roughness coefficient. A total of 288 joints were mapped on East Mountain while 79 joint were mapped on the cliff of Trail Mountain. Every effort was made to obtain a statistically random sampling of the joints present. It is important to point out that the joints which are perpendicular to the cliff are easier to recognize than those which are parallel to the cliff. Special attention was given to identification of all joints, even those of a subtle nature, because of their orientation with respect to the cliff.

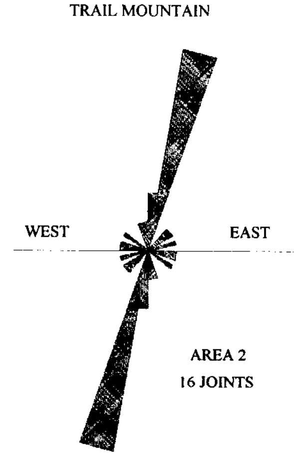
In order to better visualize the direction and concentration of the measured joints, strikes of the joints were plotted as rose diagrams. Of the 59 measured joints in Newberry Canyon, the most common trend measured is N10°W with a complementary trend of N80°E (refer to appendix for the raw data). The trend of the escarpment at the end of the 6th and 7th East Longwall Panels, Cottonwood Mine is approximately parallel to the main joint trend of N10°W. Failure did occur as a result of mining, primarily as isolated rock falls between the N80°E joint sets. The magnitude of the failure was a function of the panel versus escarpment orientation along with joint spacing.



Adjacent to the area of concern on Trail Mountain, Cottonwood Canyon, a total 99 joints were identified with a main joint orientation of N30-40°E with a complementary trend ranging from N70-80° (refer to appendix for the raw data). The trend of the escarpment at the end of the projected 4rd and 5th East Longwall panels is approximately N15°W (see attached map).



A total of 78 joint measurements were collected on Trail Mountain. Joint data were divided into four areas along the escarpment. The most prominent joint directions are north/south and east/west. These strongly parallel the canyon faces in both Straight and Cottonwood Canyon (see attached Trail Mountain map) In area 2 where subsidence occurred with the extraction of 5th East, a total of 16 joints were measured with the main joint trend of N10 to 20°E.



The spacing and continuity of the joints on the southern portion of Trail Mountain were also measured. Based on the data collected, the joint continuity and spacing is similar between Newberry, Cottonwood Canyon and Trail Mountain. The following table lists the various characteristics:

AREA	NUMBER of JOINTS	CONTINUITY (ft) STRIKE	DIP	JOINT SPACING (ft)
Newberry Canyon	59	11.7	10.7	4.4
Cottonwood Canyon	99	15.4	13.8	8.1
Trail Mountain	78	11.8	9.4	9.9

FACTORS OF STABILITY

The important factors which influence the stability of the Castlegate Sandstone cliff include the stratigraphy of the cliff exposure, orientation of the joints in respect to the escarpment, foundation failure, mine layout compared to escarpment configuration, and the stability of the subsurface material, which includes the presence of burned coal or underground mine workings. All of these factors have been included in this interpretation.

Stratigraphy: Newberry Canyon: The Castlegate Sandstone consists of three distinct stratigraphic units: the lower cliff forming unit is dominated by trough crossbedded sandstone of fine to medium grain, the middle unit consists of overbank sediments (mudstones) interbedded channel sandstones, and the upper unit is similar to the lower unit. The mudstone beds present in Newberry Canyon are located 80 to 120 feet down from the top of the Castlegate Sandstone and are 8 to 15 feet in thickness. On outcrop they appear to continue for distances of up to one-fourth of a mile.

Cottonwood Canyon and Trail Mountain: Outcrops of the Castlegate Sandstone are dominated by trough crossbedded sandstone of fine to medium grain typical of the upper and lower stratigraphic units with the middle unit (mudstones) absent. In general, the escarpment appears to be more massive on Trail Mountain than on East Mountain.

Jointing: Newberry Canyon: The most common joint trend measured is N10^{0}W with a complementary trend of N80^{0}E. The trend of the escarpment at the end of the 6th and 7th East Longwall panels is approximately parallel to the main joint trend of N10^{0}W. Average spacing between joints is 4.4 feet; and the average continuity is 11.7 and 10.7 feet on strike and dip, respectively.

Cottonwood Canyon: The main joint pattern is N30-40^{0}E with a secondary trend of N70-80^{0}E. The bearing of the escarpment in the area of the 4th and 5th East Longwall panels is approximately N15^{0}W (see attached map Drawing # KS1703D COTTONWOOD MINE ESCARPMENT MODELING STUDY 1997). Average spacing between joints is 8.1 feet; and the average continuity is 15.4 and 13.8 feet on strike and dip, respectively.

Trail Mountain: The joint pattern strongly parallels the cliff escarpment of both Straight and Cottonwood Canyons. The bearing of joints range from N/S to N-20E parallel to Cottonwood Canyon and N80°W along Straight Canyon. Average spacing between joints is 9.91: and the average continuity is 11.82 and 9.44 on strike and dip, respectively.

Foundation Failure:

Newberry Canyon: Failure of the Castlegate Sandstone escarpment observed within the eastern end of the 6th and 7th East Longwall panels has been caused by several factors. One of the main factors contributing to the failure of the Castlegate Sandstone was a function of foundation failure. Joint spacing dictated the size and shape of the collapsed strata. In every case, however, in which large blocks of sandstone have become unstable and collapsed, the foundation material of the cliff has insufficient compressive strength to support the mass of rock above. This is particularly the case with the mudstone sequence located approximately 80 to 120 feet from the top of the Castlegate Sandstone. The initial condition which exists is the disruption by settling (caused naturally or by mining) of a thin slab or block (generally less than 20 feet in thickness) of the cliff that extends from the escarpment into a joint, causing the thin slab or block to settle downward (foundation failure). Further settling causes block rotation in which the bottom of the slab moves outward toward the escarpment. In time, the slab or block falls from the cliff by mass wasting.

Trail Mountain: As in the case of Newberry Canyon, failure of the Castlegate Sandstone escarpment observed within the eastern end of the 5th East Longwall panel has been caused by several factors. Similar to Newberry Canyon, one of the main factors contributing to the failure of the Castlegate Sandstone was a function of foundation failure. In the case of Trail Mountain, joint spacing along with bedding planes dictated the size and shape of the collapsed strata. In every case, however, in which large blocks of sandstone have become unstable and collapsed, the foundation material of the cliff has insufficient compressive strength to support the mass of rock above. The initial condition which exists is the disruption by settling (caused naturally or by mining) of a thin slab or block (generally less than 20 feet in thickness) of the cliff that extends from the escarpment into a joint or beddding plane, causing the thin slab or block to settle downward (foundation failure). Further settling causes block rotation in which the bottom of the slab moves outward toward the escarpment. In time, the slab or block falls from the cliff by mass wasting.

Mine Layout: Newberry Canyon: The layout of the 6th and 7th East setup entries in respect to the Castlegate Sandstone exposure limited the amount of failure which occurred in the eastern extent of Newberry Canyon. Observed subsidence from East Mountain indicates the maximum subsidence occurs down the center of the longwall panel, with little or no subsidence occurring at the ends of the panels. Even though subsidence is minimized at the ends of longwall panels, tension fractures can occur along this zone.

Trail Mountain: The mine layout of the 5th East Longwall panel is similar to that of Newberry Canyon, i.e., perpendicular to the Castlegate escarpment (see attached map Drawing #TMS1705D TRAIL MOUNTAIN MINE: ESCARPMENT MODELING STUDY 1997). Subsidence data collected from the 6th and 7th East Longwall panels in Newberry Canyon indicates very little subsidence occurred even though the longwall panel was situated near a convex cliff exposure which commonly contains natural tension fractures due to less confining pressure. In the case of the 5th East Longwall panel the Castlegate Sandstone is more massive and the cliff exposure is slightly concave instead of convex as compared to Newberry Canyon. Failure of the Castlegate Sandstone occurred along the center of the 5th East Longwall panel. The major zone of Castlegate Sandstone escarpment failure is approximately 200 ft. in height and 239 ft. in width which was deposited over a 3.5 acre area. Direct field observation has revealed minor (2 - 4 inches in width) tension cracks, running north-south, on the slopes just to the south of the major failure zone and just below the Castlegate Sandstone escarpment. The existence of these cracks indicates foundation failure as the most likely mode of failure of the Castlegate Sandstone escarpment.

SUMMARY

The geologic factors that influence the cliff stability vary from Trail Mountain to the eastern extent of Newberry Canyon. The Castlegate Sandstone within Trail Mountain area contains fewer mudstone lenses, which reduces the chance for foundation failure from conditions found in the Newberry Canyon area. Bedding planes along with joint spacing and orientation dictated the size of material which failed Trail Mountain. The shape of the cliff exposure, concave versus convex, increases the confining stress, thereby influencing the type and shape of failure.

REFERENCE MATERIAL & MAPS

- Appendix A: Research Paper: Fluvial Sedimentology of the Upper Cretaceous Castlegate Sandstone, Book Cliffs, Utah
- Appendix B: East Mountain Joint Mapping Data
- Appendix C: Trail Mountain Joint Mapping Data

❖ MAPS: Drawing # KS1703D Cottonwood Mine: Escarpment Modeling Study 1997
Drawing # TMS1705D Trail Mountain Mine: Escarpment Modeling Study 1997
Drawing # CE10790EM Joint Mapping - Castlegate Sandstone Cliff Stability Rilda Canyon Area

FLUVIAL SEDIMENTOLOGY OF THE UPPER CRETACEOUS CASTLEGATE SANDSTONE, BOOK CLIFFS, UTAH

MARJORIE A. CHAN[1] AND BRUCE J. PFAFF[2]

ABSTRACT

The Upper Cretaceous Castlegate Sandstone in central Utah records an eastward prograding fluvial-deltaic complex, shed from the Sevier orogenic belt. Eight facies are recognized: trough crossbedded sandstone; inclined rippled sandstone; horizontal rippled sandstone; organic-rich sandstone, siltstone and shale; interbedded sandstone and siltstone; lenticular shale and siltstone; small-scale planar tabular sandstone; and conglomerate. Vertical and lateral facies relationships permit interpretation of basinal changes in the depositional system.

The Castlegate type section at Price Canyon contains three stratigraphic units. The lower unit is dominated by trough-crossbedded, multiple-scoured, fine- to medium-grained sandstone. The middle unit is characterized by: (1) rippled lateral accretion deposits; (2) rippled overbank sandstones; and (3) increased amounts of floodplain sandstones and siltstones. This middle unit also contains deep channel scours and well developed upward-fining sequences. An upper channelized unit (Bluecastle Tongue) is similar to the lower unit.

A high fluvial gradient and a relatively coarse sediment supply in the lower unit is associated with thrusting episodes of the Sevier Orogeny. These conditions favored the development of braided channels. Vertical changes from the lower to the middle unit represent a transition to higher sinuosity channels with greater overbank deposition. The middle unit also grades eastward into marine, shoreline, and coastal plain deposits, as the Cretaceous sea transgressed westward. Braided deposition of the upper unit suggests renewed orogenic activity, accompanied by a relative drop in sea level.

Lateral changes in the Castlegate Sandstone reflect the relative proximity to the orogenic belt. Areas close to the mountain belt produced braided fluvial channels. Over a 81 mi (130 km) distance, channels were larger and more sinuous in the distal part of the fluvial system. High sinuosity conditions persisted where gradients were lower and sediment was finer grained. Both vertical and lateral facies relationships in the Castlegate Sandstone indicate the interplay of tectonism and relative sea level change in fluvial sedimentation styles along the Western Interior seaway.

