108-025-08 ENFORCEMENT ACTION FILES
207b UIC - EAST POPLAR OIL FIELD ENFORCEMEN
SDWA SEC. 1431

Release in Full

Region 8
67001

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207b UIC - EAST POPLAR OIL FIELD ENFORCEMEN
SDWA SEC. 1431
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Region 8
67001

Schlumberger

COMPUTER PROCESSED LOG

COMPANY Texas Oil & Gas

WELL Buckle B #1

FIELD East Poplar

COUNTY Roosevelt STATE Montana

LOCATION Sec 22 T28N R51E

ELEVATION KB 2119 DF — GL 2106 API NO. —

Schlumberger Cyberlook
WELLSITE COMPUTATION
A CSU Service

Date		8-21-81							
Run No.		ONE							
Depth—Driller		5920							
Depth—Logger		5905							
Btm. Log Interval		5905							
Top Log Interval		5500							
Casing—Driller		8 5/8 @ 1200		@		@		@	
Casing—Logger		NOT LOGGED							
Bit Size		7 7/8							
Type Fluid in Hole		SALT STARCH GEL							
Dens.	Visc.	10.4	40						
pH	Fluid Loss	7.0	10 ml		ml		ml		ml
Source of Sample		MUD TANK							
Rm @ Meas. Temp.		.053 @ 70 °F		@	°F	@	°F	@	°F
Rmf @ Meas. Temp.		.045 @ 70 °F		@	°F	@	°F	@	°F
Rmc @ Meas. Temp.		.050 @ 70 °F		@	°F	@	°F	@	°F
Source: Rmf	Rmc	M	C						
Rm @ BHT		.021 @ 199 °F		@	°F	@	°F	@	°F
TIME Circulation Stopped		0630 8-21-81							
TIME Logger on Bottom		—							
Max. Rec. Temp.		199 °F			°F		°F		°F
Equip.	Location	8247	WLSTN						
Recorded By		SORENSON/BARBER							
Witnessed By		DYER							

MAR-832

MAR02-1078

terpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any inter-
itions, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or
ined by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our General Terms and
itions as set out in our current Price Schedule. *A mark of Schlumberger

COMPUTATION PARAMETERS

R_w		GR		SP		NEUTRON		SHALE INDEX USED		PMAX	MD	DO	DO2	SPDR	MATR	BS
Free	Bound	Clean	Shale	Clean	Shale	Clean	Shale	GR/SP BOTH	Neutron Used Y/N	PHI MAX	Clean Matrix Density	Depth Offset Tape 1	Depth Offset Tape 2	SP Drift	Neutron Matrix	Bit Size
.02	.1	5	70	—	—	—	—	GR	N	.40	2.71	-	-	-	LS	7⅞
AND .04																

COMPUTATION CONSTANTS

Service Order Number 243384

RATE DENSITY = / /

Computation used the following logs: DLL/MSFL FDC/CNL

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
[illegible]		[illegible]	[illegible]		[illegible]	RUE	OHMM	0.04000

PARAMETERS

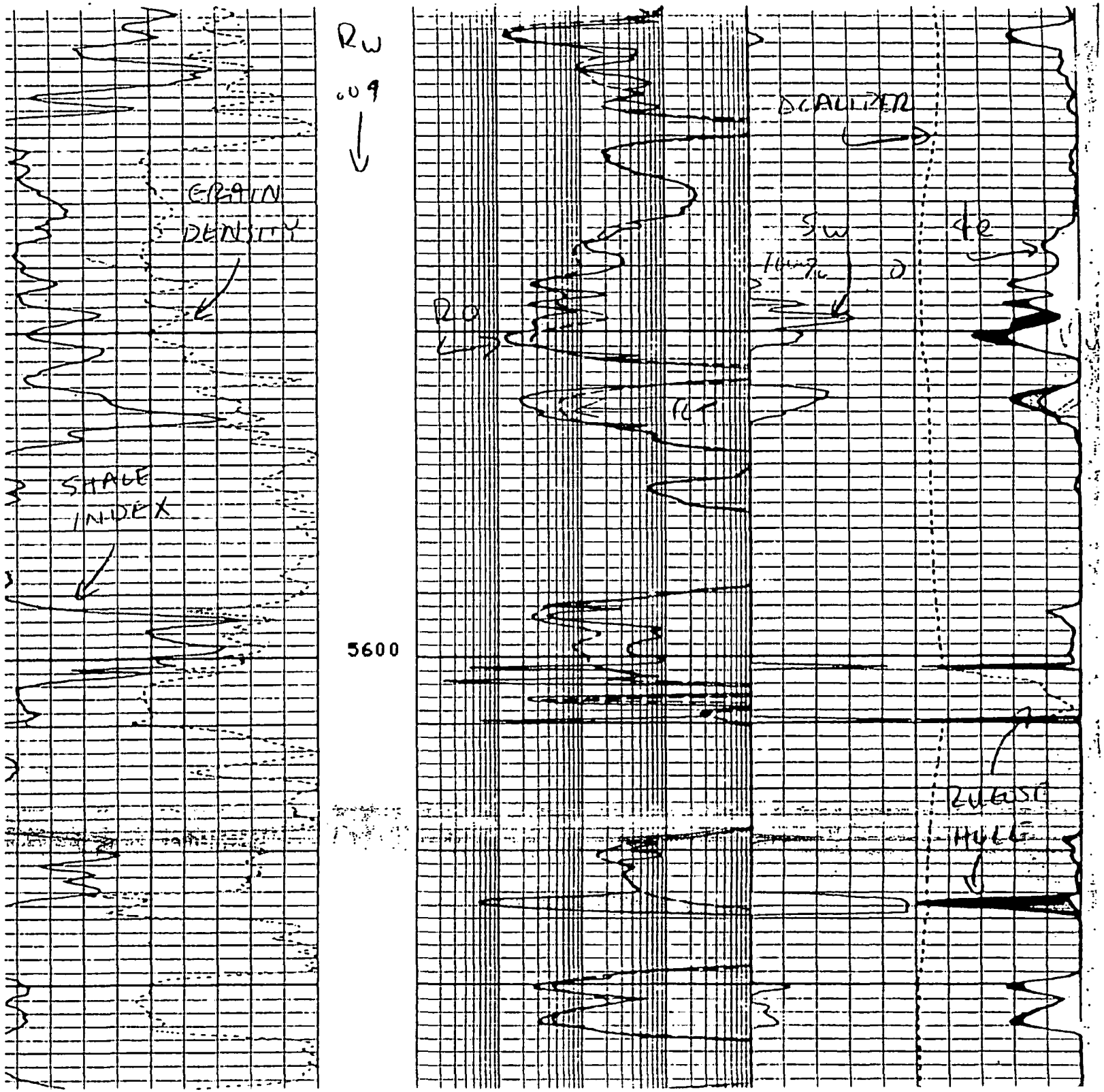
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.04000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI
DTM	US/F	47.60	CDTS		100.0	MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

RHGF(G/C3)			DCAL(IN)
2.500			-10.00 10.00
			VWXO( )
			0.5000 0.0
		RO (OHMM)	PHIE( )
		0.1000 1000.	0.5000 0.0
MSI ( )		RT (OHMM)	VW ( )
0.0 1.000		0.1000 1000.	0.5000 0.0

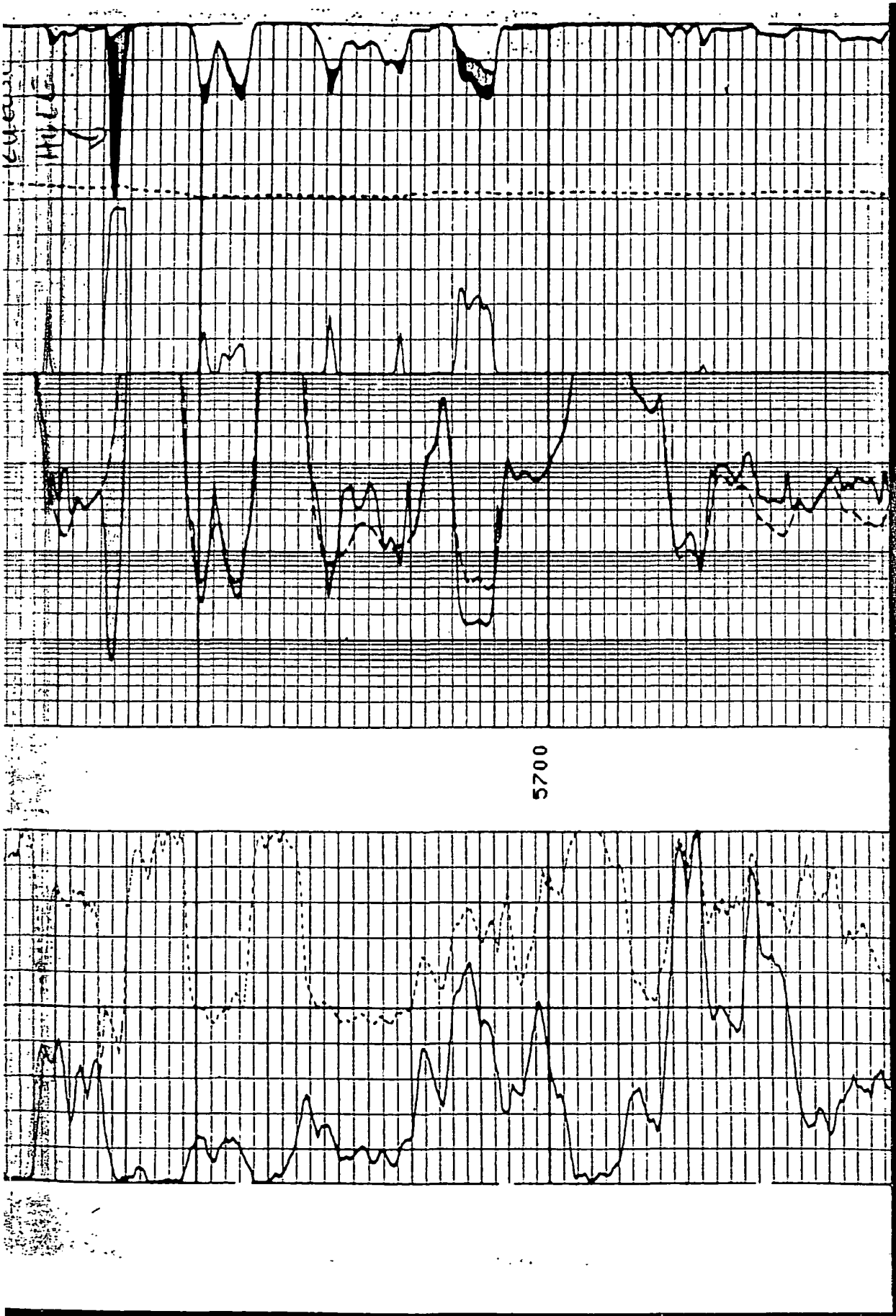
FILE

101

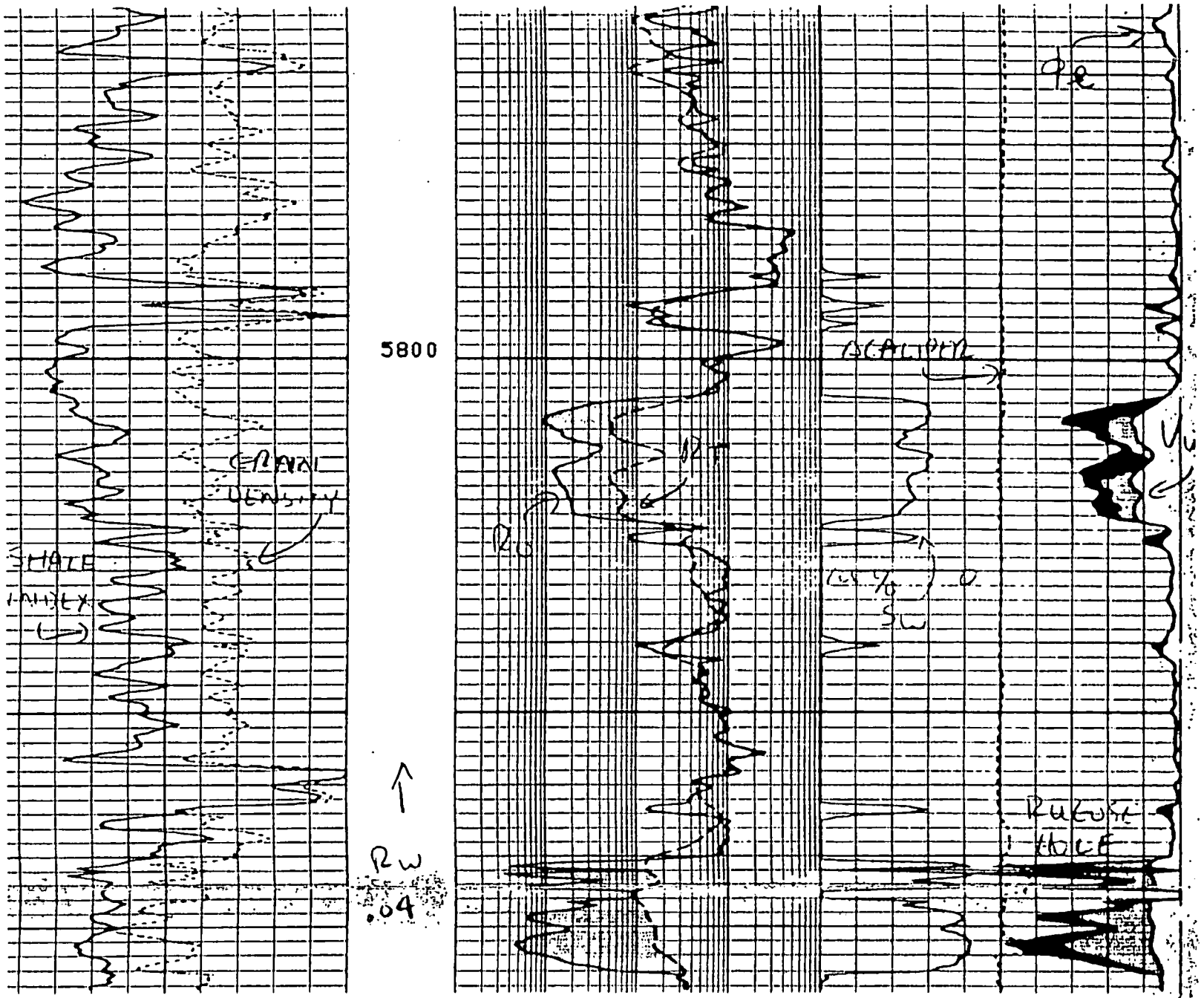
MAR02-1080



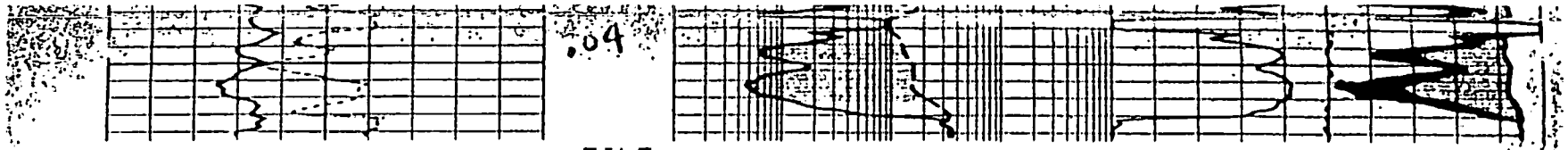
MAR02-1081



MAR02-1082



MAR02-1083



FILE

101

			DCAL(IN)
			-10.00 10.00
			VWXO( )
			0.5000 0.0
RHGF(G/C3)		RO (OHMM)	PHIE( )
2.500 3.000		0.1000 1000.	0.5000 0.0
MSI ( )		RT (OHMM)	VW ( )
0.0 1.000		0.1000 1000.	0.5000 0.0

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.04000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI

MAR02-1084

BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI
DTM	US/F	47.60	CDTS		100.0	MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

RHGF(G/C3)	RO (OHMM)	DCAL(IN)
.500 3.000	0.1000 1000.	-10.00 10.00
		VWXO( )
		0.5000 0.0
		PHIE( )
		0.5000 0.0
MSI ( )	RT (OHMM)	VW ( )
.0 1.000	0.1000 1000.	0.5000 0.0