INTRODUCTION

The Upper Cretaceous Castlegate Sandstone is an eastward-prograding clastic wedge shed from the western highlands of the Sevier orogenic belt (Spieker, 1946; Van De Graaff, 1972). The sandstone crops out in east-central Utah (Figure 1), and records the activity of an ancient fluvial-deltaic complex which formed in the foreland basin, along the western edge of the Cretaceous seaway (Figure 2). Progradational events along the margin of the Western Interior Cretaceous seaway were controlled by factors including: (1) eustatic sea level fluctuations; (2) the tectonic activity of the Sevier Orogenic Belt; and (3) the flexure of the foreland basin in response to hydrostatic, sedimentary, and tectonic loading (e.g., Jordan 1981; Weimer, 1984). The objective of this paper is to interpret the sedimentologic significance of the fluvial facies of the Castlegate Sandstone, with emphasis on vertical and lateral facies changes. A detailed description and analysis of the facies is given in Pfaff (1985).

A total of five detailed stratigraphic sections and several other generalized sections were measured. The sections cover a lateral extent of 81 mi (130 km) of the fluvial facies, and document downstream changes within the system (Figure 1). The southwesternmost section (at Joe's Valley; Fig 1) contains proximal fluvial deposits of the Castlegate system closest to the Sevier orogen. At Price Canyon (type locality), two detailed sections were measured. The Horse Canyon section is ated approximately at a midpoint within the fluvial system. The easternmost section along the Green River is located near the transition between the fluvial and the deltaic coastal plain facies; it documents the most distal part of the fluvial system.

Previous Work

Clark (1928) named the Castlegate Sandstone for the large cliff-forming sandstone (Figure 3) located near Castlegate, Utah within Price Canyon. Spieker and Reeside (1925)

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reference the Castlegate Member of the Price River Formation, but refer to Clark as the originator of the name. Fisher and others (1960) assign formational status to the Castlegate Sandstone. Lithologic and stratigraphic relationships of the Castlegate are included in Spieker (1931; 1946; and 1949) and Young (1955). Van De Graaff (1969; 1972) conducted a detailed study of depositional environments and petrology within the Castlegate Sandstone. Regional stratigraphic relationships of the Castlegate Sandstone and the Mesaverde Group by Fouch and others (1983) are based on molluscan and palynomorph correlations (Figure 4). They unofficially name the upper cliff-forming unit of the Castlegate Sandstone as the

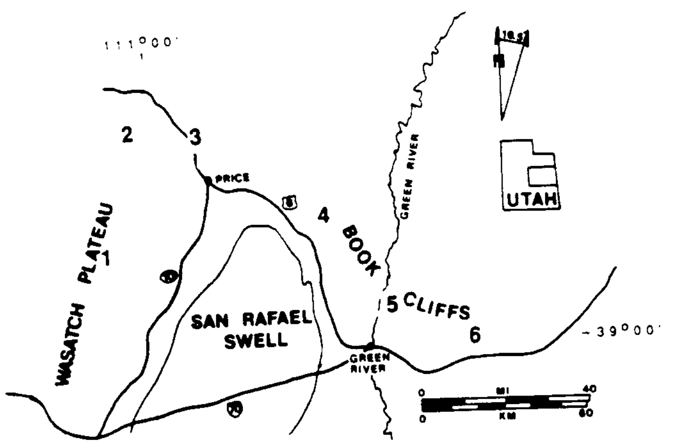

Figure 1. Location of the study area in east-central Utah. Numbers refer to locations studied: 1) Joe's Valley (Sec. 17, T17S, R6E); 2) Bennion Creek (Sec. 25, T11S, R6E); 3) Price Canyon (Sec. 26, T12S, R9E); 4) Horse Canyon (Sec. 3, T16S, R14E); 5) Green River (Sec. 1, T19S, R16E); and 6) Thompson Canyon (Sec. 34, T20S, R20E). Note: Tuscher Canyon (Sec. 13, T20S, R16E) is located just east of the Green River section.

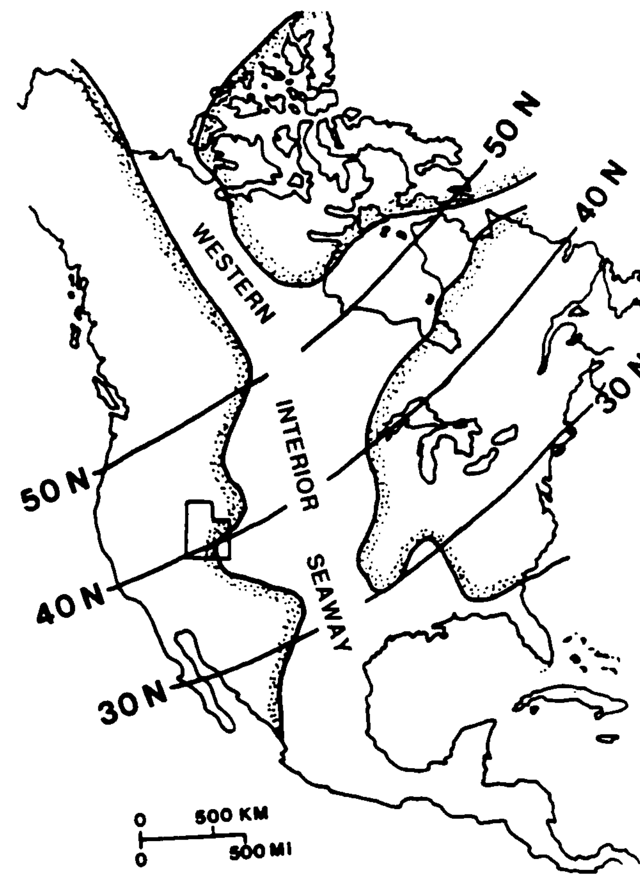

Figure 2. Extent of the Cretaceous Western Interior seaway during Campanian time. Modified from McGookey and others (1972).

Figure 3. Type section of the Castlegate Sandstone at Price Canyon, Utah. View is looking southeast from U.S. Highway 6. Vertical scale of section show is approximately 623 ft (190 m). LC= lower Castlegate unit, MC= middle Castlegate unit. (The upper Castlegate unit is to the upper left, not shown in photo.)

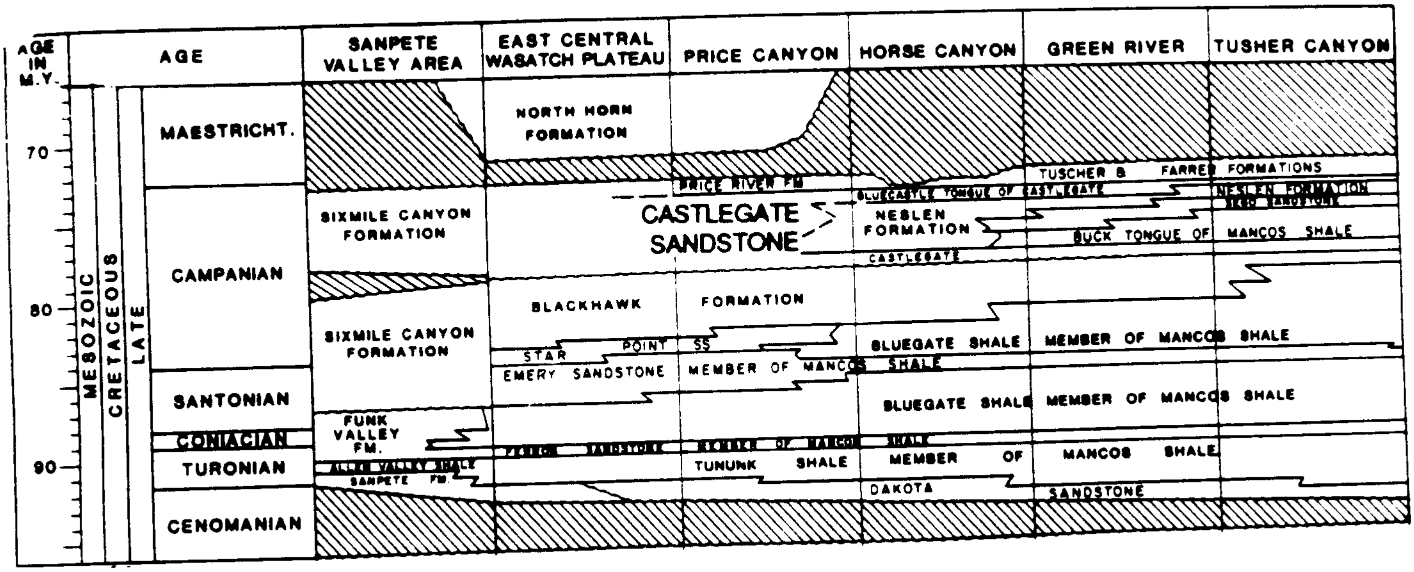

Figure 4. Stratigraphic nomenclature and correlations of Upper Cretaceous rock units from Sanpete Valley in central Utah east to Tuscher Canyon in east-central Utah. Modified from Fouch and others (1983) and Lawton (1986).

Bluecastle Tongue, at the type locality. Lawton (1983; 1985; 1986) analyzed some petrography of the Castlegate Sandstone in his synthesis of the central Utah foreland basin. He identified two fluvial Castlegate sedimentary facies, and stratigraphic correlations of proximal facies of the Sixmile Canyon Formation to the west (Figure 4).

Tectonic Setting

The Castlegate Sandstone was deposited along the western margin of the foreland basin of east-central Utah. This basin formed an asymmetric north-south oriented trough located along the eastern flank of the Sevier orogenic belt. The Western Interior seaway was an extensive epeiric sea which connected the Arctic Ocean to the Gulf of Mexico (Kauffman, 1977) (Figure 2). Armstrong (1968) recognized the spatial relationship between the orogenic belt and the foreland basin to the east. Eastward thrusting within the belt occurred along a linear trend from northern Canada to southern Nevada. In Utah, thrusting and basin subsidence occurred from late Albian through late Campanian time (Lawton, 1985; 1986).

Stratigraphic Relationships

The Castlegate Sandstone is Campanian in age, and is part of the Mesaverde Group in east-central Utah (Figures 4, 5). The lower part of the Mesaverde Group in this area consists of coastal plain, marginal marine and marine deposits of the Star Point and Blackhawk Formations (Flores and Marley, 1979; Balsley, 1982). The upper part consists of fluvial coastal plain deposits of the Castlegate and Price River Formations (Van De Graaff, 1969; Fouch and others, 1983). In the western part of the study area, the Castlegate Sandstone unconformably overlies the Blackhawk Formation (Fouch and others, 1983). Molluscan and palynologic data from Fouch and others (1983) bracket Castlegate deposition between 79 my and 74 my.

At the type locality of Price Canyon, the Castlegate Sandstone is a cliff-forming sequence (Figure 3) in which three informal units (Figure 5) within the sandstone are recognized: (1) a lower (164 ft, 50 m) cliff-forming medium to fine-grained sandstone unit, dominated by scours and trough crossbedding; (2) a middle, slope-forming unit (371 ft, 113 m) characterized by fine-grained sandstone, siltstone, organic matter and fewer trough scours; and (3) an upper, cliff-forming unit (101 ft, 31 m), named the Bluecastle Tongue by Fouch and others (1983). This upper tongue is similar to the lower unit but is coarser grained (grains up to 15 mm; Lawton, 1986).

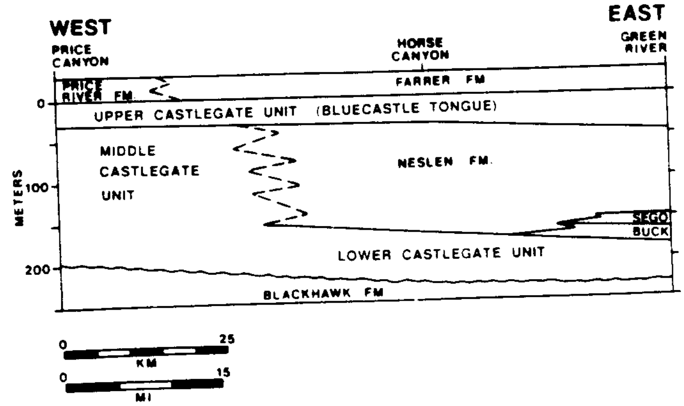

Figure 5. Correlation of the three Castlegate Sandstone units from Price Canyon east to Green River.

East of Price Canyon, the stratigraphic names change and intertonguing relationships are complex (Figures 4 and 5). In the vicinity of Horse Canyon, the middle unit grades laterally into coal-bearing deposits of the Neslen Formation which separates the lower unit of the Castlegate from the upper unit. At Green River, the lower Castlegate is separated from the upper unit (type Bluecastle Tongue) by the Buck Tongue of the Mancos Shale, the Sego Sandstone, and the Neslen Formation (Figures 4 and 5).

The stratigraphic transitions between the Castlegate and more proximal piedmont deposits to the west of the type locality (Sixmile Canyon Member of the Indianola Group) are difficult to document. The transition zone occurs within the Wasatch Plateau, where normal faulting associated with Basin and Range extension has disrupted the region (Hintze, 1988) and partially destroyed stratigraphic relationships. Furthermore, vegetation is abundant along the higher elevations of the Plateau, outcrop exposures are poor and the conglomerates contain little or no datable material. In this study, Lawton's (1985; 1986) stratigraphic relationships are used. Based on palynologic dating, stratigraphic and petrographic studies, he correlated the Castlegate with the upper member of the Sixmile Canyon Formation as defined by Spieker (1946).

FACIES DESCRIPTIONS

Eight generalized sedimentary facies are recognized within the Castlegate Sandstone of the study area. These facies include: trough crossbedded sandstone; inclined rippled sandstone; horizontal rippled sandstone; organic-rich sandstone, siltstone and shale; interbedded sandstone and siltstone; lenticular shale and siltstone; small-scale planar tabular sandstone; and conglomerate. Each facies is briefly described in their approximate relative abundance, and then interpreted largely in the following section on facies sequences (based on the sedimentologic occurrences of the facies).

The trough crossbedded sandstone facies is the most abundant and characteristic of the fluvial Castlegate deposits. This facies is up to 33 ft (10 m) thick and generally overlies an erosional scour lined by mud rip-up clasts and plant debris. Troughs are 8-39 in (20-100 cm) high, 1-10 ft (0.3-3 m) wide, and are commonly nested. Deformed bedding and repeated channel scours may also be present. Grain sizes varies from pebble sizes at Joe's Valley, to medium-grained sand at Price Canyon, and fine-grained sand at Green River (Figure 1). This facies is interpreted largely as migrating dune forms within channel fills.

The inclined rippled sandstone facies contains angled sets ($5\text{-}15^{o}$) of rippled fine- to very fine-grained sandstone, and organic-rich siltstone. The lenticular sandstone beds may be laterally continuous for up to 66 ft (20 m), but generally are 16-33 ft (5-10 m). Bedding thickness may range up to 13 ft (4.0 m), but generally averages 1.5 ft (45 cm). Structures include a variety of planar laminations, common climbing asymmetric ripples, and small trough cross beds. The ripple crests are generally oblique to the orientation of the foresets within a channel fill. These inclined rippled sandstone deposits are interpreted mostly as small-scale migrating bedforms (current ripples) superimposed on lateral accretion sets. A few thin units of the inclined ripple sandstone facies may also represent splay deposits.

Horizontal rippled sandstone is similar to the inclined rippled sandstone described above, except that the sandstone beds are horizontally bedded, more lateral continuous, contain less internal truncations and less climbing ripples, and are generally finer grained (mostly very fine-grained sandstone). The beds are slightly more continuous (up to 115 ft or 35 m), occur in thicknesses of 4-12 in (10-30 cm), and are not confined to channel scours. Mudchips and plant fragments are common along bedding planes. This rippled facies is interpreted as bar deposits, characteristic of lower flow regime conditions.

The organic-rich sandstone, siltstone and shale facies is a slope former characterized by thin-bedded sandstone, siltstone and shale, rich in organic material. Carbonized wood and plant fragments are common. Siderite concretions typically occur in shale horizons. Various types of disturbed bedding appears to be associated with load casts. Deposits of this facies are up to 13 ft (4 m) thick, and are laterally continuous, especially in the middle Castlegate unit. Rooting and soil-forming processes may have contributed to some of the blocky, mottled appearance within lithologies of this facies. This facies is interpreted to represent a floodplain environment, with some of the thin, lenticular sandstones representing crevasse splays and overbank deposits. A similar facies of interbedded sandstone and siltstone occurs in the same types of stratigraphic positions as the organic-rich lithologies, but lacks all the plant material, and contains less of the shale.

The lenticular shale and siltstone facies is uncommon, but is characterized by a lack of sand-sized grains, and its localized occurrence directly over scour surfaces and/or the trough crossbedded sandstone facies (e.g., Horse Canyon locality). It is up to 6.6 ft (2 m) thick, and is interpreted to represent a mudstone channel plug when there was sudden channel abandonment and avulsion of flow.

Small-scale planar tabular sandstone comprise a facies which is observed at the Green River section. These tabular to wedge-shaped beds overlie the trough crossbedded sandstone facies and are generally succeeded by the organic-rich sandstone, siltstone and shale. Individual crossbed sets are 2-20 in (5-50 cm), with cosets (2-15 sets) producing packages up to 8 ft (2.5 m) thick. These tabular sets may represent sandwave stratification on top of braided sand sheets.

Cliff-forming, clast-supported cobble conglomerates occur at Joe's Valley, with well-rounded quartzite, chert and quartz arenite clasts up to 1 ft (30 cm), and typical clast sizes of 4-8 in (10-20 cm). This facies may also contain scattered occurrences of trough crossbedded sandstone and horizontally bedded sandstone. The conglomerate lithologies are interpreted to represent bed-load channel deposition in the proximal portions of the fluvial system, close to the ancient thrust belt.

FACIES SEQUENCES

Two distinct upward-fining facies Sequences are identified in the Castlegate fluvial deposits, although these sequences may be variable and/or incomplete. A more detailed account y be found in Pfaff (1985). Note that the term "sequence" sed in this discussion has no relation to the sequence stratigraphy terminology (e.g., Van Wagoner and others, 1990).

Upward-Fining Facies Sequence A

The upward-fining facies Sequence A (Figure 6) is characterized by an erosional scour lined with mudclasts, overlain by the trough crossbedded sandstone facies (± deformed bedding), the horizontal rippled sandstone facies, and capped by the interbedded fine-grained sandstone and siltstones facies or the organic-rich sandstone, siltstone and shale facies. Trough paleocurrents (Figure 7) are dominantly unidirectional to the east-southeast.

The mudclast-strewn scoured surfaces are interpreted to represent the initiation of channelling events. Mudclasts were probably derived from upstream floodplain deposits. As flow proceeded through the channels, large dunal bedforms migrated along the bottom, forming the trough crossbedded sandstones. In-channel deposition of this facies is inferred from its occurrence directly above and within the scoured surfaces. High discharge episodes and channel aggradation occurred intermittently; with repeated scours and small upward-fining sequences to indicate multiple flooding cycles. Siltstone drapes were deposited during periods of low discharge.

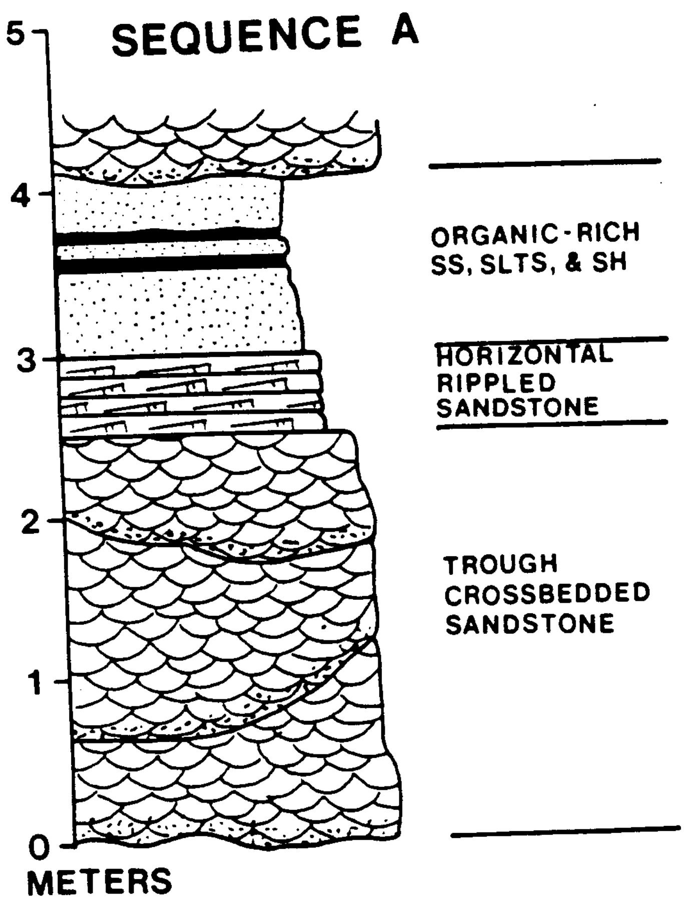

Figure 6. Generalized summary of Sequence A from measured sections in the Castlegate Sandstone.