FILE

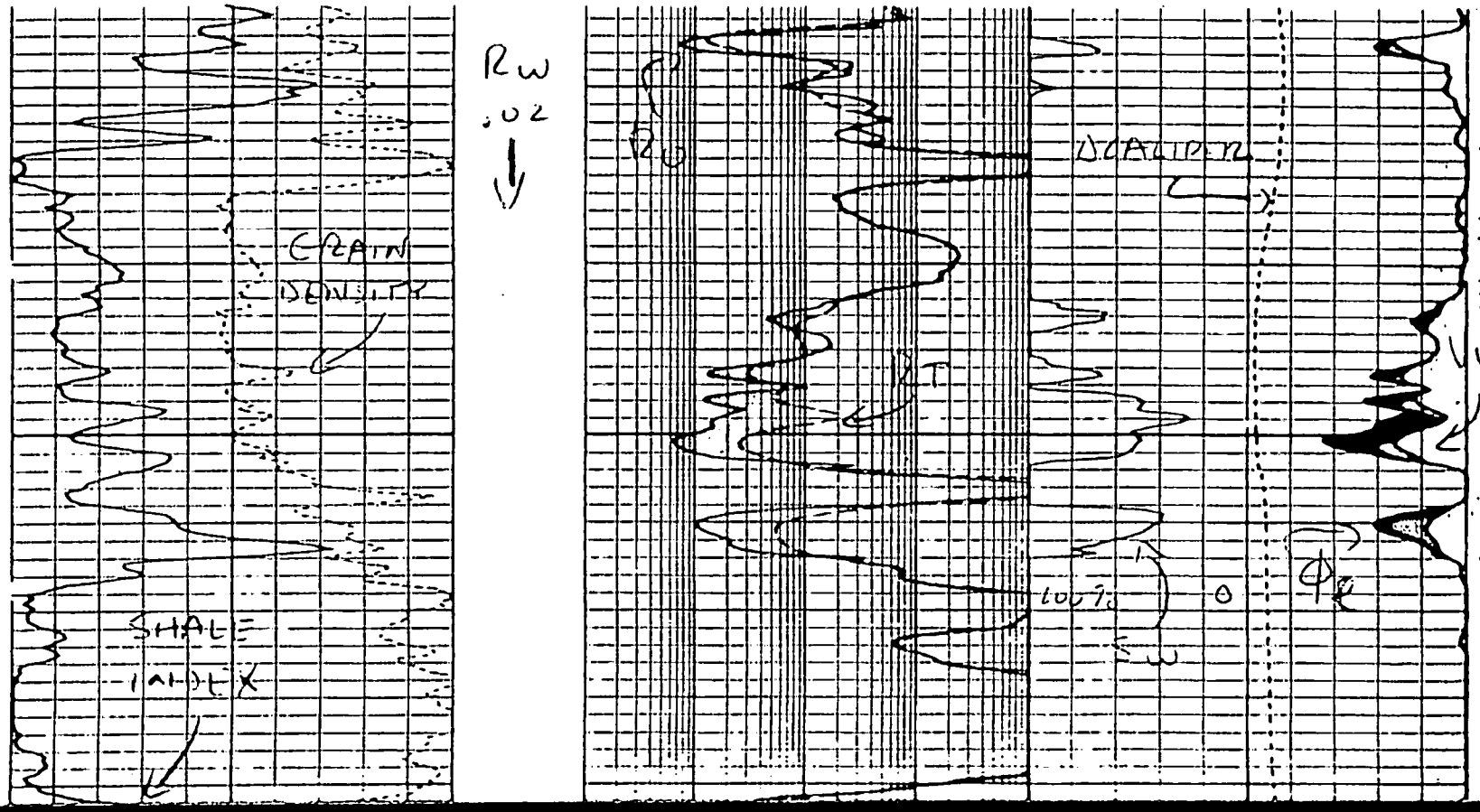
101

MAR02-1085

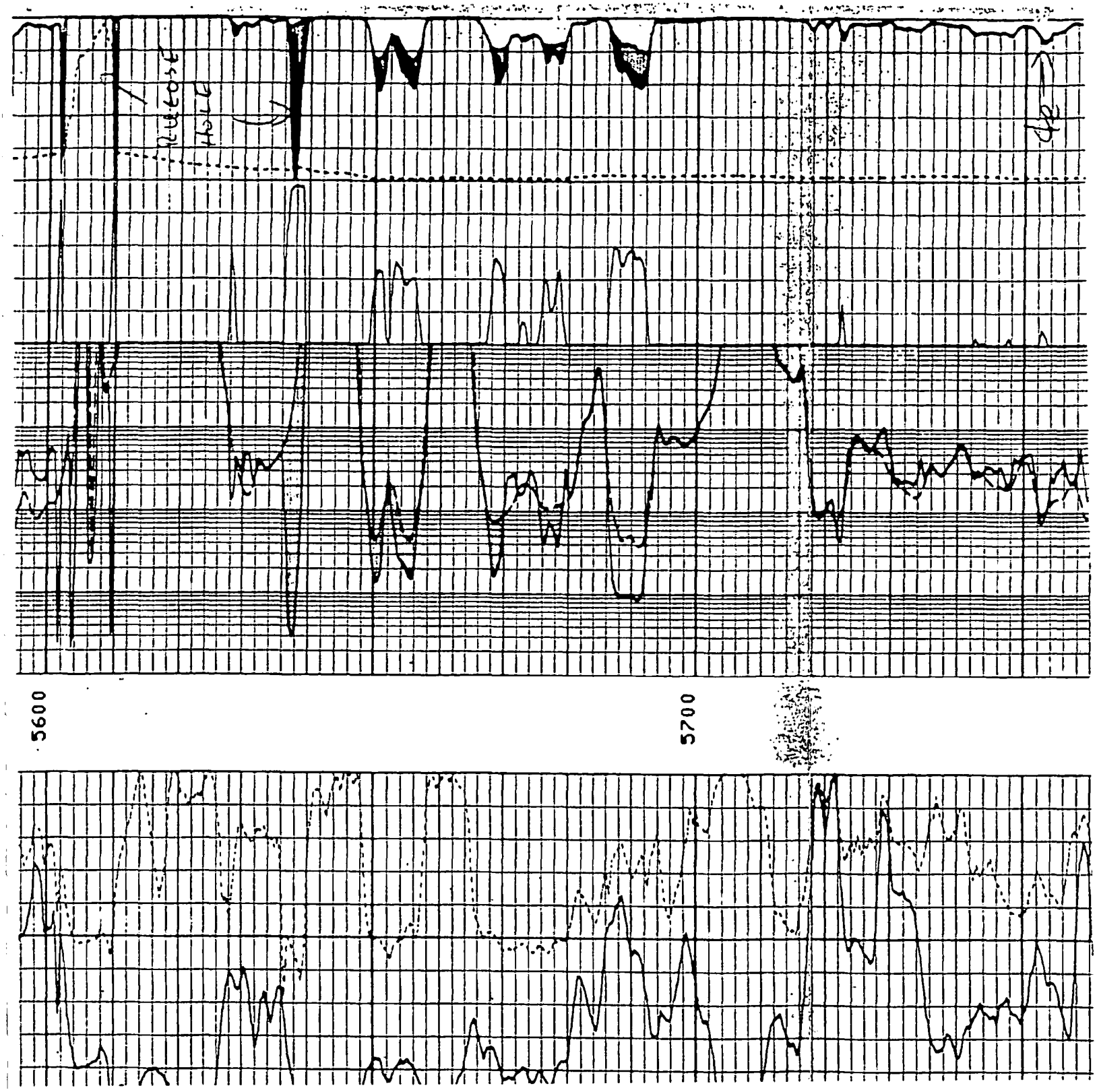
RHGF(G/C3)		RO (OHMM)		PHIE( )	
2.500	3.000	0.1000	1000.	0.5000	0.0
MSI ( )		RT (OHMM)		VW ( )	
0.0	1.000	0.1000	1000.	0.5000	0.0

FILE

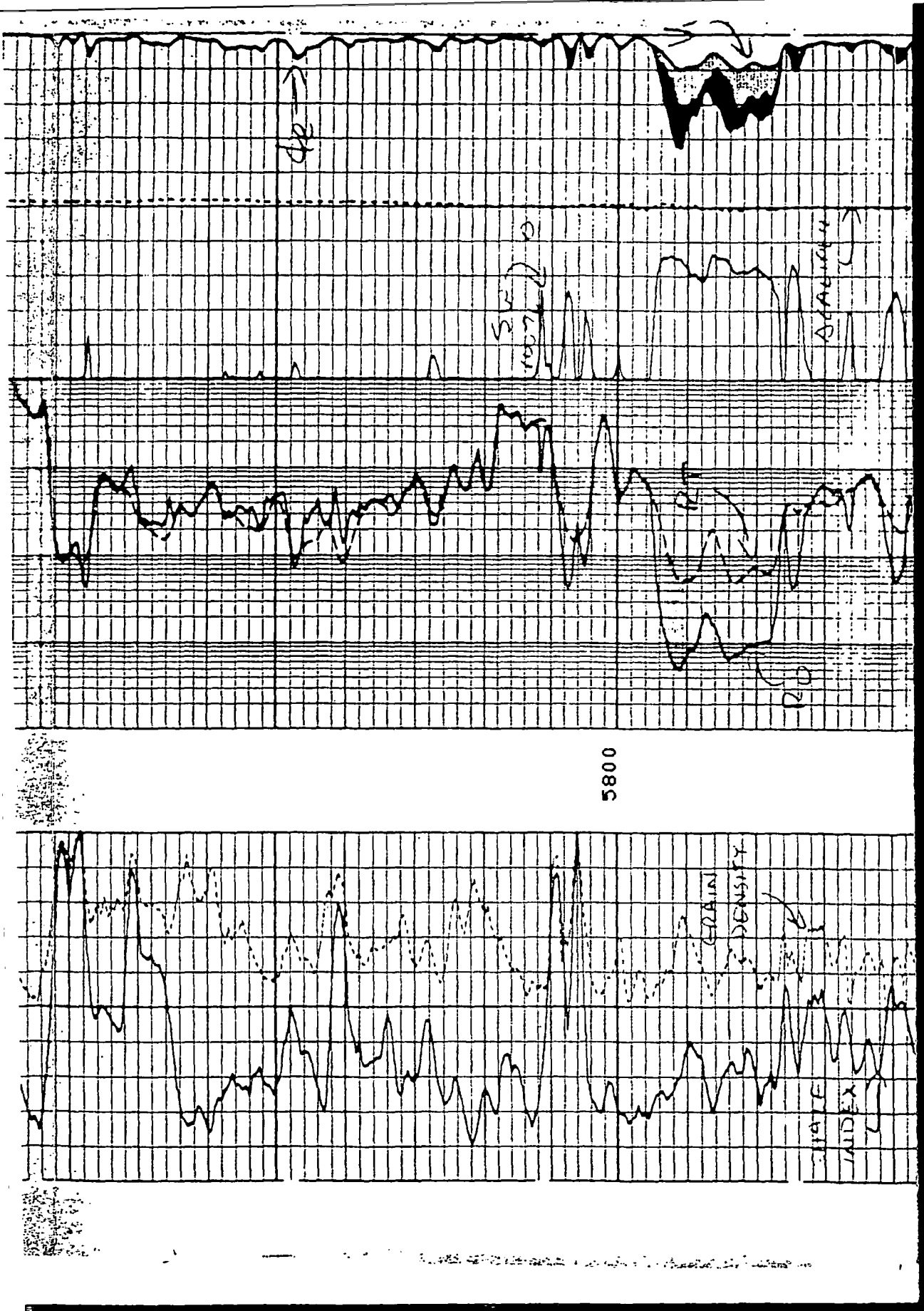
101



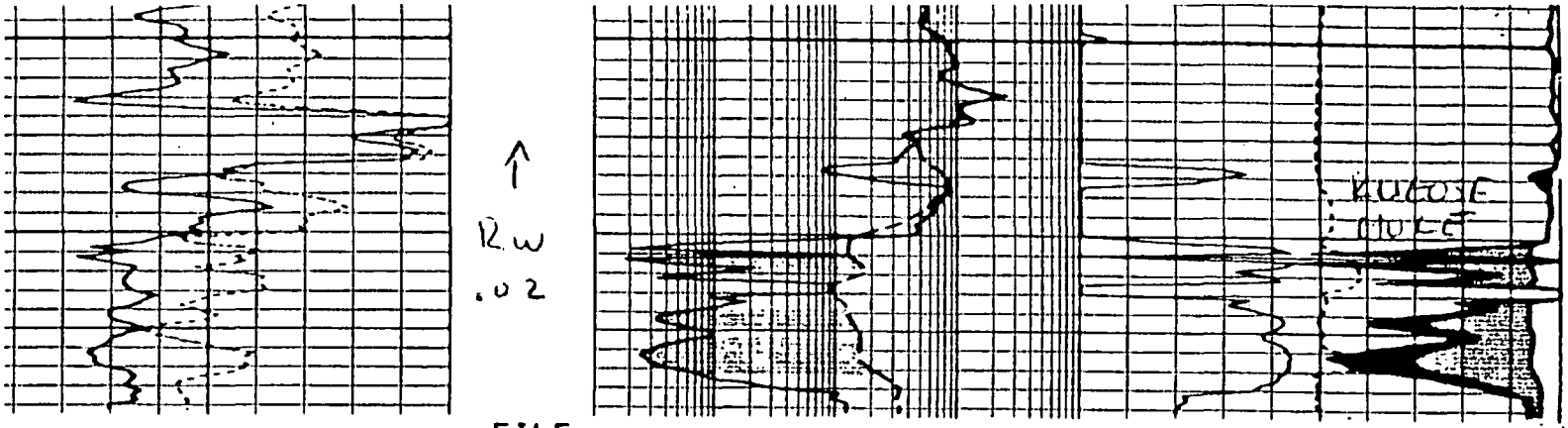
MAR02-1086



MAR02-1087



MAR02-1088



FILE

101

			DCAL(IN)
			-10.00 10.00
			VWXO( )
			0.5000 0.0
RHGF(G/C3)		RO (OHMM)	PHIE( )
.500 3.000		0.1000 1000.	0.5000 0.0
MSI ( )		RT (OHMM)	VW ( )
.0 1.000		0.1000 1000.	0.5000 0.0

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI
DTM	US/F	47.60	CDTS		100.0	MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI
DTM	US/F	47.60	CDTS		100.0	MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES

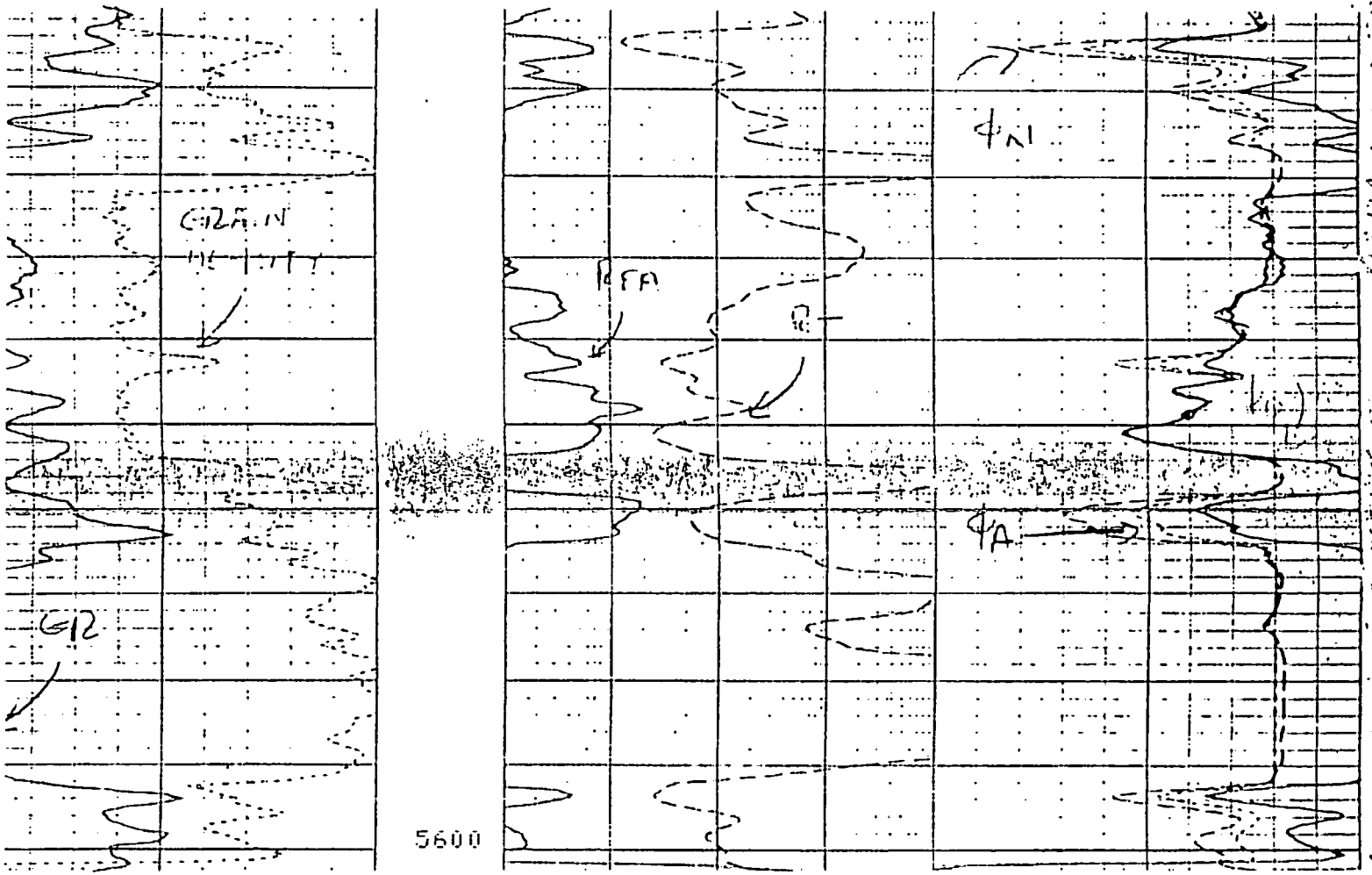
MAR02-1090

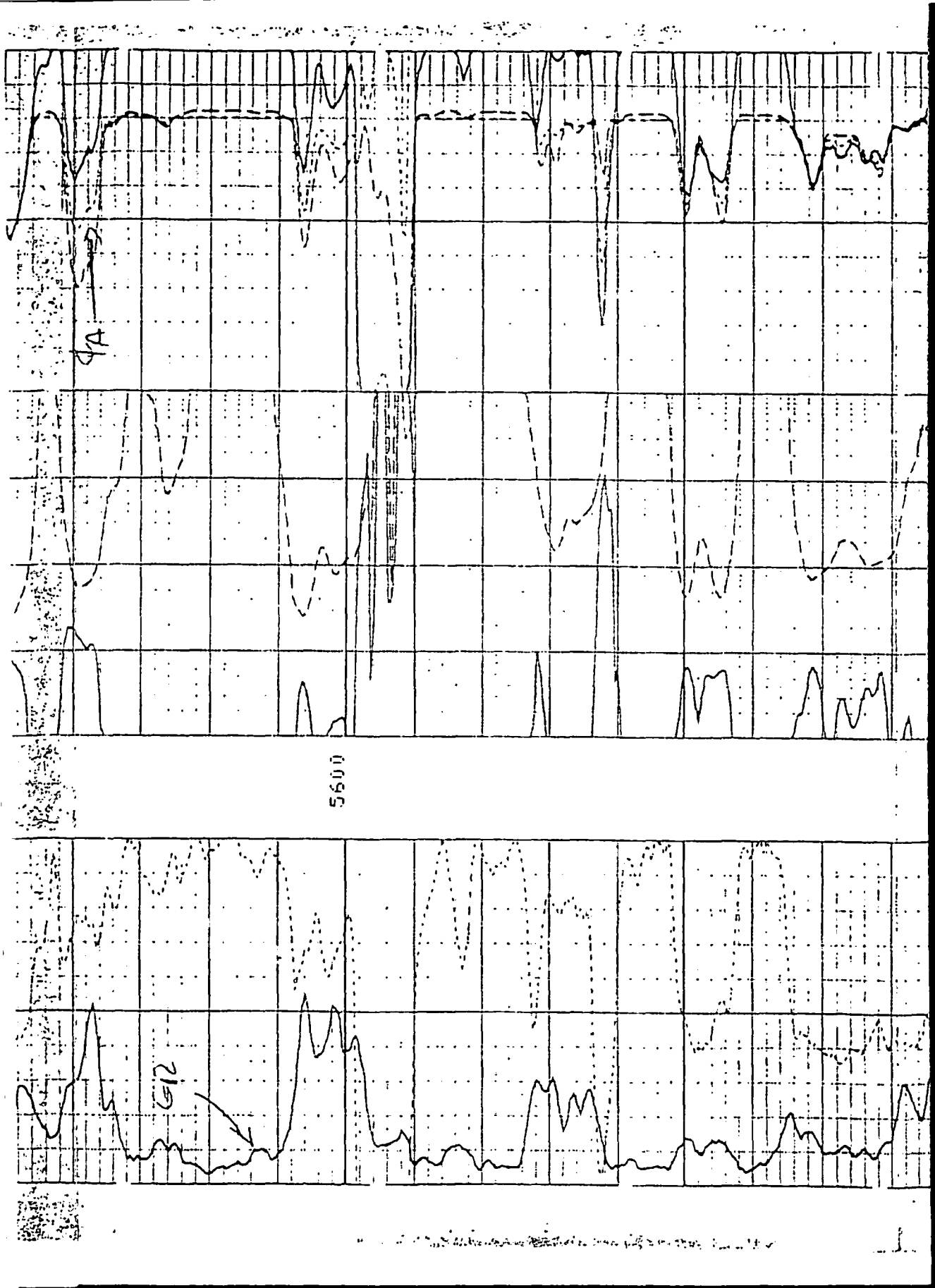
FD	G/C3	1.100	MATR		LIME		HC		CALI
DTM	US/F	47.60	CDTS		100.0		MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX		DTF	US/F	189.0
DO		0.0							

			PHIA( )
			0.4000 -0.100
RHGA(G/C3)		RFA (OHMM)	DPHI( )
500 3.000		0.0100 100.0	0.4000 -0.100
GR (GAPI)		RT (OHMM)	NPHI( )
) 100.0		0.1000 1000.	0.4000 -0.100

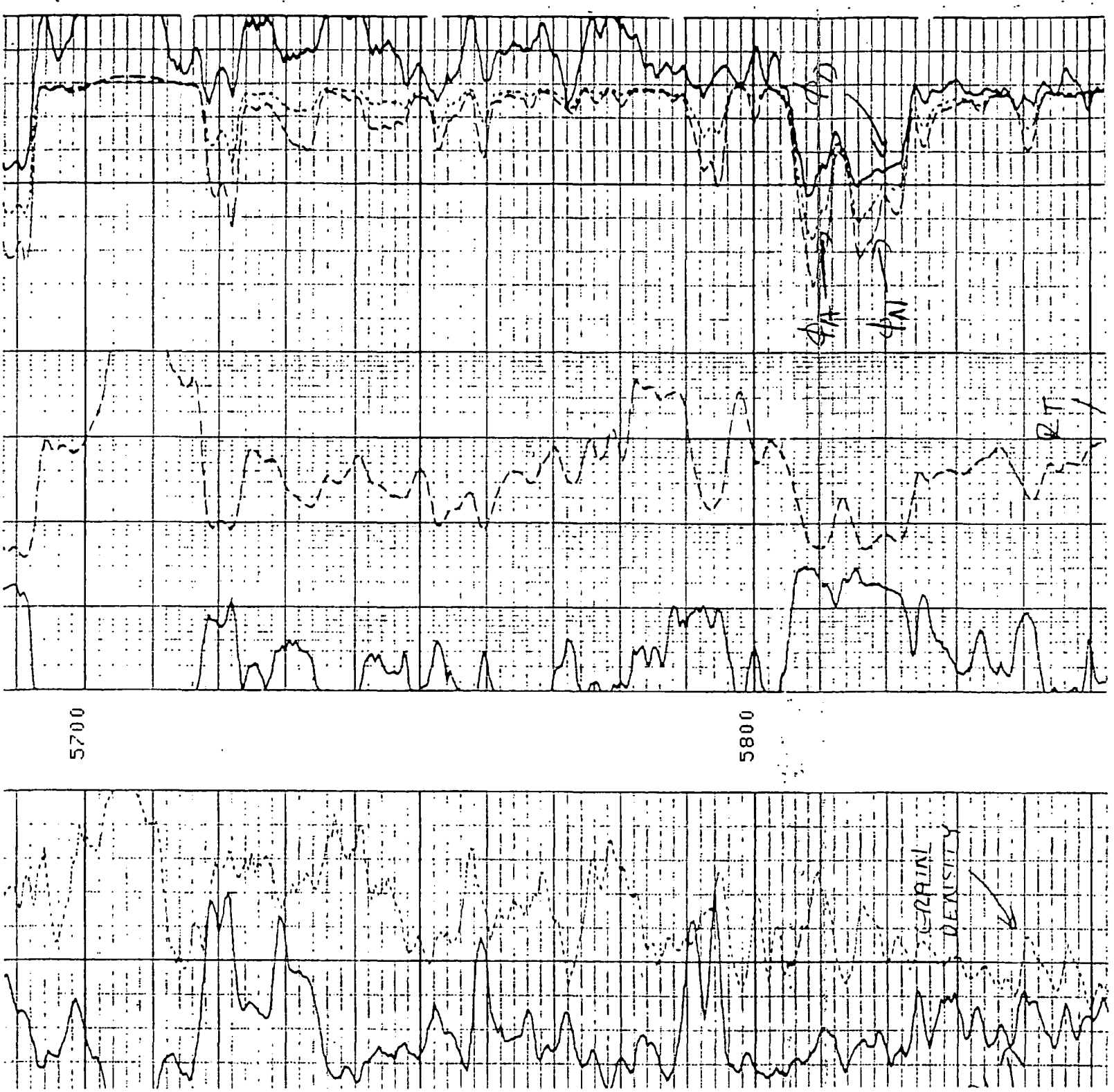
FILE

101

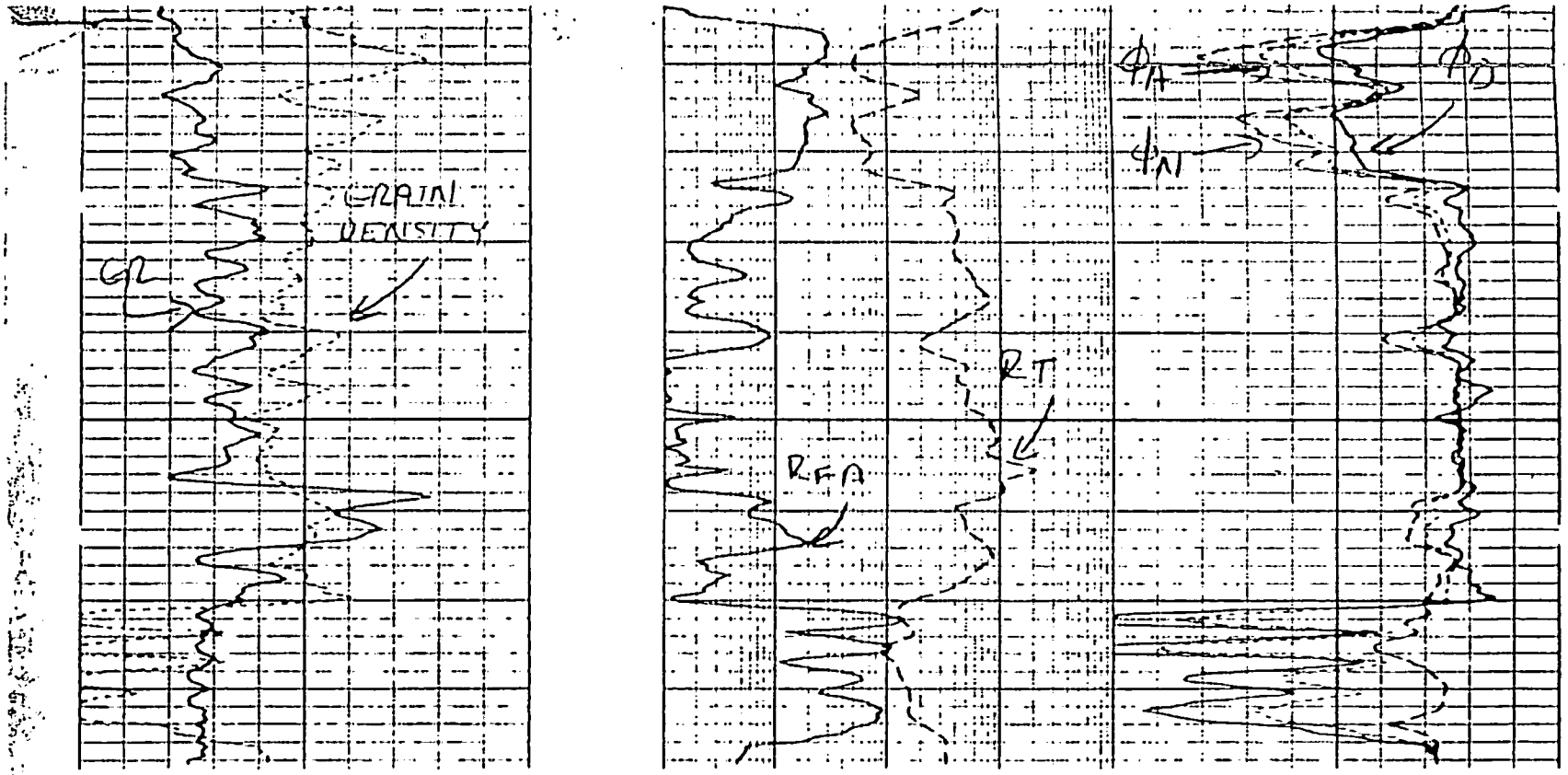




MAR02-1092



MAR02-1093



FILE

101

RHGA(G/C3)		RFA (OHMM)		PHIA( )	
2.500	3.000	0.0100	100.0	0.4000	-0.100
GR (GAPI)		RT (OHMM)		DPHI( )	
0.0	100.0	0.1000	1000.	0.4000	-0.100
				NPHI( )	
				0.4000	-0.100

PARAMETERS

MAR02-1094

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	999.0	BS	INCH	7.875
LSWB		ALLO	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	999.0
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.3000	GRCL	GAPI	5.000
RXOF		PRES	CLIM	IN	16.00	SINP		GR
RTLF		DISA	BHT	DEGF	139.2	SONI		PRES
FD	G/C3	1.100	MATR		LIME	HC		CALI
DTM	US/F	47.60	CDTS		100.0	MDEN	G/C3	2.710
BHS		OPEN	FPHI		PHIX	DTF	US/F	189.0
DO		0.0						

MAR02-1095

Williston
Schlumberger

COMPUTER PROCESSED LOG

COMPANY Texas Oil & Gas Corp

WELL Buckles #A-1

FIELD East Poplar

COUNTY Roosevelt STATE Montana

LOCATION 1980' FNL x 1980' FWL S22-28N-51E

ELEVATION KB 2097 DF _____ GL 2085 API NO. _____

Schlumberger Cyberlook
WELLSITE COMPUTATION
A CSU* Service

Date	4-16-81								
Run No.	1								
Depth—Driller	5938								
Depth—Logger	5944								
Btm. Log Interval	5930								
Top Log Interval	5490								
Casing—Driller	8 5/8 @ 1214		@					@	
Casing—Logger	1220								
Bit Size	7 1/8								
Type Fluid in Hole	Salt Low Solids								
Dens. / Visc.	11.3	41							
pH / Fluid Loss	6.4	6 ml		ml		ml		ml	
Source of Sample	Mud Tank								
Rm @ Meas. Temp.	.056 @ 68 °F		@	°F	@	°F	@	°F	
Rmf @ Meas. Temp.	.049 @ 69 °F		@	°F	@	°F	@	°F	
Rmc @ Meas. Temp.	.084 @ 68 °F		@	°F	@	°F	@	°F	
Source: Rmf / Rmc	M	C							
Rm @ BHT	.022 @ 188 °F		@	°F	@	°F	@	°F	
TIME Circulation Stopped	0600 : 4-16								
TIME Logger on Bottom	1500 : 4-16								
Max. Rec. Temp.	208 °F			°F		°F		°F	
Equip. / Location	8135	WLSTN							
Recorded By	M Sachau								
Witnessed By	M. Walen, M Perius								

MAR-833

MAR02-1096

'pretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any inter-ns, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or d by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our General Terms and ns as set out in our current Price Schedule. *A mark of Schlumberger

COMPUTATION PARAMETERS

R_w		GR		SP		NEUTRON		SHALE INDEX USED		PMAX	MD	DO	DO2	SPDR	MATR	BS
Free	Bound	Clean	Shale	Clean	Shale	Clean	Shale	GR/SP BOTH	Neutron Used Y/N	PHI MAX	Clean Matrix Density	Depth Offset Tape 1	Depth Offset Tape 2	SP Drift	Neutron Matrix	Bit Size
.02 & .04	.1	5	70	—	—	—	—	GR	N	.4	2.71	0	—	—	Lime	7 7/8
												1				

COMPUTATION CONSTANTS

Service Order Number: 213161

TE DENSITY = 1.1 gm/cc

Computation used the following logs: DLL MSFL FDC CNL

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	PDUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.04000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000

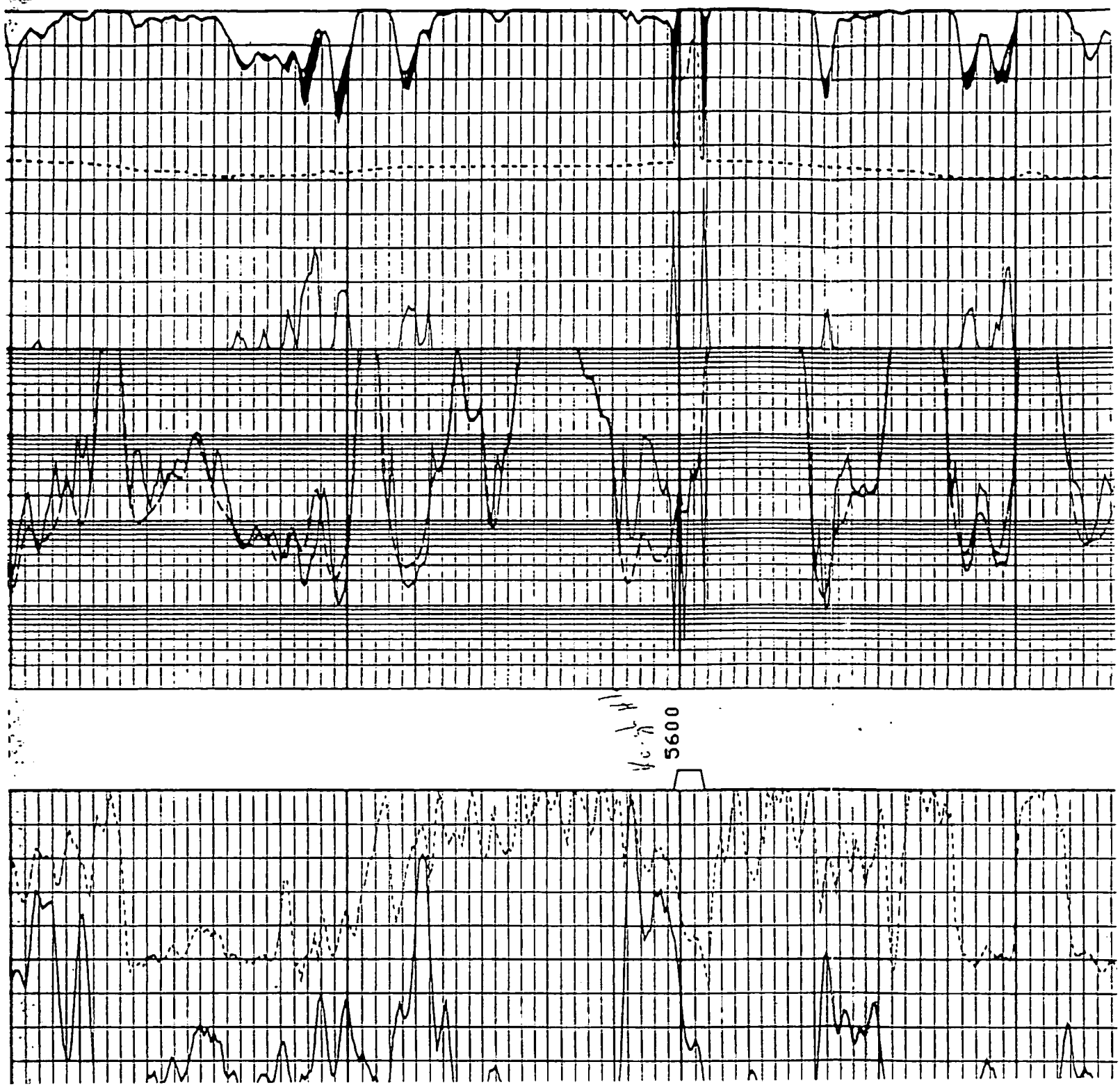
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.04000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		1.000	BHS		OPEN			