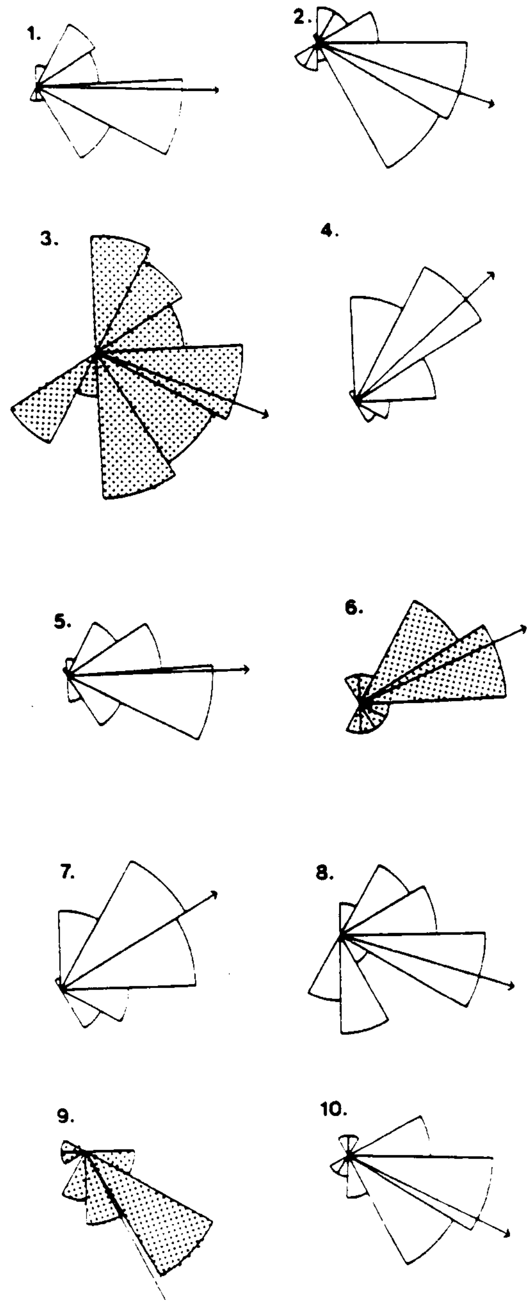

Figure 7. Paleocurrent rose diagrams for measured sections of the Castlegate Sandstone. Numbers refer to the following locations: 1) Joe's Valley - TA; 2) Price Canyon (Lower and Middle Castlegate) - TA; 3) Price Canyon (Lower and Middle Castlegate) - R; 4) Price Canyon (Upper Castlegate) - TA; 5) Horse Canyon (Lower Castlegate) - TA; 6) Horse Canyon (Lower Castlegate) - R; 7) Horse Canyon (Upper Castlegate) - TA; 8) Green River (Lower Castlegate) - TA; 9) Green River (Lower Castlegate) - R; 10) Green River (Upper Castlegate) - TA. TA = trough axes (blank-white rose diagrams), and R= ripples (shaded rose diagrams).

Disturbed bedding suggests that deposition was very rapid within the channels due to soft-sediment deformation from loading and/or fluid expulsion.

The occurrence of horizontal rippled sandstones directly above the trough crossbedded sandstones indicates deposition within topographically higher parts of the channel (Cant and Walker, 1976). These deposits may have been created by migrating bedforms within the uppermost part of a channel after it had been filled. Because the facies extends beyond the confines of scoured channel margins, bar deposition is inferred. Furthermore, this facies is located within a positively identified bar sequence discussed in Sequence B.

Alternating beds within the capping organic-rich sandstone, siltstone and shale facies is typical of vertical accretion deposition in a floodplain setting. The blocky and mottled appearance and abundant carbonaceous material supports the interpretation of rooting and/or soil forming processes.

Commonly, partial sequences of only the basal trough crossbedded sandstone facies are preserved, perhaps due to repeated erosional truncation by subsequent scouring events. In rare places, the trough crossbeds pass directly upwards into the fine-grained facies, suggesting that relatively rapid channel abandonment occurred after flooding events and prohibited extensive bar formation. Overall, the abundance of sand in this sequence (and even in the capping lithology), and the occurrence of fluvial structures suggest vertical accretion. These facies show many of the lithofacies and sedimentary structures characteristic of braided river systems (Miall, 1977).

Upward-Fining Sequence B

Sequence B differs from Sequence A because it contains abundant intervals of inclined cosets of rippled sandstones (Figure 8), as well as volumetrically greater proportion of the shale-rich capping lithology. The Sequence B generally contains the facies succession of: an erosionally scoured surface; multiply scoured trough crossbedded sandstone; inclined rippled sandstone; horizontal rippled sandstone; and organic-rich siltstone or shale. In many places, the rippled crossbedded sandstone facies occurs directly above the erosionally scoured surfaces, thereby producing an "incomplete" sequence. Paleocurrents indicate that the inclined rippled sandstone sets are at an angle oblique to the general trend of the channel.

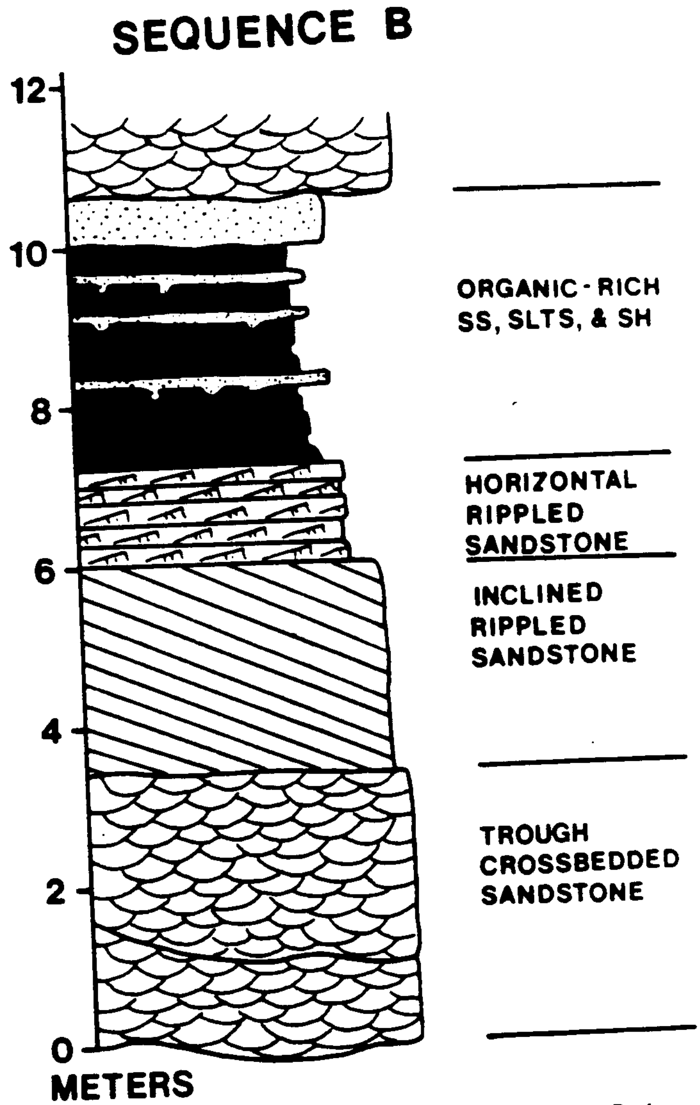

Figure 8. Generalized summary of Sequence B from measured sections in the Castlegate Sandstone.

These sequences are interpreted to contain channel-fill deposits over a scour surface. Large dunes migrated along the channel bottom to produce the trough crossbedded facies. Multiple scours within the facies suggest variable discharge and sporadic channel aggradation similar to Sequence A. The presence of the inclined rippled sandstone facies indicates lateral accretion deposition along the migrating front of a point bar (Walker and Cant, 1979) or a braid bar. Trough crossbeds and ripple stratification are common features in lateral accretion deposits (Allen, 1965).

The overlying horizontal rippled sandstones indicate deposition along topographically higher parts of the bar, producing small-scale bedforms. The interpretations for the organic-rich facies and the interbedded sandstone and siltstone are identical to those presented in Sequence A, though they are more volumetrically significant in this sequence, and have an increased abundance of sandy splay deposits.

The facies of Sequence B are interpreted to have formed largely by channel migration, with moderate channel sinuosity inferred. The presence of lateral accretion deposits indicates typical point bar development. Sequence B channels were more stable, causing laterally continuous sand sheets and overlying floodplain deposits to form. Discharge variations in Sequence B do not appear as pronounced as in the multiple-scoured facies of Sequence A.

FACIES RELATIONSHIPS

Vertical Facies Relationships

The lower cliff-forming unit (of the Castlegate at Price Canyon, Figure 9) consists of medium-grained sandstones at

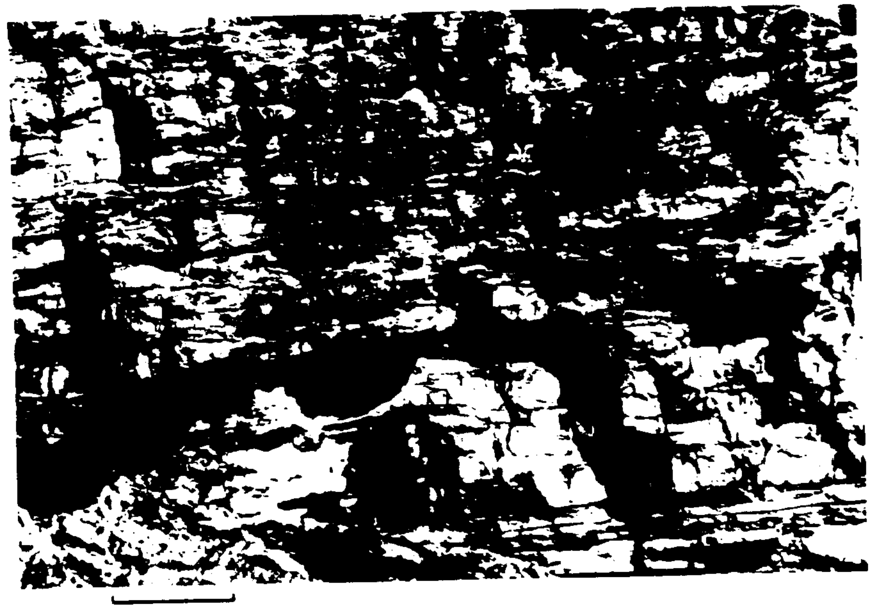

Figure 9. Typical section of the lower unit of the Castlegate Sandstone comprised of stacked facies Sequences A, Price Canyon, Utah.

the base which grade upwards into fine-grained sandstones near the top. Figure 10 is a detailed measured section of part of this unit. Facies Sequences A, multiple scours, and trough crossbedded sandstone facies dominate the lower unit. Fully developed upward-fining sequences are uncommon. Rippled sandstones and fine-grained deposits (shales and siltstones) are subordinate and discontinuous. Channels are generally shallow (less than 6 ft or 2 m deep) and lenticular, with either scoured or flat tops. Shale lithologies are rare and lateral accretion bedding is uncommon.

The middle unit consists of fine-grained sandstone and siltstone (Figures 11-12). The grain size in this middle unit typically fines upward, with siltstones and shales more abundant towards the top. In general, facies Sequence B is dominant, although facies Sequence A is locally present. Full upward-fining sequences are well-developed, and vertical accretion fines are volumetrically important. In comparison to the lower unit, the middle unit contains greater amounts of (1) inclined rippled sandstone, (2) horizontal rippled sandstone, (3) floodplain sandstone and siltstone, and (4) organic content. Cross-sectional channel geometries indicate an increase in channel size from the base of the sequence.

The upper unit (Bluecastle Tongue) abruptly overlies the middle unit of the Castlegate Sandstone and is characterized by an erosive basal contact. Generally, it is similar in appearance to the lower unit with abundant trough crossbedding and erosional scours (Figure 13). The grain size of these deposits range from very coarse to medium-grained sand. Scattered gray mudstone clasts (pebble sized) are concentrated near the base of this tongue.

Lateral Facies Relationships

At Joe's Valley (western locality of Figure 1), the Castlegate measures 240 ft (73 m) in thickness. Medium-grained sandstones are dominant and coarse-grained sandstones and pebble conglomerates occur locally. The trough crossbedded facies is very common and small-scale planar tabular crossbedded sandstones are also present. Shales and iltstones are locally present in the uppermost part of the section. Facies Sequence A dominates, but Sequence B is also present. Complete upward-fining sequences and shales are very rare. The upper part of the formation is capped by a 20 ft (6 m) thick cobble conglomerate, possibly an equivalent to the Bluecastle Tongue.

East of Price Canyon, the lower unit thins to 188 ft (42 m) and becomes fine-grained. The lower unit at the Green River locality (in contrast to Price Canyon) contains: abundant planar tabular crossbeds, organic matter, and the inclined rippled sandstone facies; well developed upward-fining sequences (commonly facies Sequence B); and larger channel sizes. The upper part of the lower unit along the Green River contains large channels with approximate dimensions of 50 x 333 ft (17 x 100 m) and smaller subordinate channels. Paleocurrents generally trend towards the southeast (Figure 7). The lower unit displays a generalized upward-fining grain size trend throughout the section.

The middle unit grades eastward into the Neslen Formation at Horse Canyon (Fouch and others, 1983). This formation represents lagoonal and tidal flat deposition at the base (Lawton, 1983), and passes upwards into meandering fluvial

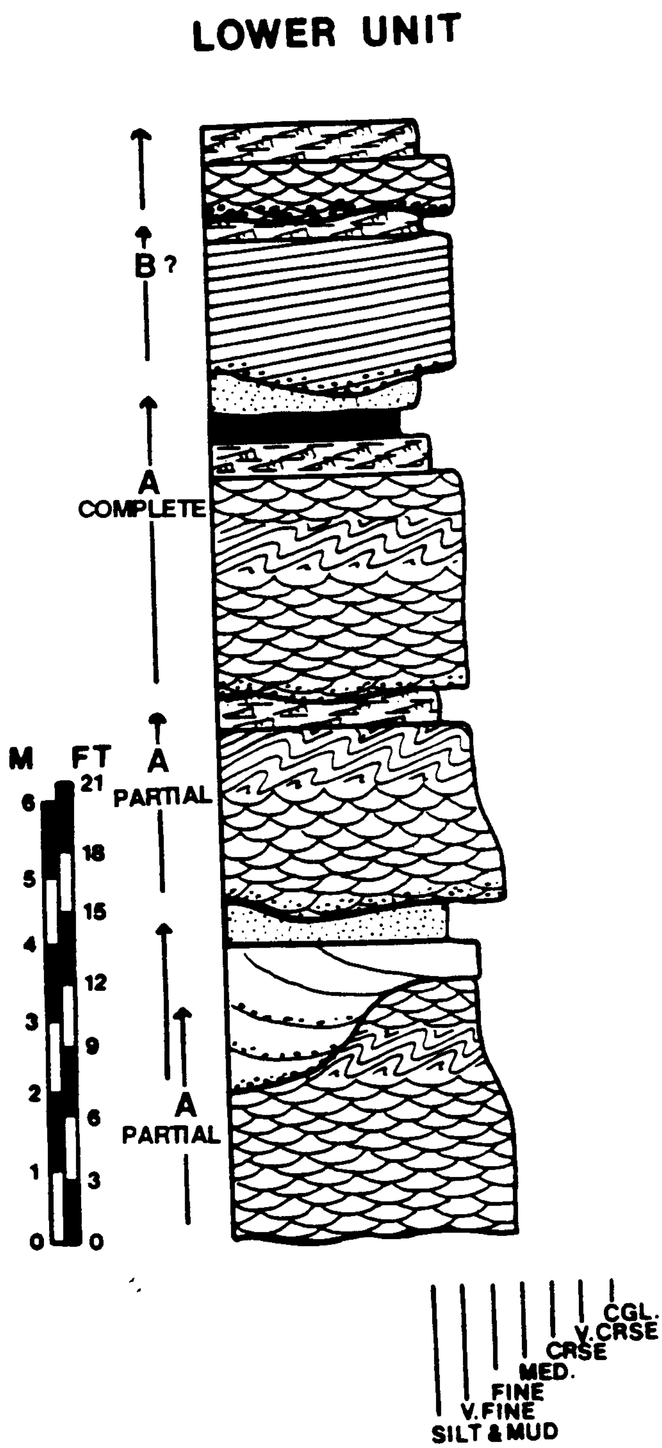

Figure 10. Detailed measured section of part of the lower unit of the Castlegate Sandstone, Price Canyon, Utah. Arrows to the left of the column indicate upward-fining sequences. A= facies Sequence A, and B= facies Sequence B. Tick marks at lower right indicate grain sizes from siltstones and mudstones, to sandstones, and conglomerates.

deposition. The Sego Sandstone represents a shallowing of water depth with deposition occurring in middle and upper shoreface environments.

The upper unit (Bluecastle Tongue) is present throughout the Book Cliffs and fines eastward to fine- to medium-grained sandstones at Green River, where the unit measures 130 ft (42 m) thick. At this Green River location, upward-fining sequences and small-scale planar tabular sandstones are abundant. Vertical accretion deposits are common and laterally extensive. The basal contact with the underlying Neslen Formation is erosive.

SIGNIFICANCE OF VERTICAL AND LATERAL RELATIONSHIPS

Vertical Facies Changes

Commonly cited sedimentologic criteria for identifying non-meandering (low sinuosity) fluvial deposits are compared with the characteristics of the lower Castlegate and Bluecastle Tongue (Table 1). None of the features are exclusively diagnostic of braided fluvial deposition. However, collectively these characteristics are strongly suggestive of deposition in a braided fluvial system. Generally, the lower Castlegate and Bluecastle Tongue show close agreement with the low-sinuosity fluvial features. An important difference is that the coarse-grained member is absent in the Castlegate deposits. This is probably a function of provenance which contributed largely fine- to medium-grained sand.

Characteristics of the middle Castlegate display striking similarities to sedimentological criteria for high-sinuosity fluvial deposits (Table 2), although some differences occur. Scroll bars, chute bars, natural levees, and exhumed meander belts were not observed. In the Castlegate Sandstone, the floodplain deposits, while thick, are not laterally continuous on the order of miles (km); they are more localized features. Because of these differences, it is difficult to ascertain whether the middle Castlegate was truly meandering or braided. However, in comparison to the lower unit and upper Bluecastle Tongue, the middle Castlegate represents higher sinuosity fluvial deposition with better developed floodplains. Relative percentages of sedimentary facies for each of the three Castlegate units is given in Table 3.

Bluecastle deposition indicates a resumption of braided conditions and slightly smaller channel sizes than the middle unit; the greater grain sizes in this unit indicate greater competence in comparison with the braided channels of the lower unit. It appears that the Bluecastle channels were more stable or better established than channels within the lower unit.

Lateral Facies Changes

Generally, sedimentologic criteria in the Castlegate Sandstone indicate an increase in sinuosity towards the east (Figure 14), where lateral accretion deposits are abundant and channel sizes are larger. Evidently, the numerous small braided channels in the proximal part of the system, coalesced

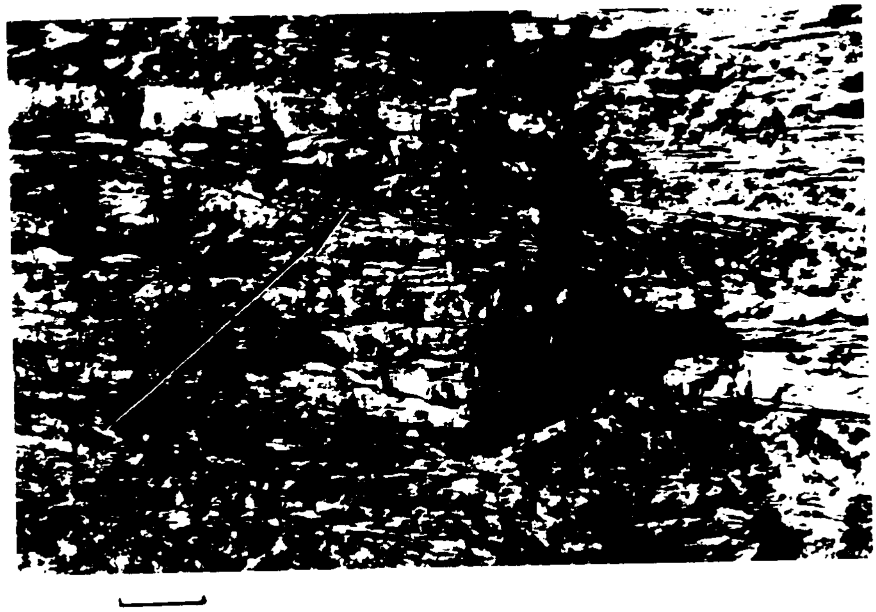

Figure 11. Typical appearance of the middle unit of the Castlegate Sandstone, Price Canyon, Utah. Note large channel and lateral accretion (see arrow) foresets. Channel axis is towards the right.

ıble 1. Comparison of the Lower and Upper Castlegate with Commonly Cited Sedimentologic Criteria for Low-Sinuosity Fluvial Deposits (Modified from Jackson, 1978).

	LOW-SINUOSITY FLUVIAL	LOWER AND UPPER CASTLEGATE
VERTICAL SEQUENCE OF LITHOFACIES	No consistent sequence	Fining-upwards sequences truncated by erosion
FINE MEMBER	Uncommon and thin	Uncommon, thin, and laterally discontinuous
ROCK GRAVEL IN COARSE MEMBER	Can be abundant with large clasts	Absent, except at Joe's Valley locality
SCROLL BARS	Absent	Absent
EPSILON CROSS-STRATIFICATION	Absent	Absent
SCOURING SURFACES IN COARSE MEMBER	Abundant	Abundant
CHANNEL-FILL MUD DEPOSITS	Minor; short	Very rare
CHUTE-FILL AND CHUTE BARS	Uncommon	Uncommon
NATURAL LEVEES	Minor	Absent
EXHUMED MEANDER BELT	Absent	Absent
CONTINUITY OF SAND AND GRAVEL BEDS (IN COARSE MEMBER)	Beds typically lenticular and discontinuous	Beds typically lenticular and discontinuous

ɔwnstream with a corresponding decrease in gradient to form ɹrger channels. The eastern facies equivalents of the middle unit of the Castlegate represent the incursion of marine conditions. The Buck Tongue of the Mancos Shale represents offshore marine deposition; the Sego Sandstone indicates a progradational beach environment; and the Neslen Formation contains lagoonal and fluvial coastal plain deposits (Fouch and others, 1983). The Bluecastle Tongue caps this progradational sequence and represents braided deposition. A summary of lateral changes for deposition of each different Castlegate unit is given in Figure 15.

DISCUSSION

Fluvial sedimentation styles in the Castlegate Sandstone show diversity in the lithofacies, sedimentary structures, as well as geometries. Channel morphology is generally dependent on three variables: (1) slope; (2) sediment type and discharge; and (3) water discharge and regime (Collinson, 1978). A complex interplay between these factors was responsible for the change in Castlegate channel geometry. These factors, in turn, are controlled by climate, source area, tectonics, and eustatic sea level fluctuations. Aspects of these variables are discussed below.

Climatic changes directly alter discharge characteristics, vegetation, and the degree of weathering of the source rocks, all of which may have been contributing factors in the evolution of the Castlegate system. In east-central Utah, a warm climate is inferred from paleomagnetic data which indicates that it was located in warm-temperate to subtropical latitudes through the Late Cretaceous (McGookey and others, 1972). Thick coal sequences in the Blackhawk and the deltaic Castlegate deposits indicate swampy conditions and probably a

Table 2. Comparison of the Middle Castlegate with Commonly Cited Sedimentologic Criteria for High-Sinuosity Fluvial Deposits (Modified from Jackson, 1978).