			DCAL(IN)
			-10.00 10.00
			VWXO( )
			0.5000 0.0
RHGF(G/C3)		R0 (OHMM)	VW ( )
2.500 3.000		0.1000 1000.	0.5000 0.0
MSI ( )		RT (OHMM)	PHIE( )
0.0 1.000		0.1000 1000.	0.5000 0.0

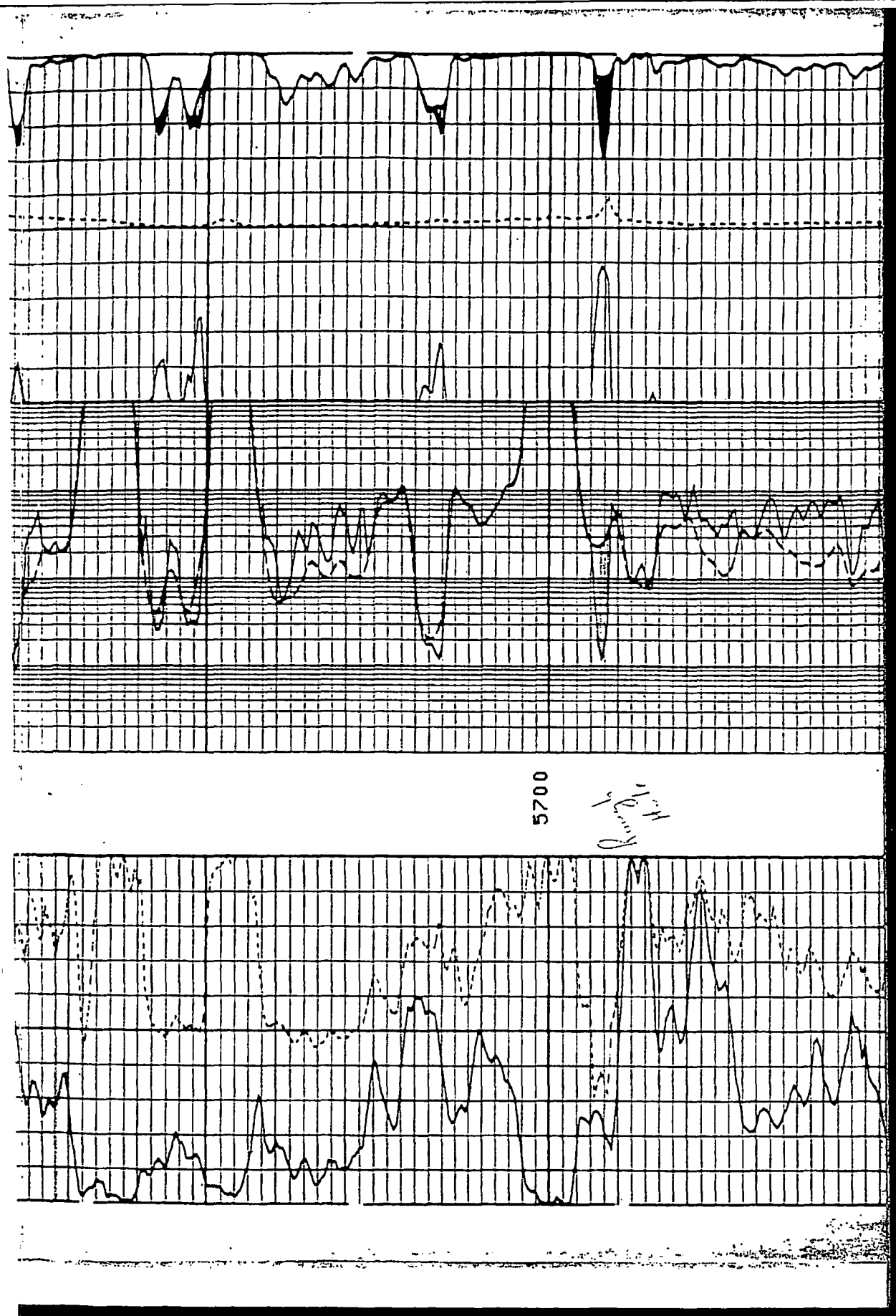
FILE

4

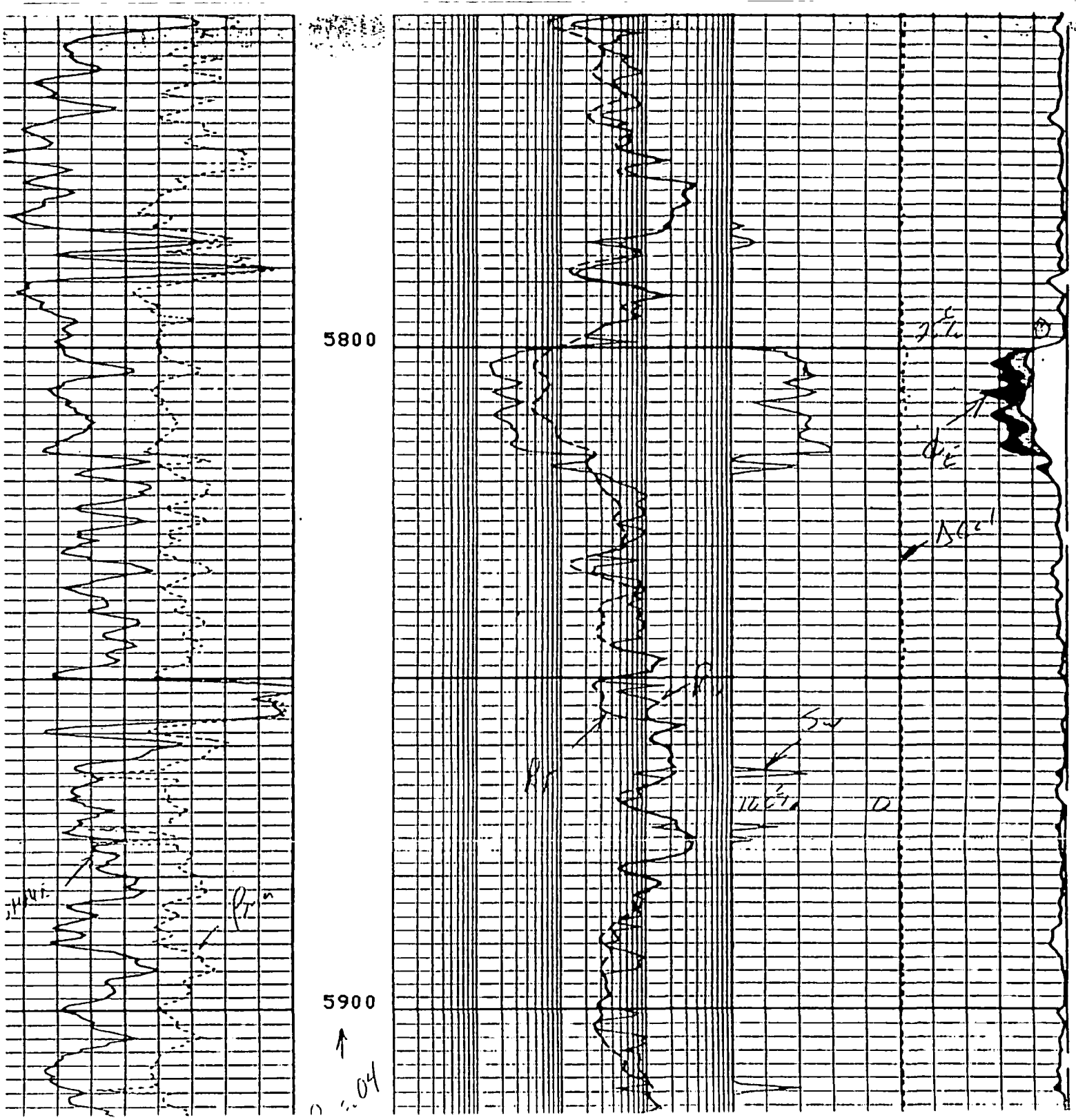
MAR02-1098



MAR02-1099



MAR02-1100



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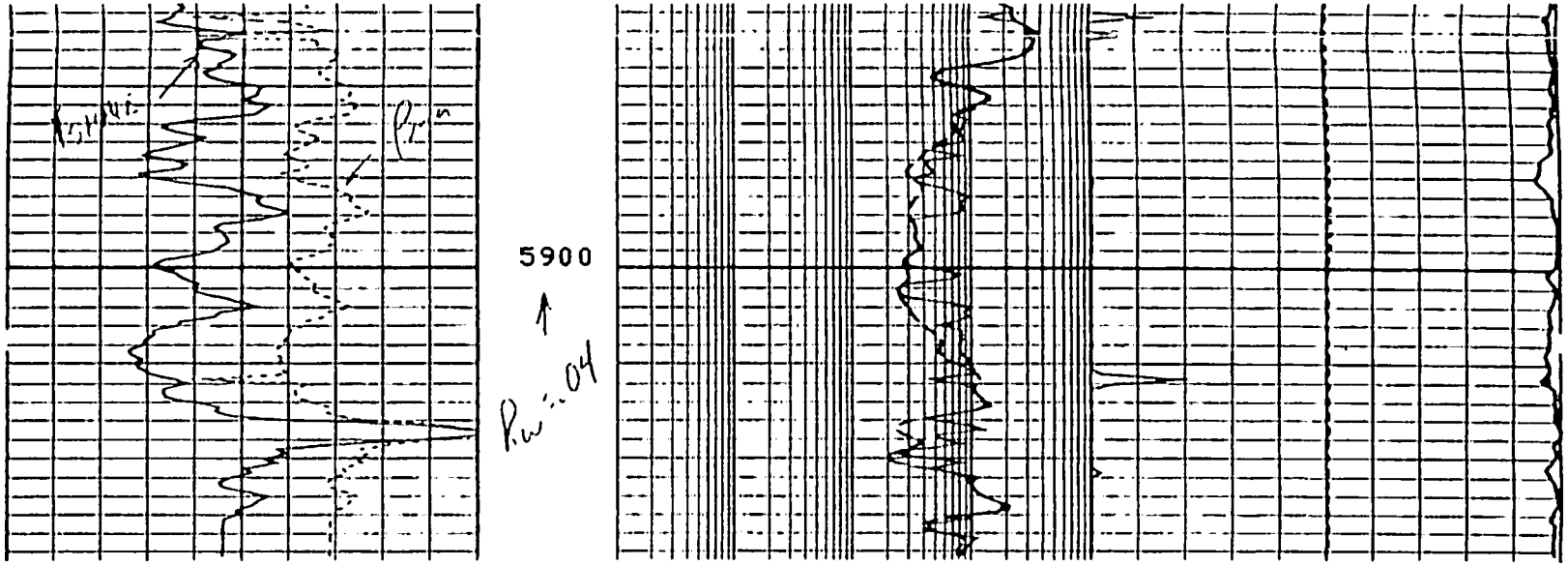


FILE

4

RHGF(G/C3) 2.500 3.000		R0 (OHMM) 0.1000 1000.	DCAL(IN) -10.00 10.00
			VWXO( ) 0.5000 0.0
MSI ( ) 0.0 1.000		RT (OHMM) 0.1000 1000.	VW ( ) 0.5000 0.0
			PHIE( ) 0.5000 0.0

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE

MAR02-1102

DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.04000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		0.0	BHS		OPEN			

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		1.000	BHS		OPEN			

DCAL(IN)
-10.00 10.00
VWXO( )
0.5000 0.0

MAR02-1103

CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		1.000	BHS		OPEN			

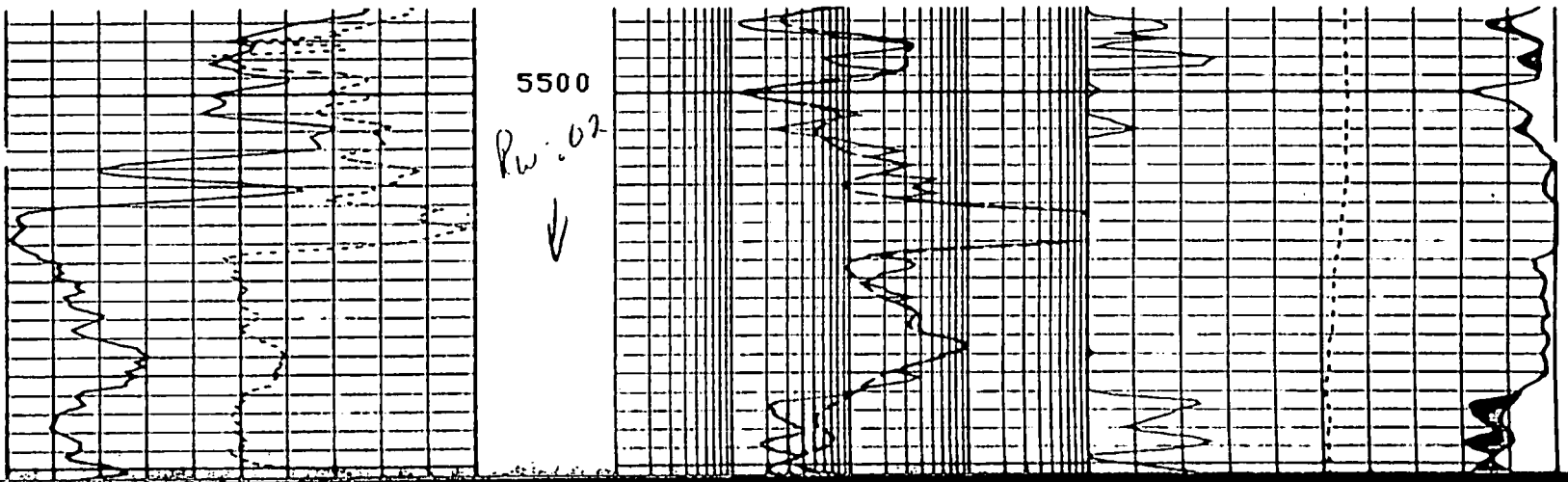
RHGF(G/C3)	R0 (OHMM)	DCAL(IN)
2.500 3.000	0.1000 1000.	-10.00 10.00
		VWXO( )
		0.5000 0.0
		VW ( )
		0.5000 0.0
MSI ( )	RT (OHMM)	PHIE( )
0.0 1.000	0.1000 1000.	0.5000 0.0