	HIGH-SINUOSITY FLUVIAL	MIDDLE CASTLEGATE
VERTICAL SEQUENCE OF LITHOFACIES	Fining-upwards cycles of grain size and sed. structures	Fining-upwards cycles
FINE MEMBER	Normally common and appreciably thick	Normally common and appreciably thick
ROCK GRAVEL IN COARSE MEMBER	Small amounts; few large clasts	Small amounts; some some large clasts
SCROLL BARS	Common	Absent
EPSILON CROSS-STRATIFICATION	Common	Lateral accretion bedding abundant
SCOURING SURFACES IN COARSE MEMBER	Uncommon	Present
CHANNEL-FILL MUD DEPOSITS	Common, esp. in muddy streams; long and arcuate	Present but not common
CHUTE-FILL AND CHUTE BARS	Expected in "coarse-grained" streams	Absent
NATURAL LEVEES	Typically prominent	Absent, but crevasse splay deposits common
EXHUMED MEANDER BELT	Can be expected in proper sect.	Absent
CONTINUITY OF SAND AND GRAVEL BEDS (IN COARSE MEMBER)	Commonly great, with little lateral change in texture	Relatively great

temperate, humid climate. The abundance of organic matter in the overbank setting and the sandstone facies of the Castlegate Sandstone (carbonized woodchips, etc.) is an additional indicator of humidity. Furthermore, plant morphology in the underlying Blackhawk Formation indicates a warm temperate to subtropical environment (Parker, 1976).

An evolving source area or a change in tectonism may have effected the nature of sediment supplied to the fluvial system and could cause a change in channel types. Whatever the direct cause of grain size changes, the grain size may have correspondingly been important in the evolution of the Castlegate fluvial system (as shown in the vertical succession of the three informal units).

Tectonic activity may alter the relief of a fluvial system, causing a subsequent change in slope and water discharge characteristic, as well as a possible rearrangement of drainages, independent of slope. The interaction between the thrust belt and foreland basin was complex and was capable of producing profound changes in fluvial sedimentation. A variety of workers have modelled foreland basin formation (e.g., Beaumont, 1981; Jordan, 1981). Some models (e.g., Quinlan and Beaumont, 1984) explain sedimentary cycles as being produced by intervals of thrusting. Although these models provide a mechanism which alters relief/gradient and sea level, they are generally for geologically long periods of time (tens of million years) which are greater than the thrusting cycles associated with the Castlegate Sandstone. However, the Castlegate correlates well with specific thrusting episodes studied by other workers (Royse and others, 1975; Fouch and others, 1983; Lawton, 1985; 1986). During lower Castlegate deposition, active thrusts included the Meade-Crawford thrust system in northern Utah and Wyoming (Royse and others, 1975; Fouch and others, 1983), and the Charleston-Nebo thrusts farther south (Lawton, 1985; 1986). After the gradient decreases with time, finer-grained sediments may be have been supplied to the Castlegate system. Sinuous channel deposition may have resulted as the fluvial system adjusted to the new lower gradient (middle Castlegate). Upper Castlegate deposition coincides with thrusting in the Absaroka system in Wyoming and northern Utah (Fouch and others, 1983), and in the Charleston-Nebo system farther to the south (Lawton, 1985; 1986). Renewed thrusting may have caused the return to braided conditions (upper Castlegate).

Recently, several authors present models in which maximum sedimentary progradation is associated with tectonic quiescence, and rapid basinal subsidence is caused by orogenic activity (e.g., Blair and Bilodeau, 1988; Heller and others, 1988). These workers suggest that there is flexural rebound of the thrust belt during postorogenic phases of adjustment, in which reworked proximal deposits are transported into the distal foreland basin. Although these models may conflict with ideas presented here, it may also be useful to test the effects of thrusting, lithospheric flexure, and eustasy, when better time constrains are available on the geologic events surrounding Castlegate deposition.

Sea level fluctuation can also alter the base level of the system, causing a change in slope. During the Late Cretaceous, a general transgression occurred, with several third-order transgressions and regressions just within the Campanian (Haq and others, 1988). At the top of the Blackhawk Formation (and base of the Castlegate Sandstone) a major regression occurred, producing an unconformity (Swift and others, 1987), and a sequence boundary (Van Wagoner and others, 1990) using the sequence stratigraphy terminology. During this regression, the lower Castlegate Sandstone was deposited over the deltaic and coastal plain deposits of the Blackhawk Formation. The marine and marginal marine facies shifted eastward and did not return to the study area until the deposition of the Buck Tongue of the Mancos Shale. At Green River and Tuscher Canyon localities (Figure 1), the

Table 3. Percent Contribution of Sedimentary Facies Comprising Measured Stratigraphic Sections.

FACIES	JOE'S VALLEY	PRICE CANYON			HORSE CANYON		GREEN RIVER	
		Low	Mid	Up	Low	Mid	Low	Mid
TROUGH X-BEDDED SS	59	69	10	71	53	58	36	27
INCLINED RIPPLED SS	20	16	26	–	22	10	22	8
HORIZONTAL RIPPLED SS	–	9	15	5	4	–	11	11
ORGANIC SS SLTS, SHALE	–	6	10	6	8	7	6	9
INTERBEDDED SS, SLTS	–	–	39	18	13	18	16	25
LENTICULAR SLTS, SHALE	–	–	–	–	**	–	–	–
PLANAR X-BEDDED SS	–	–	–	–	–	7	9	20
CONGLOMERATE	7	–	–	–	–	–	–	–
TOTALS	100	100	100	100	100	100	100	100

** Observed once, but not measured in stratigraphic section.

Low=Lower Castlegate Unit, Mid=Middle Castlegate Unit, Up=Upper Castlegate Unit (Bluecastle Tongue).

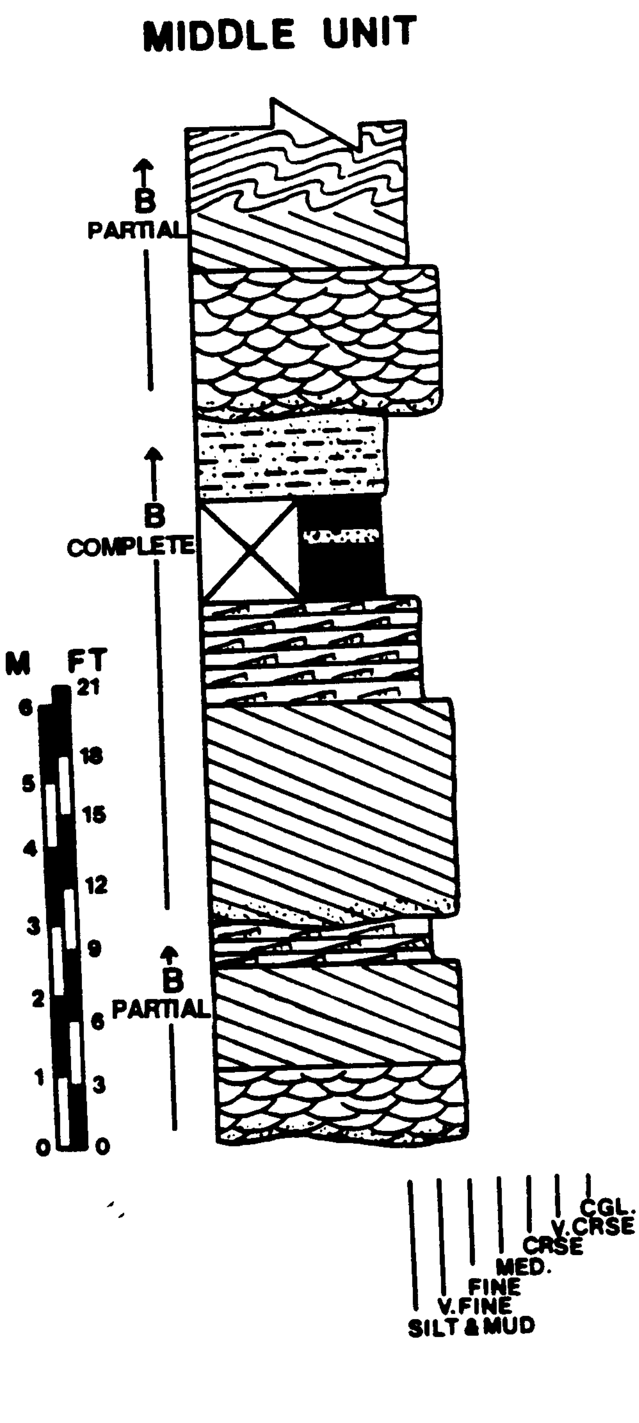

Figure 12. Detailed measured section of part of the middle unit of the Castlegate Sandstone, Price Canyon, Utah. Arrows to the left of the column indicate upward-fining sequences. B= facies Sequence B. Tick marks at lower right indicate grain sizes from siltstones and mudstones, to sandstones, and conglomerates.

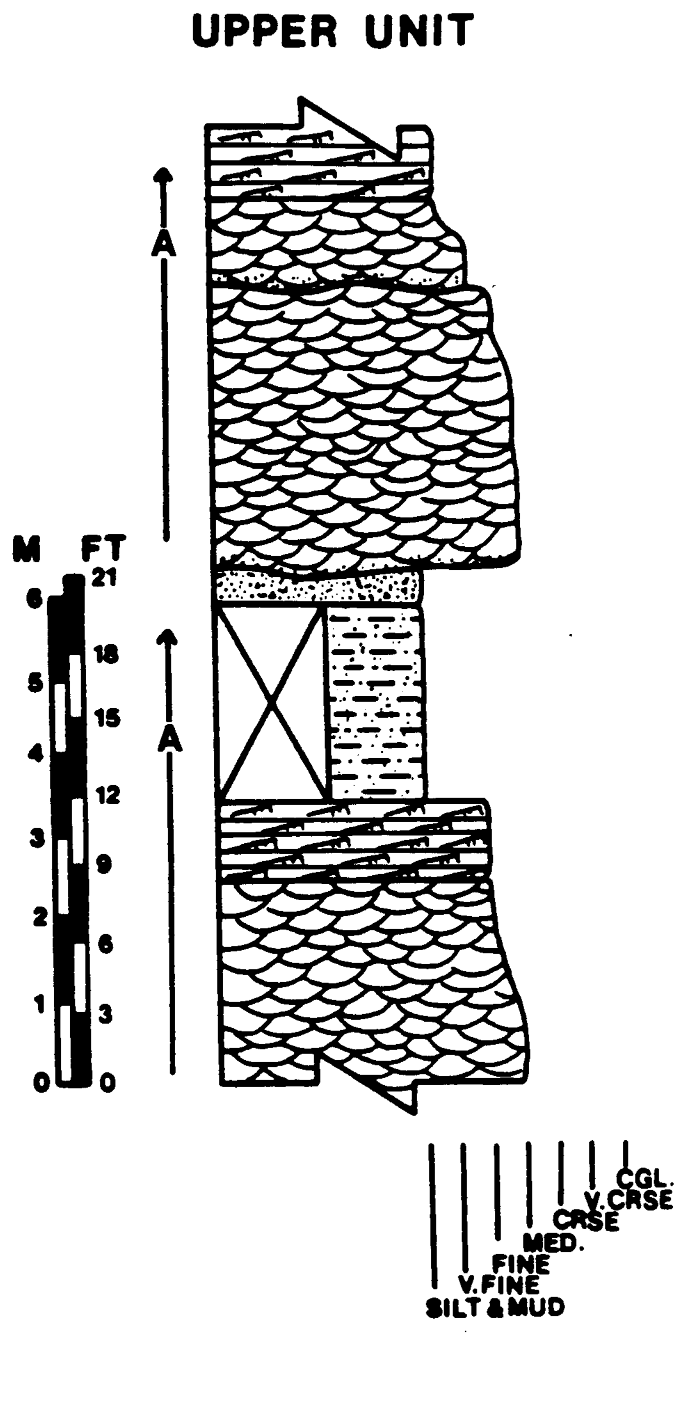

Figure 13. Detailed measured section of part of the upper unit (Bluecastle Tongue) of the Castlegate Sandstone, Price Canyon, Utah. Arrows to the left of the column indicate upward-fining sequences. A= facies Sequence A. Tick marks at lower right indicate grain sizes from siltstones and mudstones, to sandstones, and conglomerates.

;tlegate Sandstone channels deeply into the underlying ,sert Member (marine facies) of the Blackhawk Formation. This channelling presents conclusive evidence that the depositional base level was lowered prior to lower Castlegate deposition. Van Wagoner and others (1990) relate these changes to eustatic fluctuations, with the lower Castlegate unit interpreted to represent a lowstand systems tract.

It is concluded that the controls which influenced Castlegate deposition were complexly interrelated. Thrusting episodes, basinal flexure, and eustatic sea level fluctuations may have acted simultaneously to cause the observed changes in the deposits in both the lateral and vertical directions (Figure 15 and Table 3).

SUMMARY

The Castlegate Sandstone is characterized by vertical and lateral facies changes which reflect the evolution of fluvial sedimentation. These changes may be primarily due to: (1) the tectonic interactions between the Sevier orogenic belt and the adjacent foreland basin, and (2) eustatic sea level fluctuations within the Cretaceous Western Interior seaway.

Vertical changes at Price Canyon reveal three distinct units in the sandstone. The channeled braided deposition of the lower Castlegate may have been associated with vigorous orogenic activity within the thrust belt, and also corresponds to major regression (eustatic fall) of the Western Interior :away. These factors created a fairly steep gradient, and a :latively coarse sediment supply. Resultant channels were shallow and braided. Thrusting activity may have waned and a major transgression occurred during the deposition of the middle Castlegate. The effect of these events was a decrease in the gradient and the sediment grain size supply to the system. Larger, more sinuous channels characterized by the abundant lateral accretion and floodplain deposits prevailed. The upper unit (Bluecastle Tongue) may reflect a period of renewed orogenic activity and a relative drop in the sea level. In comparison to the lower unit, the coarse grain size may be indicative of greater relief, or of a more proximal uplift. The latter explanation seems plausible because thrust sheets progressively migrated eastward through time.

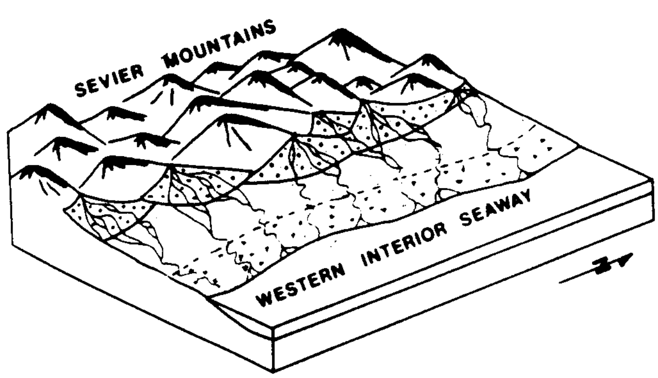

Figure 14. Generalized paleogeography during the deposition of the Castlegate Sandstone in Campanian time.

Lateral changes reveal that channels within the Castlegate system became larger and more sinuous towards the east. The numerous braided channels in the proximal parts coalesced to form the larger channels downstream. The more sinuous conditions resulted from diminished gradients and smaller sediment grain sizes in the distal parts of the system.

The sedimentologic variability of the Castlegate illustrates that many fluvial sandstones (particularly thick ones) may not be broadly classified as braided or meandering. Rather, they should be examined in detail because channel sinuosity and depositional processes may spatially change and/or evolve through time. Such distinctions allow refined interpretations of paleogeography, sea level change, and tectonic evolution within the foreland basin setting.

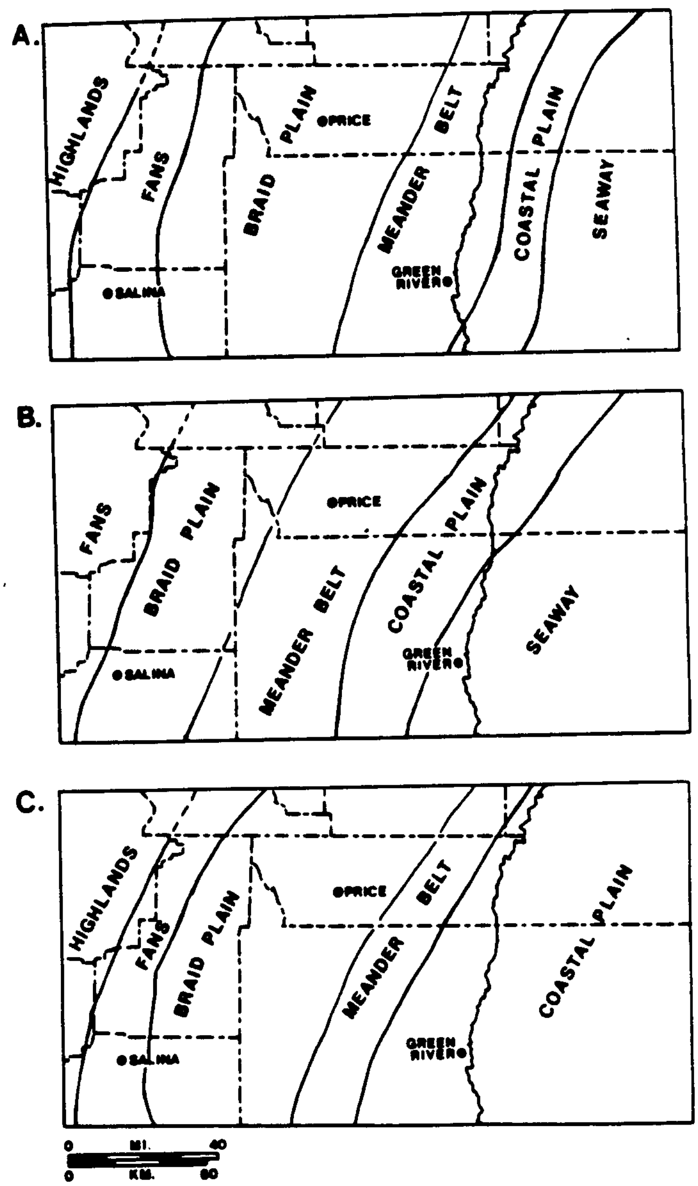

Figure 15. Paleogeographic reconstructions for Castlegate units: A) lower Castlegate deposition at ~ 79 my; B) middle Castlegate deposition at ~ 76 my; and C) upper Castlegate deposition (Bluecastle Tongue) at ~ 74 my. Modified after Fouch and others (1983).

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CASTLEGATE SANDSTONE CLIFF STABILITY

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Mining Division

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CASTLEGATE SANDSTONE CLIFF STABILITY STUDY

Utah Power & Light Company's East Mountain property is surrounded on all sides by a prominent cliff formed by the massive and resistive Castlegate Sandstone Member of the Mesa Verde Group. Where this cliff has been undermined in the extraction of the coal, it has been demonstrated that the stability of the cliff can be affected. In order to evaluate the possible impacts that underground coal mining might have on the cliffs, two semi-independent studies of the cliff stability were initiated. This report summarizes the findings of one of the studies. Findings of the second study, which is being completed by Seegmiller International, Inc., will be reported separately.

DATA COLLECTION

The Castlegate Sandstone is a very competent, massive unit. Therefore, where it is exposed on outcrop, it yields to stress only along joints within the rock. This is unlike other formations which crop out on East Mountain such as the North Horn formation which yields to stress through plastic deformation. Because the joints play an important part in the way that stress is relieved in the Castlegate Sandstone, it was important to map the nature of the joints which are present in the cliff surrounding the southern end of East Mountain.

The joints within the Castlegate Sandstone cliff were mapped in detail. The mapping included measuring the location, strike, and dip of the joints as well as their spacing and continuity, both horizontally and vertically. A total of 288 joints was mapped on the cliff. The majority of the mapping was completed by Messrs. Charles Semborski and Kurt Snider. Every effort was made to obtain a statistically random sampling of the joints present. It is important to point out that the joints which are perpendicular to the cliff are easier to recognize than those which are parallel to the cliff. Special attention was given to identification of all joints, even those of a subtle nature, because of their orientation with respect to the cliff. The raw data collected was also supplied to Seegmiller International for use in its study.

In addition to the field mapping low level aerial stereo photographs were inspected to augment the mapping, and helicopter reconnaissance was conducted to gain an overall understanding of the cliff's stability in both the pre-mining and post-mining condition. Dr. Ben Seegmiller was also present during the helicopter reconnaissance.

DATA INTERPRETATION

The important factors which influence the stability of the Castlegate Sandstone cliff include the stratigraphy of the sandstone itself, topography, orientation of the joints in respect to the escarpment, and the stability of the subsurface material which includes the presence of burned coal or underground mine workings. All of these factors have been included in this interpretation.

Stratigraphy

The Castlegate Sandstone is the upper member of the Mesa Verde Group and overlies the Blackhawk Member unconformably. Within the study area its lower contact is gradational and variable. The thickness of the Castlegate Sandstone is variable and ranges from 260 feet to 380 feet within the study area. This unit is comprised predominantly of medium to fine-grained moderately sorted sandstone having trough cross stratification interbedded with thin, lenticular, discontinuous beds of pebble conglomerate and mudstone. The entire sequence was deposited in a braided stream environment so that none of the individual units is continuous. However, the predominance of sandstone allows for several troughs to be deposited in succession to form what appears from a distance to be a massive unit.

The presence of the thin lenticular beds of mudstone within the Castlegate Sandstone appears to play an important role in the stability of the cliff. Cliff exposure and drill hole data were inspected to identify the distribution of mudstone units within the Castlegate Sandstone. It was determined that the mudstone beds are more prevalent on the east side of East Mountain in Newberry Canyon than on the west side in Miller Canyon. The mudstone beds present in Newberry Canyon are located 80 to 120 feet down from the top of the Castlegate Sandstone and are eight to 15 feet in thickness. On outcrop they appear to continue for distances of up to one-fourth of a mile. In Miller Canyon the mudstone beds are much less prevalent than to the east, and they are less continuous laterally. In some locations within the Castlegate Sandstone no mudstone beds could be identified. The impact of the mudstone beds on cliff stability will be discussed later in the report.

Joints

The strata present on East Mountain contain joints or natural fractures induced by tectonic stresses to which they are subject. Normally, joints are found as sets of two fractures at nearly right angles to each other. Most of the joints are vertical or near vertical and extend from well below the coal seams through the Flagstaff Limestone present on the highest portions of the plateau. These joints form natural planes of weakness in the Castlegate Sandstone whereby blocks of the sandstone can move vertically or settle near the outcrop. In order to better understand the direction the joints were trending throughout the study area, the strikes of the joints were plotted as rose diagrams (see Attachment 1). Rose diagrams, as well as a composite diagram representing all of the 288 joint measurements taken along the escarpment, for five different areas along the escarpment have been made.