FILE

4

5500

Rw .02



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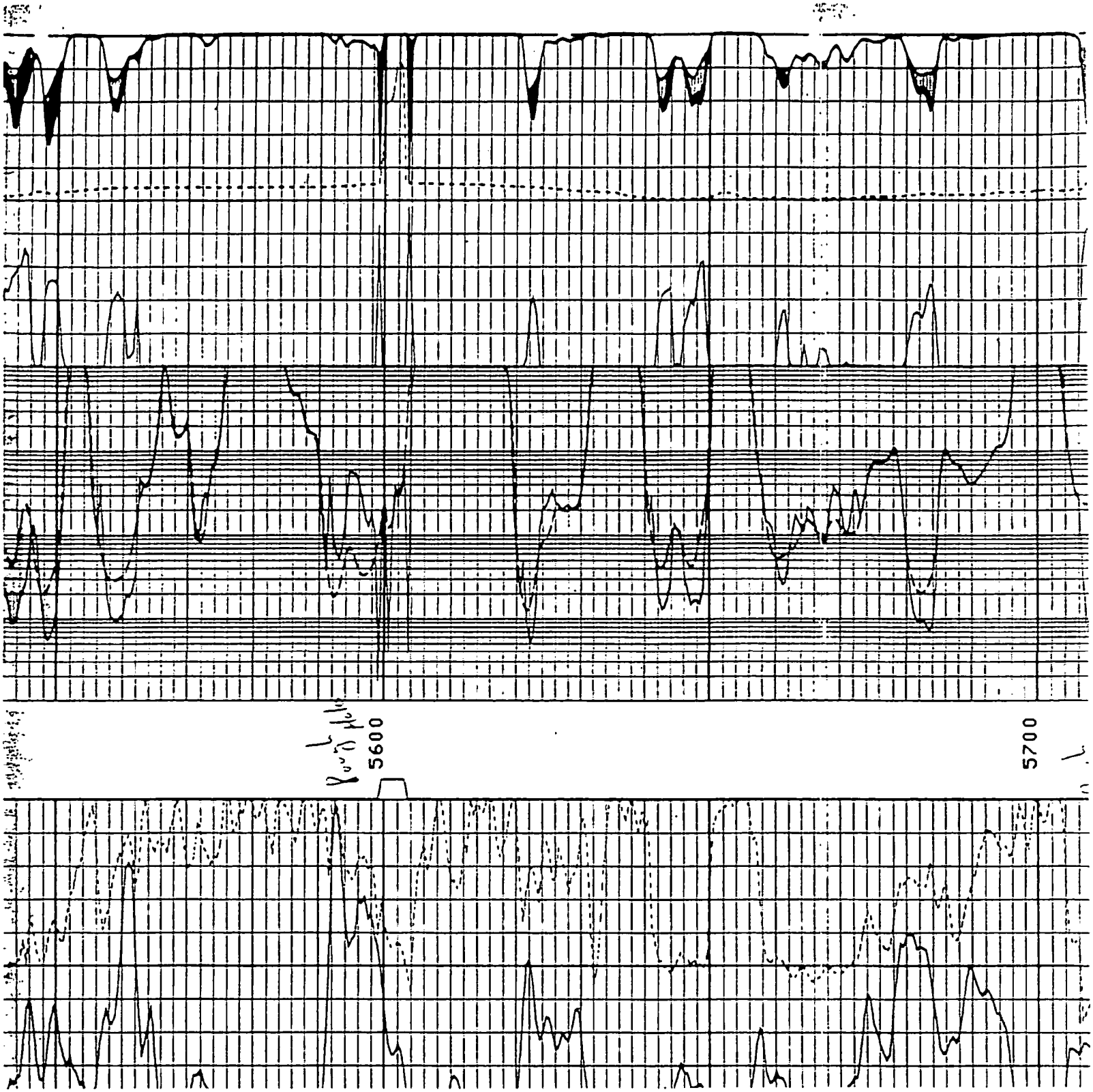

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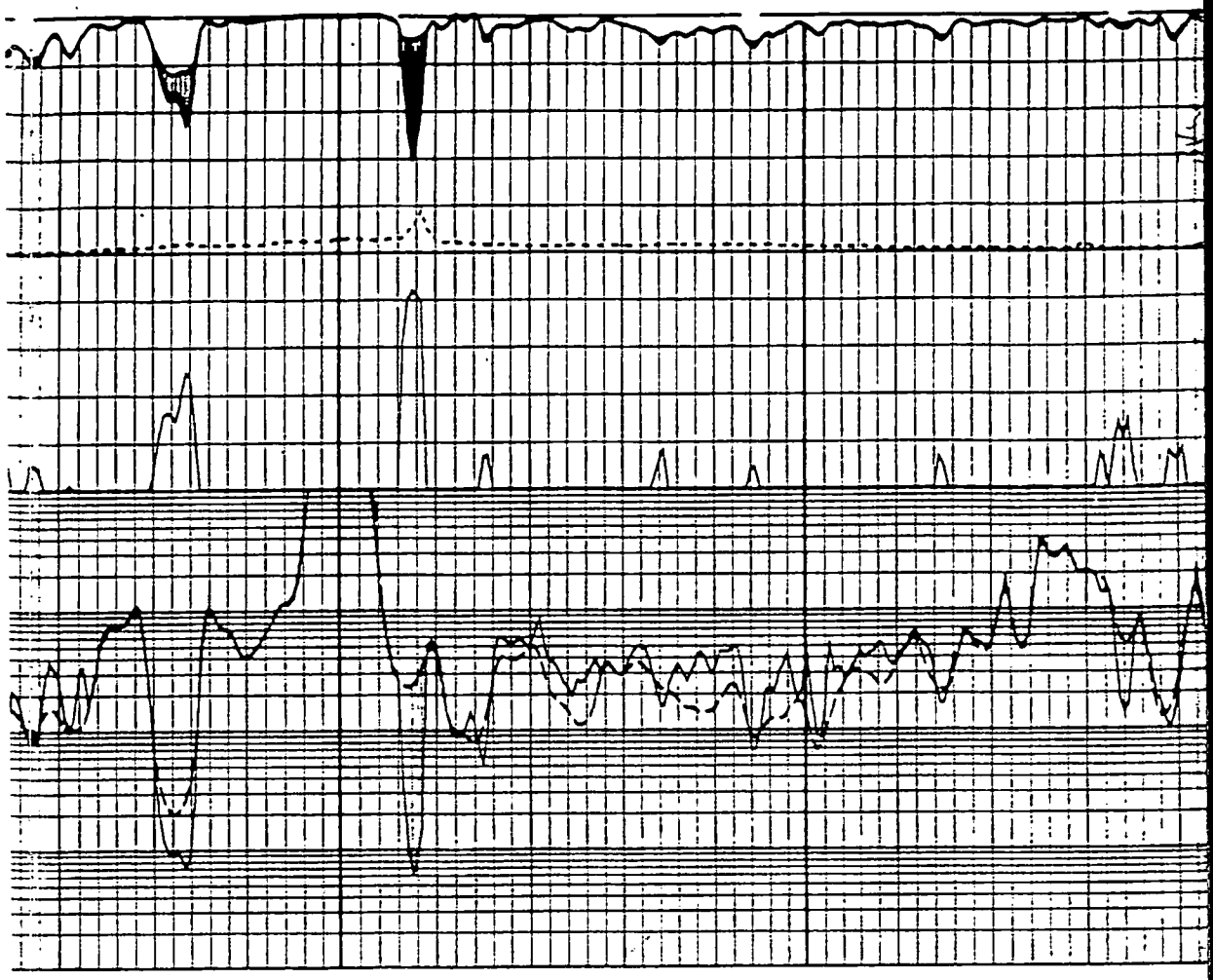

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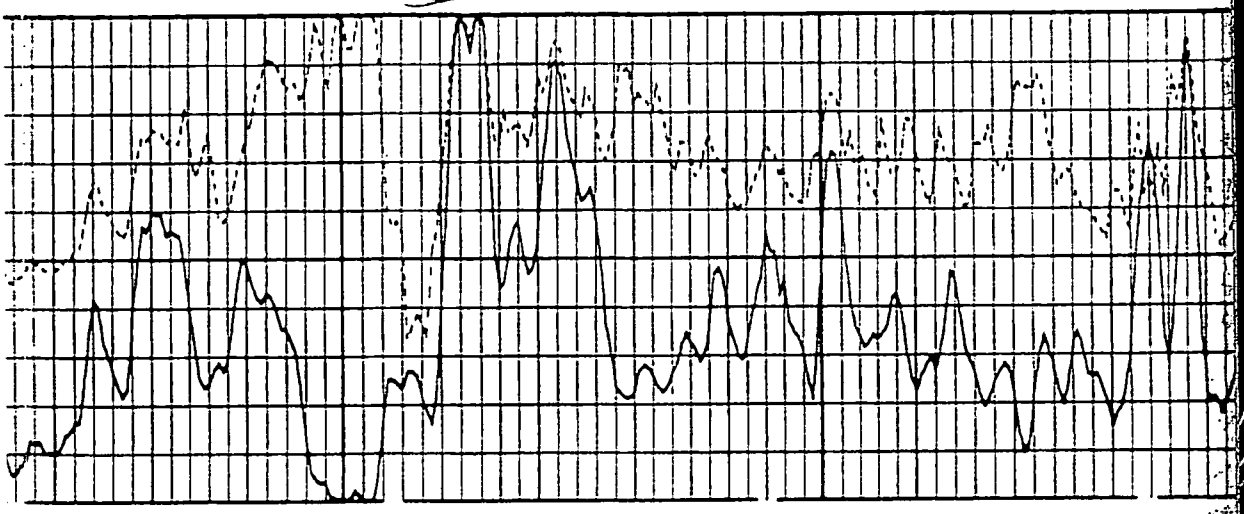
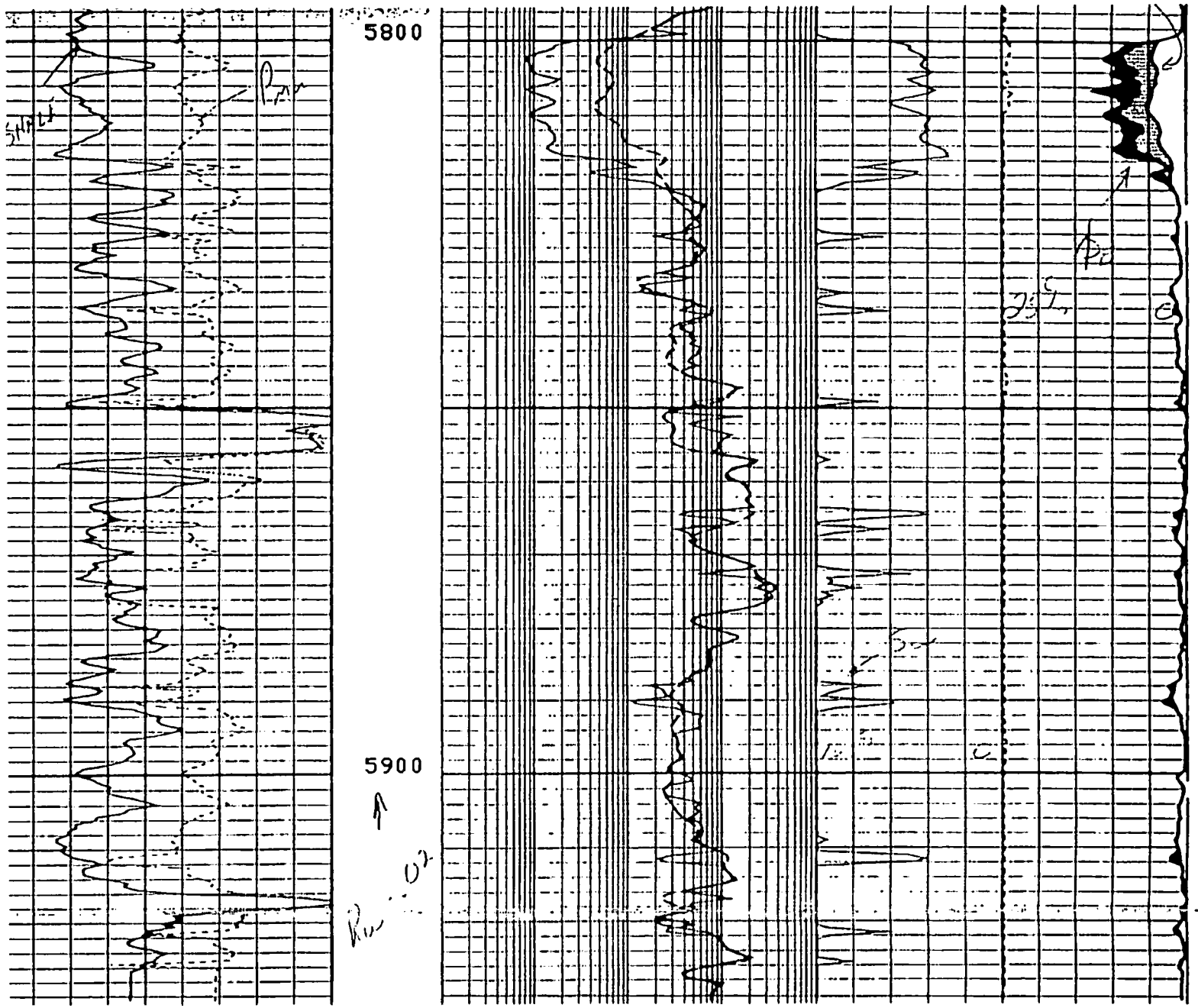
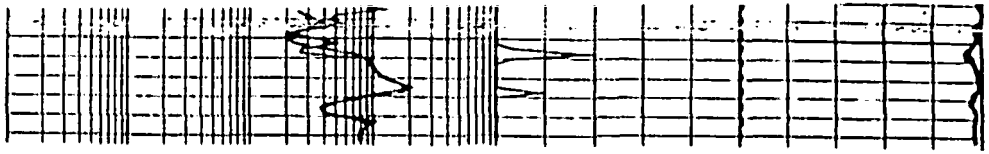


MAR02-1106



			DCAL(IN)
			-10.00 10.00
			VWXO( )
			0.5000 0.0

MAR02-1107



FILE

4

RHGF(G/C3) 2.500 3.000			DCAL(IN) -10.00 10.00
			VWXO( ) 0.5000 0.0
		R0 (OHMM) 0.1000 1000.	VW ( ) 0.5000 0.0
MSI ( ) 0.0 1.000		RT (OHMM) 0.1000 1000.	PHIE( ) 0.5000 0.0

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
[illegible]		[illegible]	[illegible]	G/C3	[illegible]	[illegible]	G/C3	[illegible]

MAR02-1108

FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		0.0	BHS		OPEN			

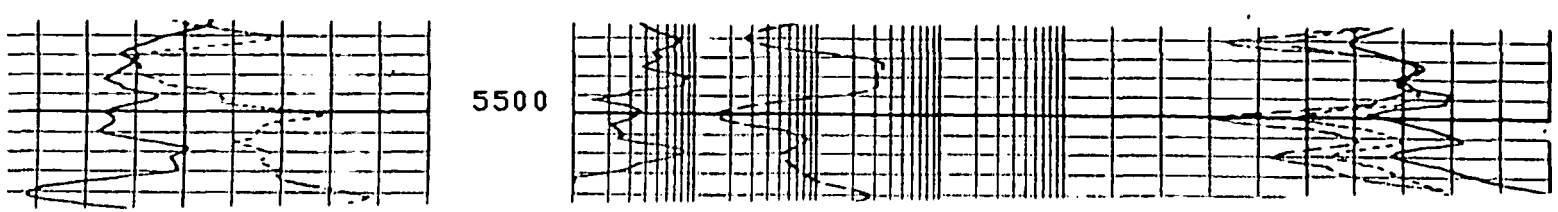
PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		1.000	BHS		OPEN			

RHGA(G/C3)		RFA (OHMM)	PHIA( )
500 3.000		0.0100 100.0	0.4000 -0.100
GR (GAPI)		RT (OHMM)	DPHI( )
0 100.0		0.1000 1000.	0.4000 -0.100
			NPHI( )
			0.4000 -0.100