On the north side of Newberry Canyon (Area 1) the most common joint trend measured is N 10 W with a complementary trend of N 80 E. The escarpment is roughly parallel to the N 80 E trend, and much of the failure in that region appears to have occurred by the spalling of slabs of sandstone located between the joint system and the escarpment. The south side of Newberry Canyon (Area 2) shows the same joint trend in addition to several other joints which trend from N 70 W to N 60 E. It may be that the additional joint sets were also present to the north but were not identified due to the orientation of the escarpment.

Moving in a clockwise direction around the escarpment from Newberry Canyon toward Miller Canyon (Area 6) it appears that the primary joint pattern rotates clockwise to where the primary joint's trend is N 30 E with a complementary trend of N 80 W. The change in joint direction, along with a different trend of the escarpment in Miller Canyon as compared to Newberry Canyon, allows for different cliff stability conditions in the two areas.

The spacing and continuity of the joints in the various areas was also measured. (See Table 1.)

TABLE 1

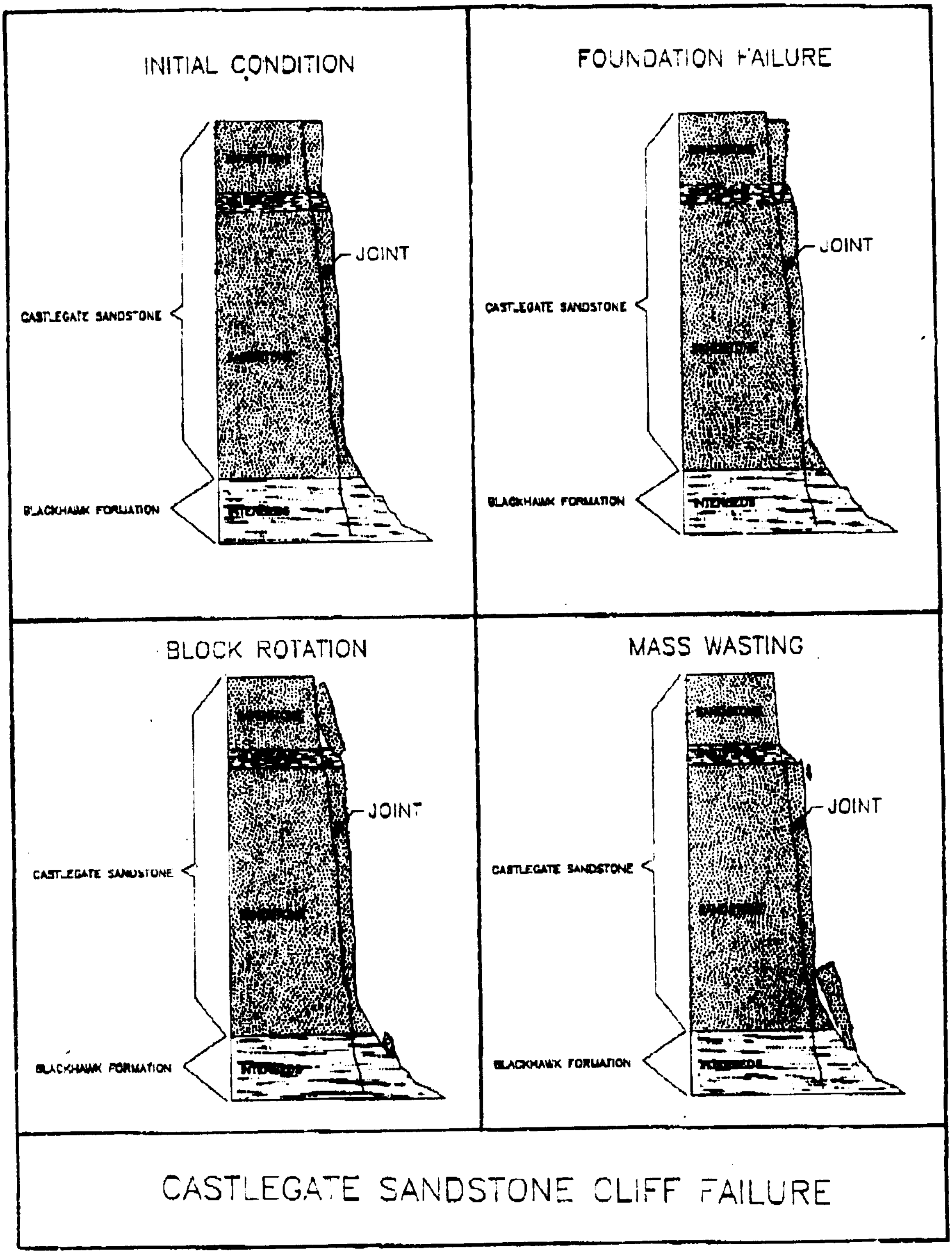
Area	No. of Joints	Continuity Strike	Continuity Dip	Joint Spacing
1	59	11.7	10.7	4.4
2	52	36.8	31.7	30.4
3	54	15.5	9.0	10.4
4	69	15.2	13.9	7.5
5	30	15.9	13.6	9.7
6	24	10.9	13.4	5.3
All Areas	288	16.0	13.9	11.6

Table 1 shows that the average spacing between joints is 11.6 feet and that the average continuity is 16.0 and 13.9 feet on strike and dip, respectively. The joint spacing and continuity in Area 2 is much greater than in any other area. The reason is unknown. It appears that joint spacing in all other areas inspected is similar.

Foundation Failure

Failure of the Castlegate Sandstone escarpment observed within the study area has been caused by numerous factors acting in combination. In every case, however, in which large blocks of sandstone have become unstable and collapsed, the foundation material of the cliff has insufficient compressive strength to support the mass of rock above. Figure 1 illustrates how the foundation failure occurs. The initial condition which exists is the disruption by settling (caused naturally or by mining) of a thin slab (generally less than 50 feet in thickness) of the cliff that extends from the escarpment into a joint, causing the thin slab to settle downward (foundation failure). Further settling causes block rotation in which the bottom of the slab moves outward toward the escarpment. In time, the slab falls from the cliff by mass wasting. The areas in which cliff failure was observed by field mapping are shown as red fractures on Attachment 1.

For several months the area above the 6th and 7th East longwall panels in the Cottonwood Mine has been the focus of attention regarding cliff stability. Mining in the 6th East panel began in September, 1986 and was completed in March, 1987. Mining in the 7th East panel began in April, 1987 and was completed in August, 1987. Movement on the cliffs above the longwall panel was first observed in February, 1987. This area is located in the Northeast ¼ of Section 28 and the Northwest ¼ of Section 27, Township 17 South,



INITIAL CONDITION
JOINT
CASTLEGATE SANDSTONE
BLACKHAWK FORMATION
FOUNDATION FAILURE
JOINT
CASTLEGATE SANDSTONE
BLACKHAWK FORMATION
BLOCK ROTATION
JOINT
CASTLEGATE SANDSTONE
BLACKHAWK FORMATION
MASS WASTING
JOINT
CASTLEGATE SANDSTONE
BLACKHAWK FORMATION
CASTLEGATE SANDSTONE CLIFF FAILURE

FIGURE 1

Range 7 East. It is quite apparent that the cliff instability was spawned by the mining activities below. The factors which played the greatest role in the cliff movement were 1) strong north-south and east-west jointing, 2) the cliff escarpment's being roughly parallel to the east-west jointing, and 3) the weak mudstone layer present in the middle of the Castlegate Sandstone. Cliff movement has been monitored since it was first observed, and it appears that the movement has stabilized. The debris which fell from the cliff formed talus slopes below the cliff. The talus slopes are shown as shaded areas on Attachment 1. The cliff movement had little if any impact on the current land use in the area. Perhaps the greatest effect was the visual impact on the area. It is important to point out that the spalling of material from the cliff in this area is a natural phenomenon. The material would eventually have become unstable and fallen even if the underlying coal were never mined, but the time it took for this natural process to occur was accelerated by mining. The acceleration was on the order of magnitude of thousands of years.

The only region within the study area in which mining has occurred is in the 6th and 7th East longwall panel, but several areas of naturally occurring cliff movement were mapped. In most cases the naturally occurring cliff movement is more significant than that caused by mining. The areas in which cliff movement was noticed in unmined areas are in the Southwest ¼ of Section 33; the South ½ of Section 32, Township 17 South, Range 7 East; the North ½ of Section 5, Township 17 South, Range 7 East; and the North ½ of Section 5, Township 18 South, Range 7 East. It is speculated that the underlying coal has been naturally burned in these areas. The overburden pressures on the clinker beds formed from the burned coal were too great and caused them to yield, propagating movement of the Castlegate Cliff. The cliff movement in the Southern ½ of Section 32, Township 17 South, Range 7 East was great enough to create graben structures 40 feet deep and as much as 150 feet back from the escarpment. This movement appears to be more significant than any which has been observed associated with mining anywhere on East Mountain.

SUMMARY

The cliffs surrounding the southern end of East Mountain are all undergoing natural weathering and mass wasting, dictating that none of the cliffs are stable and will remain in their current state for long periods of time. Many natural or manmade conditions can and will cause the degradation of the cliffs to be accelerated. These conditions may include heavy rainfall, seismicity, frost wedging, and mining. It is safe to assume that underground mining anywhere on East Mountain will accelerate the degradation process to some degree. In the areas where steep escarpments exist, the amount of acceleration may be more pronounced.

The cliff movement in the area of the 6th and 7th East longwall panels in the Cottonwood Mine has, without question, been accelerated by mining. This cliff movement has had little or no effect on the current land use of the area.

Because of the geologic conditions present, it is felt that anywhere the Castlegate Cliff is undermined by longwall or room and pillar mining methods (pillar extraction), the degradation of the cliff will be accelerated to some degree. In many cases the amount of acceleration will be nil, to the point that no noticeable change will occur in one's lifetime. In other areas the impact will be almost immediate.

The geologic factors which influence the cliff stability vary in the different areas of the study area. Because of the rotation of the joint trends between the Newberry Canyon and Miller Canyon areas and the change in relationship between the escarpment trend and the joints, the acceleration of degradation in the Miller Canyon area will be much less than in the Newberry Canyon area. The Castlegate Sandstone within the Miller Canyon area contains fewer mudstone lenses, which reduces the chance for foundation failure, from conditions found in the Newberry Canyon area. Where the setup entries are currently located for 9th and 10th West longwall panels in the Cottonwood Mine below Miller Canyon, it is likely that mining will have no immediate effect on cliff stability.

The area in which mining beneath the escarpment is most likely to accelerate escarpment failure is the southern portion of the escarpment (see Attachment 1). Much movement of the cliffs has already occurred in that area, and any additional condition which disrupts the material supporting the escarpment will surely cause an almost immediate impact on the cliff. However, at worst case, the cliff failure will have little or no impact on the land use of the area above or below the escarpment and the visual effects of any cliff movement should blend in with the visual quality of the surrounding areas.

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ENERGY WEST
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HUNTINGTON, UTAH 84528

TRAIL MOUNTAIN MINE
5TH EAST CASTLEGATE ESCARPMENT
STUDY AREA – 12/96

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TRAIL MOUNTAIN MINE
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