FILE

4



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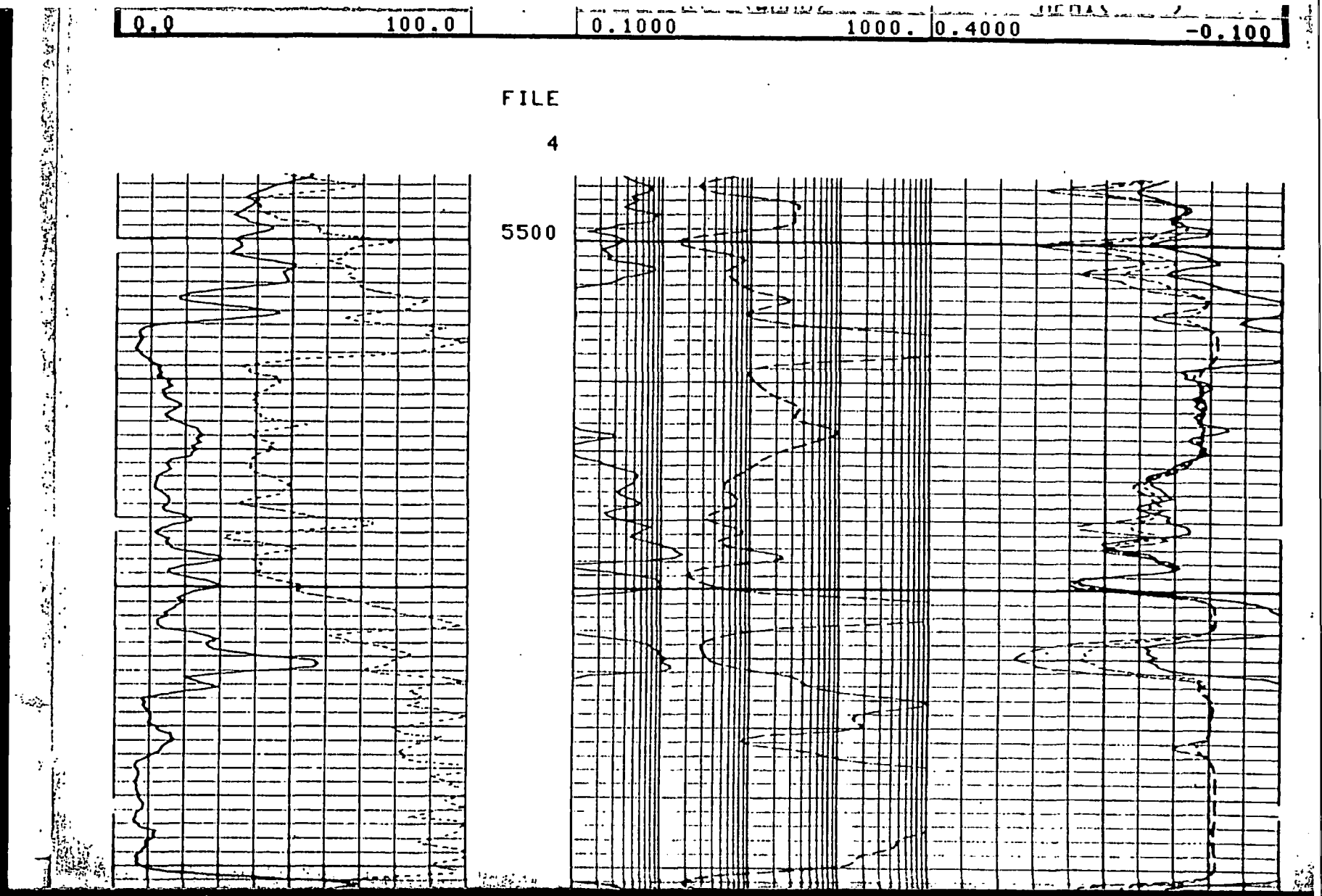
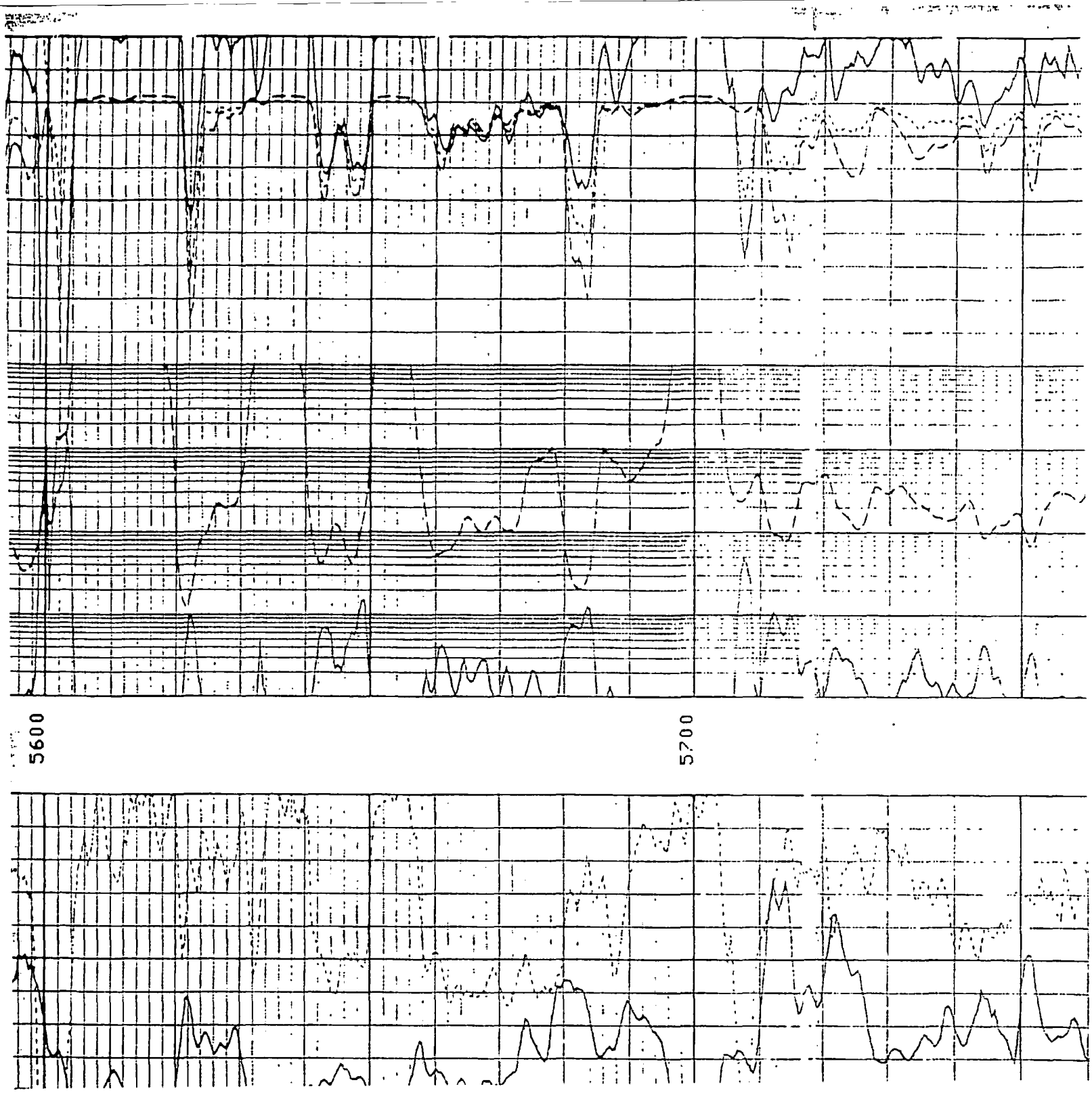


MAR02-1110



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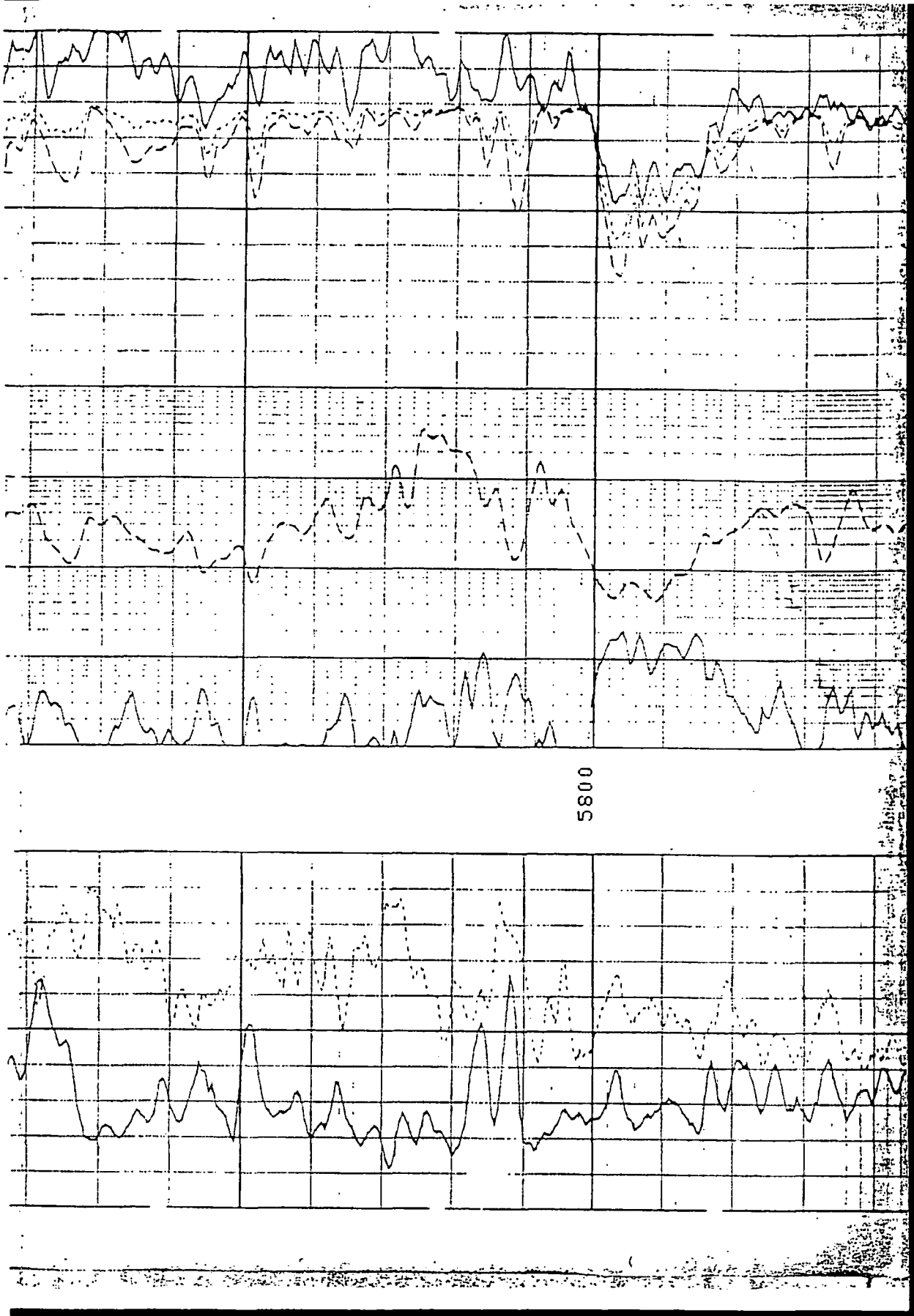

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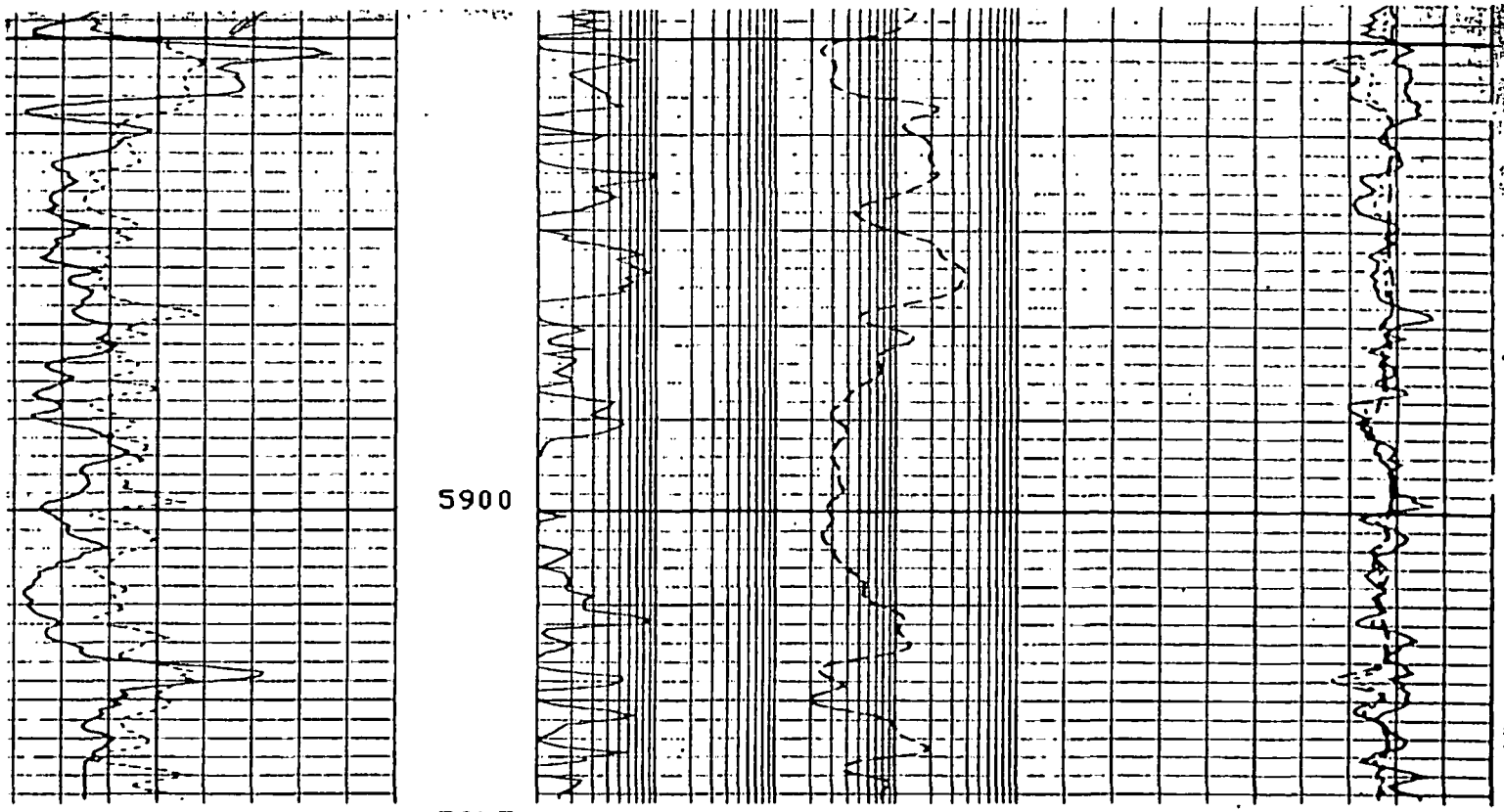


RHGA(G/C3)			PHIA( )
0 3.000		RFA (OHMM)	0.4000 -0.100
GR (GAPI)		0.0100 100.0	DPHI( )
100.0		RT (OHMM)	0.4000 -0.100
		0.1000 1000.	NPHI( )
			0.4000 -0.100

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
ILLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
SWB		DISA	MDET		NEIT	NLIM		0.01000
DCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
PDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
EPT		NONE	FESX		DISA	TPSM		7.200

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
DLLM		0.3500	GULM	GAPI	30.00	BS	INCH	7.875
LSWB		DISA	MDET		NEIT	NLIM		0.01000
GDCL	G/C3	0.0	GDSH	G/C3	2.900	FRTC		MSFL
TPDM		8.700	TPFM		7.200	DRUL	G/C3	0.3000
FEPT		NONE	FESX		DISA	TPSM		7.200
RWB	OHMM	0.1000	FCAL		PRES	POUT		LIME
NPCL		0.0	NPSH		0.5000	RWF	OHMM	0.02000
GRSH	GAPI	70.00	SPCL	MV	-200.0	SPSH	MV	0.0
NGSI		NEIT	PMAX		0.4000	GRCL	GAPI	5.000
CLIM	IN	16.00	WMUD	LB/G	11.30	SINP		GR
BHT	DEGF	139.5	SONI		PRES	RXOF		PRES
MATR		LIME	HC		CALI	RTLF		DISA
CDTS		100.0	MDEN	G/C3	2.710	FD	G/C3	1.100
FPHI		PHIX	DTF	US/F	189.0	DTM	US/F	47.60
DO		0.0	BHS		OPEN			

MAR02-1114

PRAIRIE

Gamma Ray Log

FILE NO.

COMPANY TEXAS OIL AND GAS CORPORATION

PRODUCTION DEPT.

WELL BUCKLES SALTWATER DISPOSAL #1

FIELD EAST POPLAR

County ROOSEVELT State MONTANA

LOCATION: 1803FNL 1853FWL SEC. 22 TWP. 28N RGE. 51E

OTHER SERVICES: CEMENT BOND

PERMANENT DATUM G.L. ELEV. 2085

LOG MEASURED FROM TWELVE FT. ABOVE PERM. DATUM

DRILLING MEASURED FROM K.B.

ELEV.: K.B. 2097 G.L. 2085

		Shot Density	No. of Shots	Perforating From	Interval To
DATE	JUNE 1, 1981				
RUN NO.	ONE				
TYPE LOG	GAMMA RAY	4spf	21	785	790
DEPTH - DRILLER	850	4spf	13	794	797
DEPTH - LOGGER	858 *(SEE REMARKS)	4spf	17	807	811
LOGGED INTER.	857	4spf	9	822	824
TOP LOGGED INTER.	0	4spf	29	839	846
FLUID IN HOLE	WATER				
LEVEL	FULL				
TRUCK NO.	THREE				
OPER. RIG TIME	1 HOUR				
RECORDED BY	ONEIL				
WITNESSED BY	DYK				

Gun Type G.O. TORNADO JET and Size 2 1/8" EXPENDABLE

CASING RECORD

Size In.	Weight	From	To
7	17	SURF	920
10 3/4		SURF	30

COLLAR LOCATION

OTHER SERVICES

Casing	Tubing	Service	Type	Size	Depth

Remarks:

MAR-834

MAR02-1115

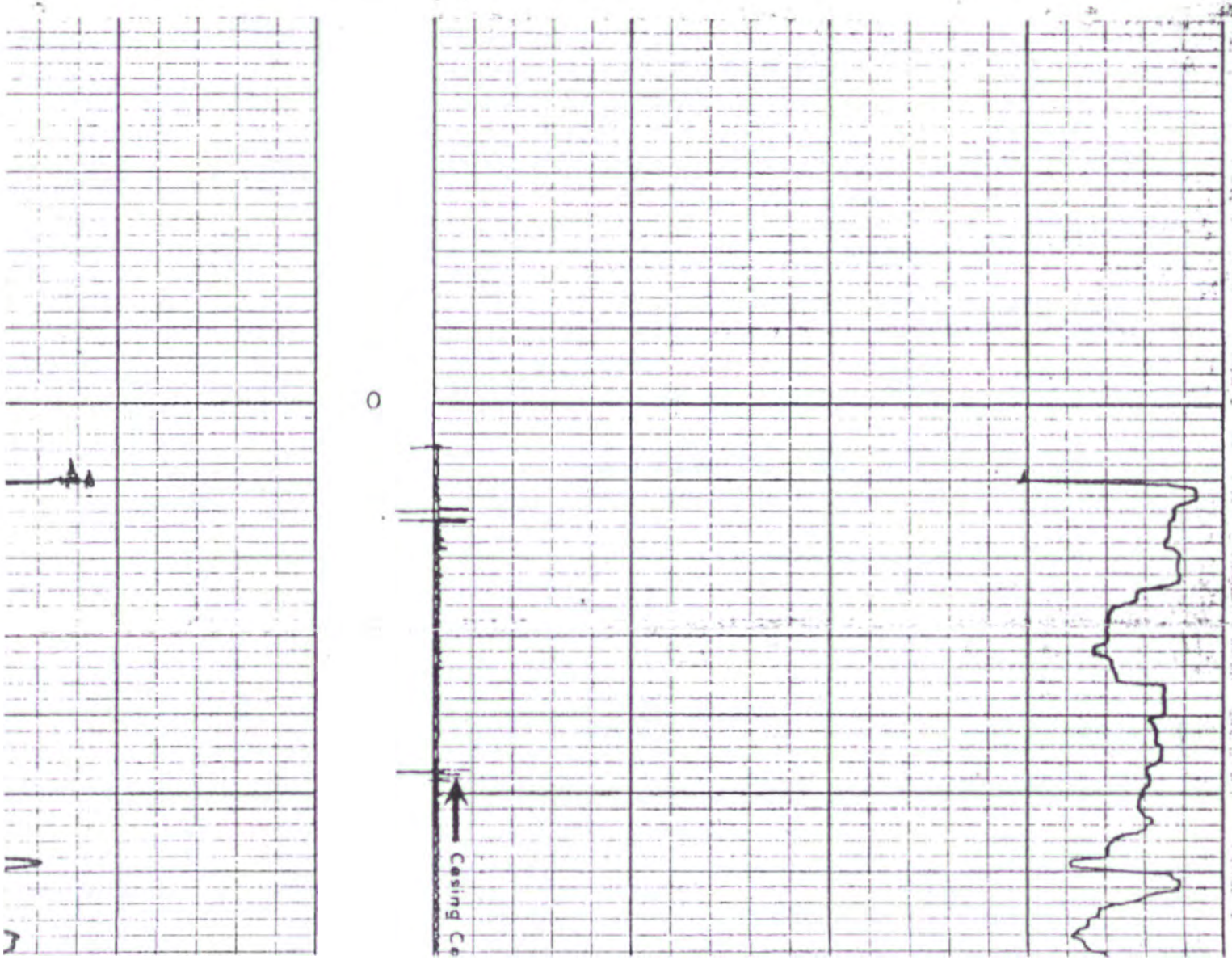
ous Completion Information

Control Log Yes No

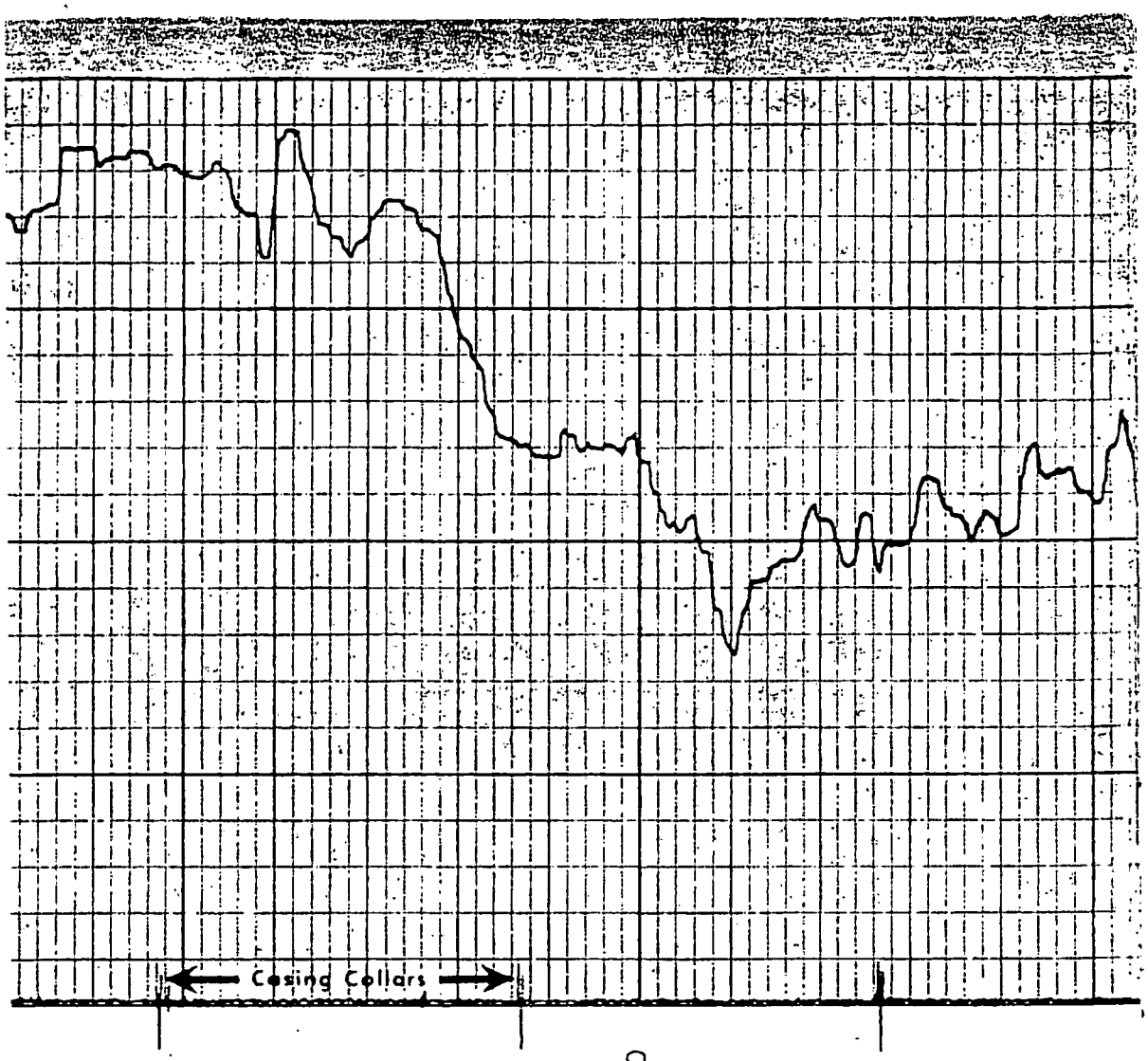
ated No Yes From To

Gamma Ray

Gamma Ray



MAR02-1116



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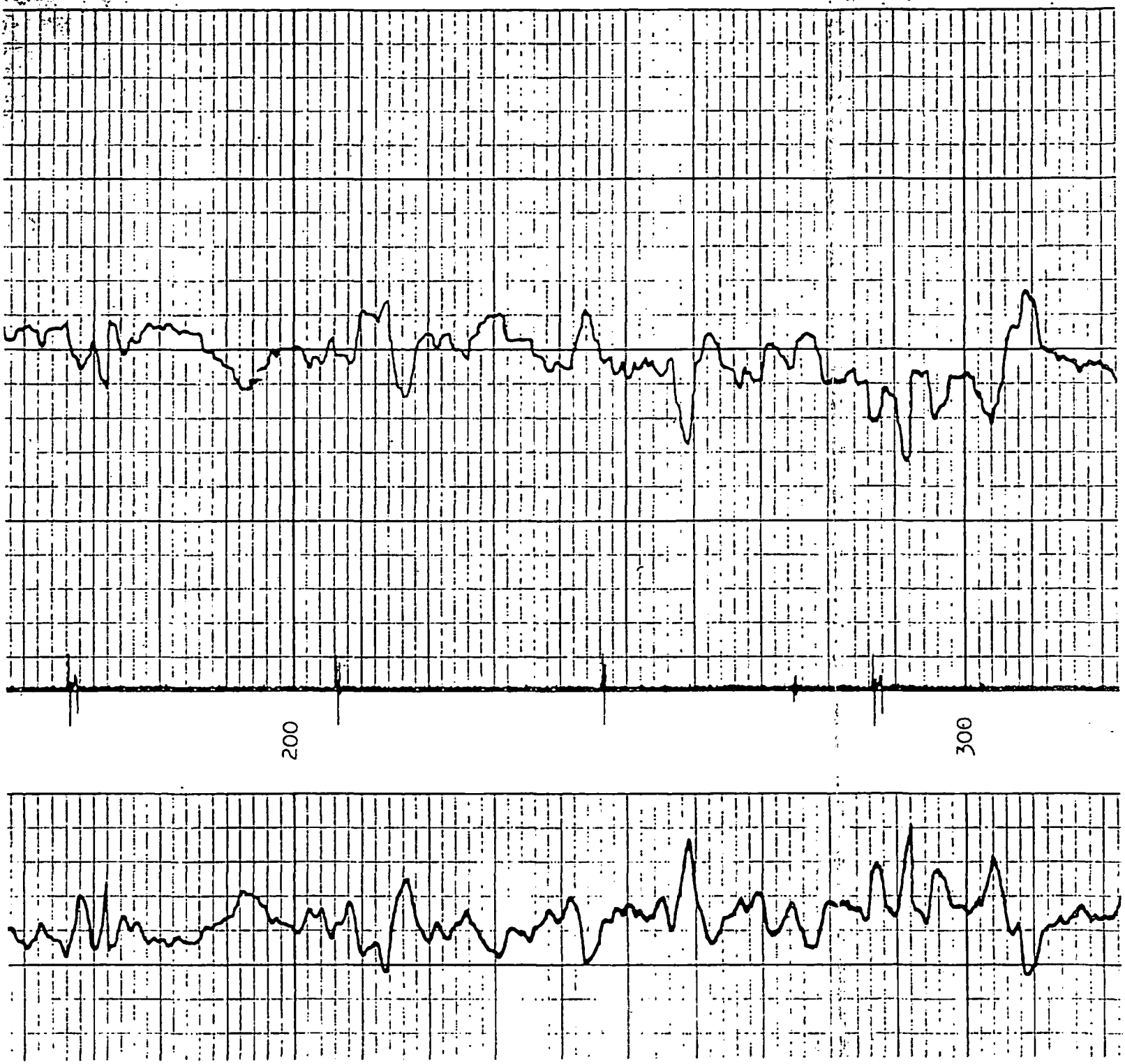
MAR02-1117



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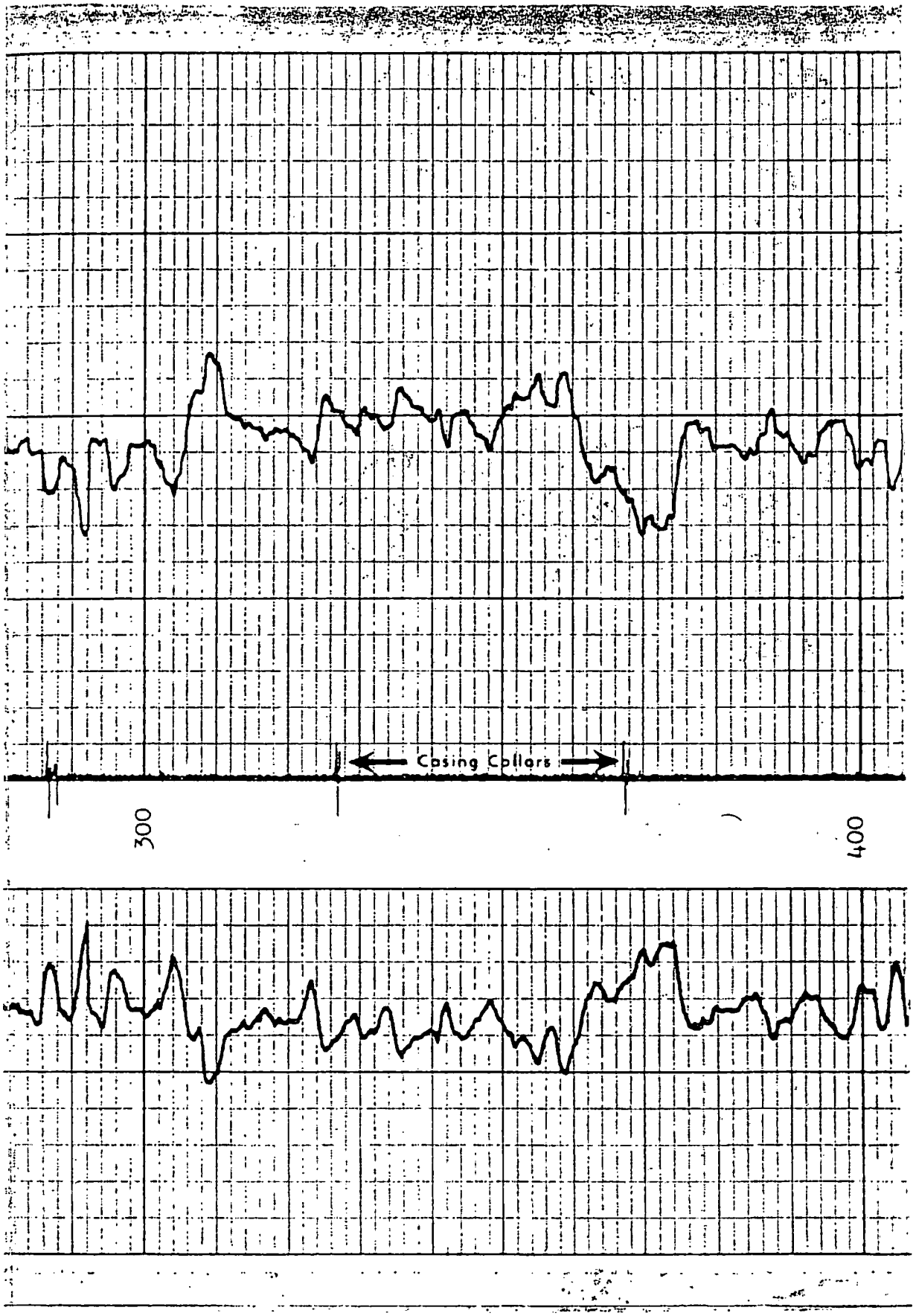
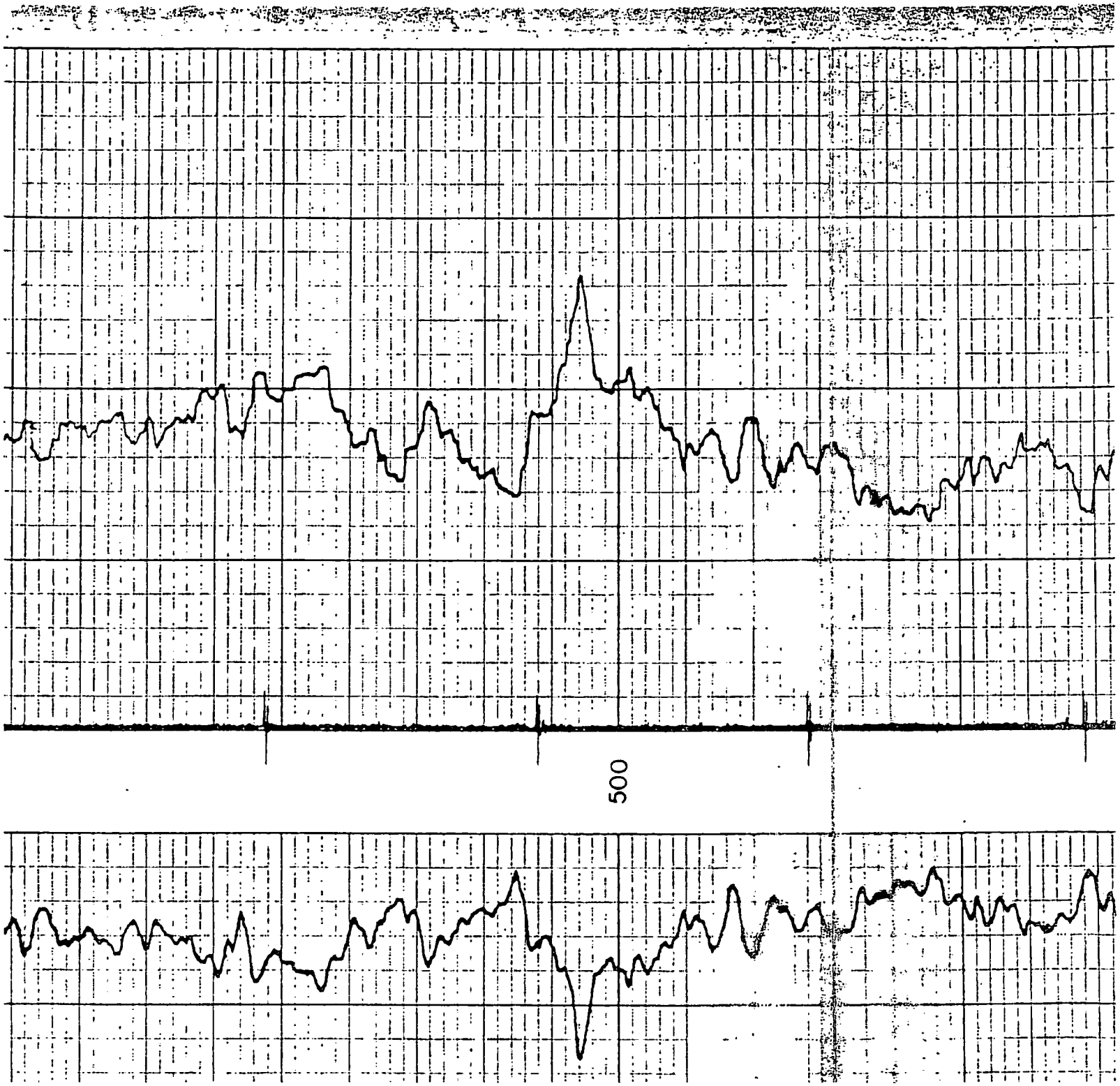


MAR02-1119



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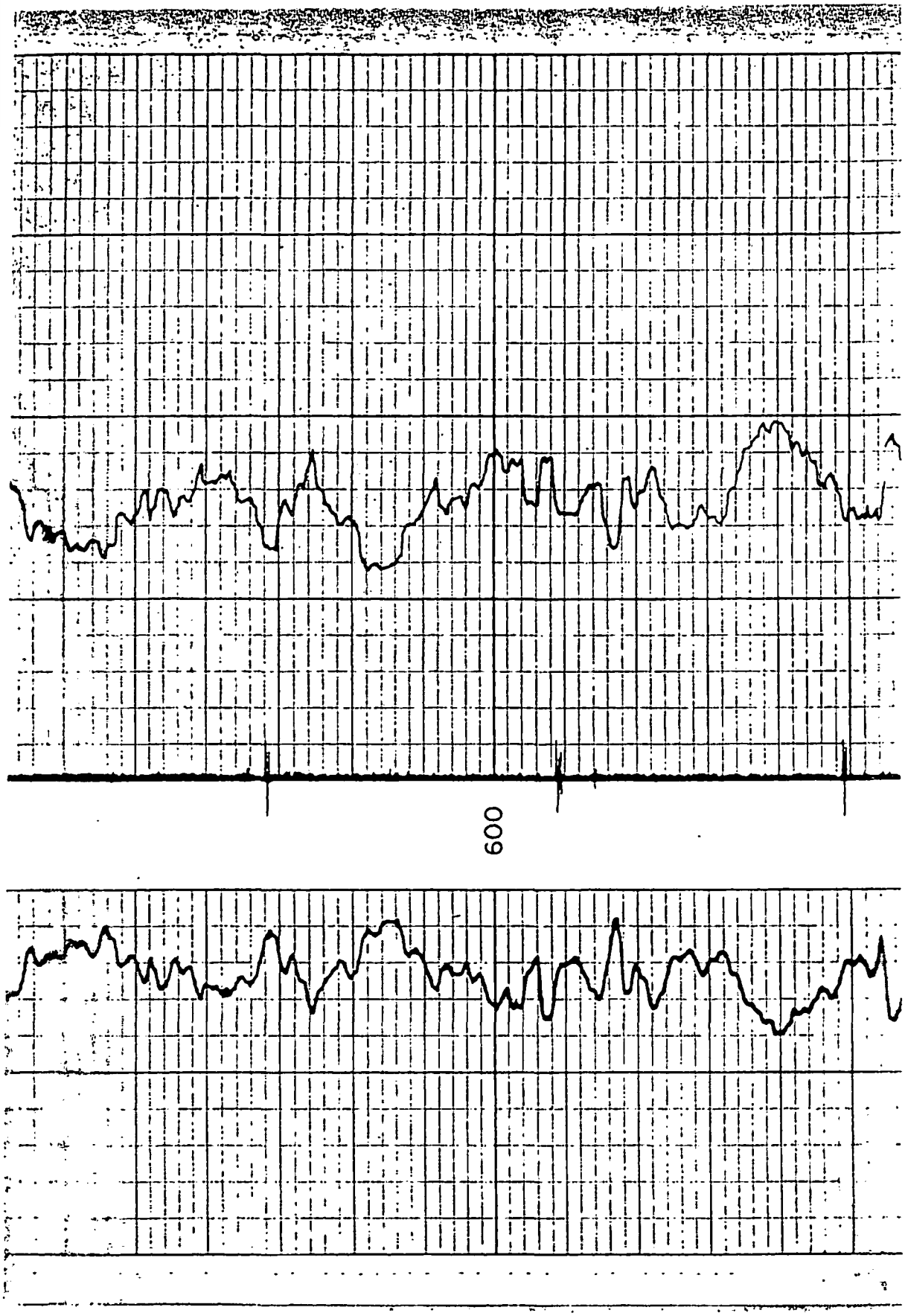

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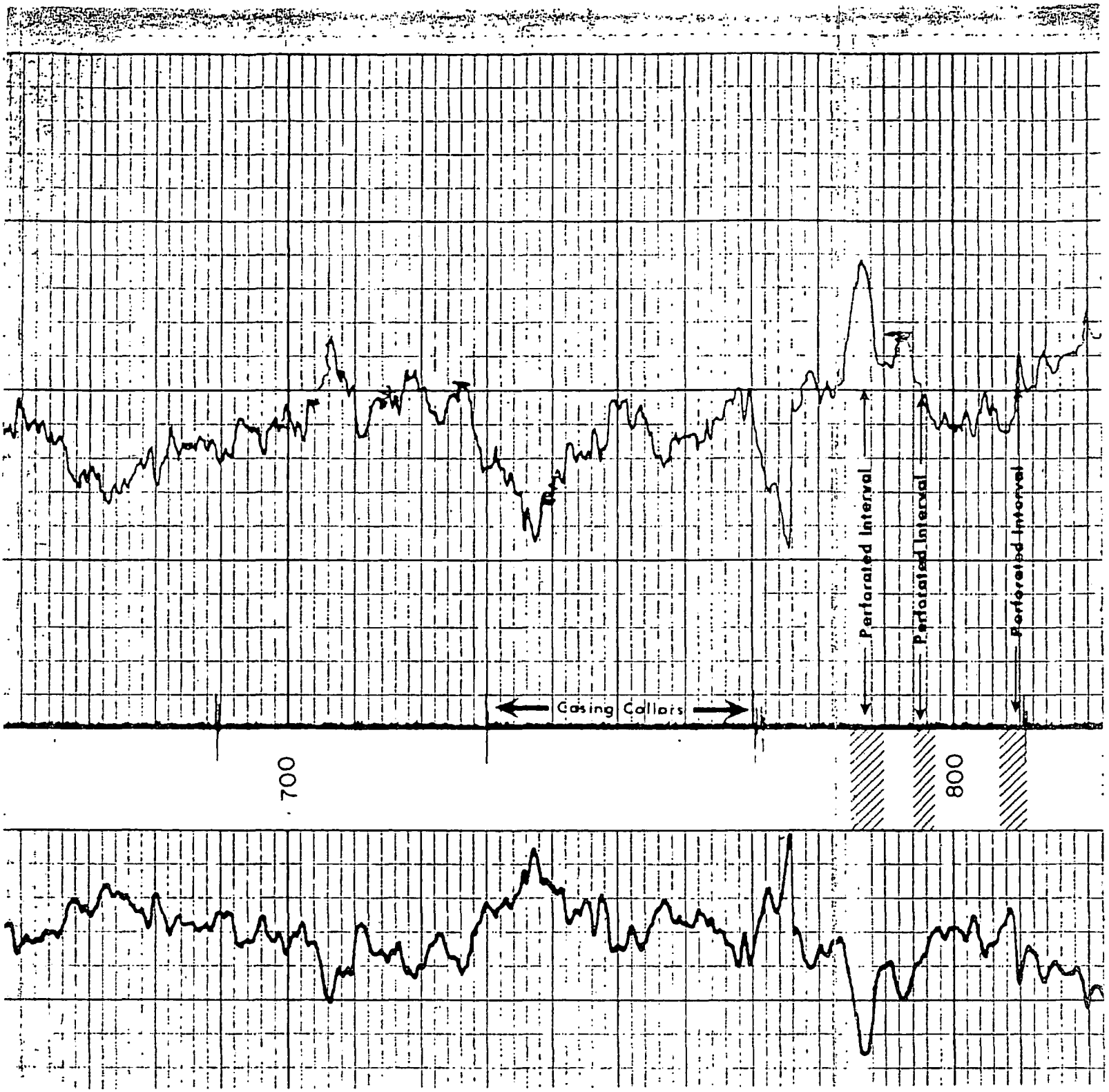
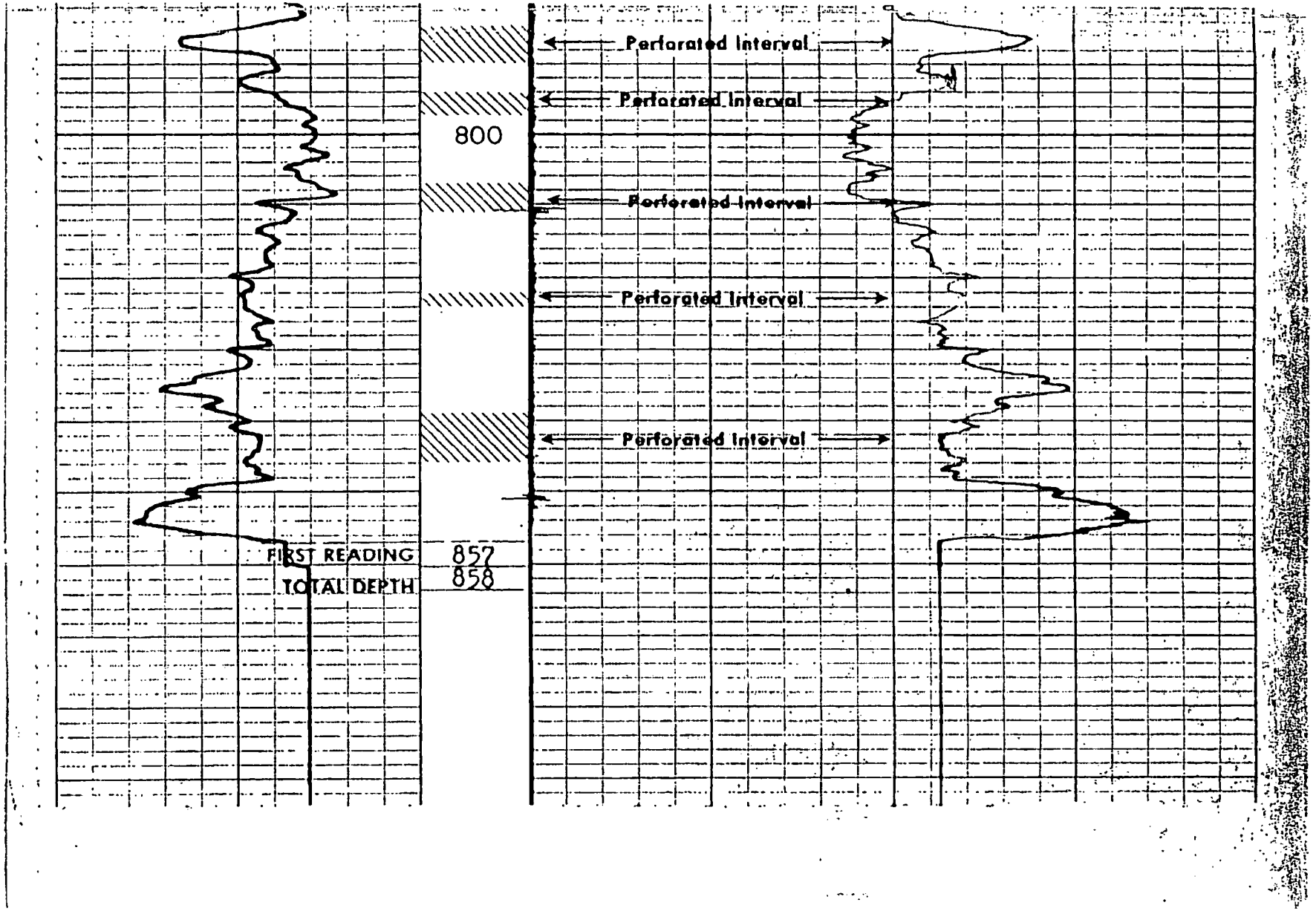

Perforated Interval
Perforated Interval
Perforated Interval
Casing Collars
700
800

MAR02-1122


Perforated Interval
Perforated Interval
800
Perforated Interval
Perforated Interval
Perforated Interval
FIRST READING 857
TOTAL DEPTH 858

MAR02-1123

PRAIRIE

Cement Bond Log

FILE NO.

COMPANY TEXAS OIL AND GAS CORPORATION

WELL BUCKLES SALTWATER DISPOSAL #1

FIELD EAST POPLAR

County ROOSEVELT State MONTANA

LOCATION: 1803FNL 1853FWL
SEC 22 TWP. 28N RGE. 51E W.

OTHER SERVICES:
GAMMA RAY
TEMP. SURVEY

PERMANENT DATUM G.L. ELEV. 2085
LOG MEASURED FROM EIGHT FT. ABOVE PERM. DATUM
DRILLING MEASURED FROM K.B.

ELEV.: K.B. 2093
G. 2085

		Shot Density	No. of Shots	Perforating From	Interval To
DATE	MAY 29,1981				
RUN NO.	TWO				
TYPE LOG	CEMENT BOND				
DEPTH - DRILLER	961				
DEPTH - LOGGER	910				
LOGGED INTER.	907				
TOP LOGGED INTER.	0				
FLUID IN HOLE	WATER				
LEVEL	FULL				
TRUCK NO.	THREE				
OPER. RIG TIME	1 HOUR				
RECORDED BY	ONEIL				
WITNESSED BY	CROFT				

Gun Type and Size

CASING RECORD

Size in.	Weight	From	To
7	17	SURF	920

COLLAR LOCATION

Casing	Tubing

OTHER SERVICES

Service	Type	Size	Depth

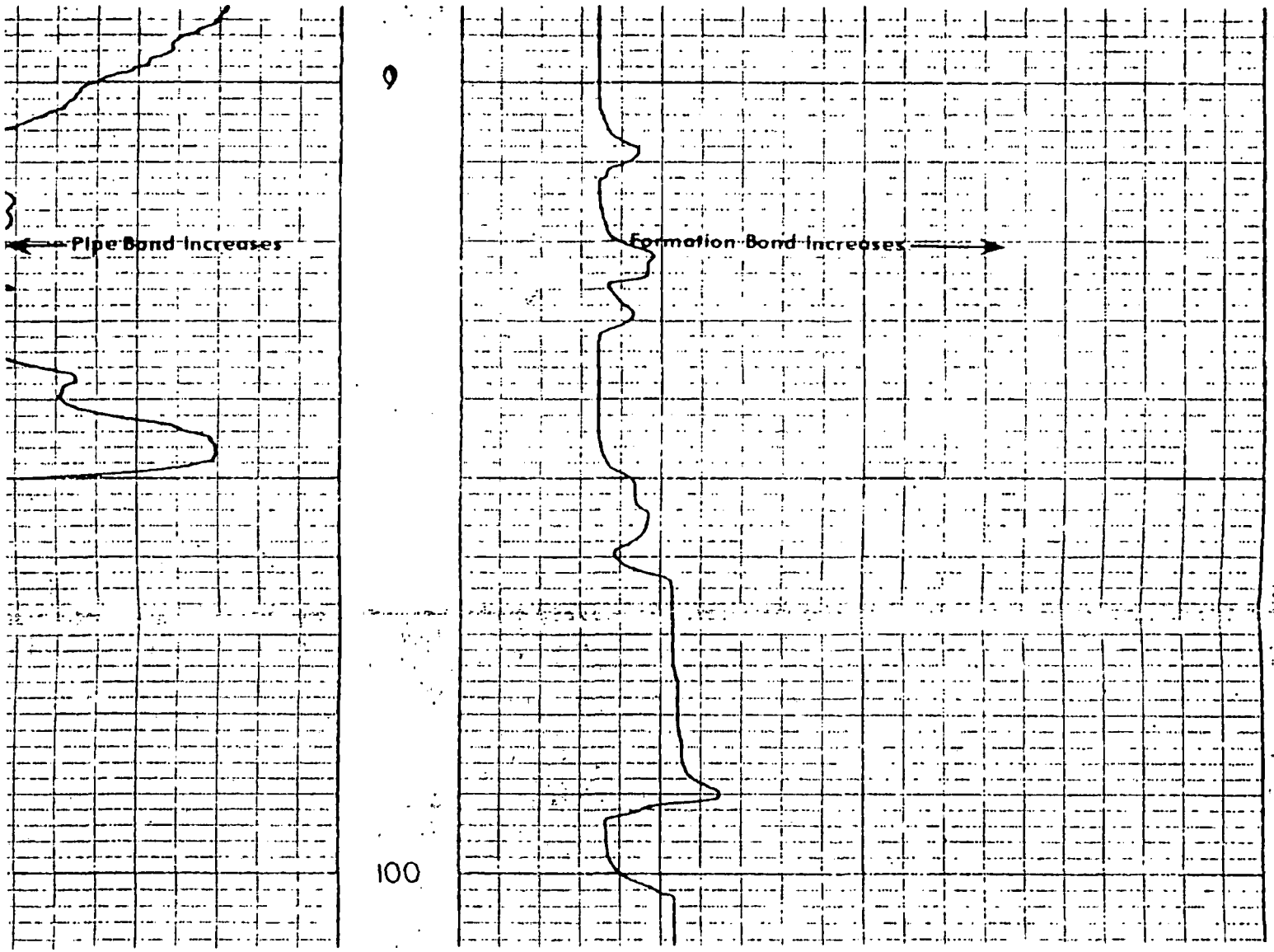
MAR02-1124

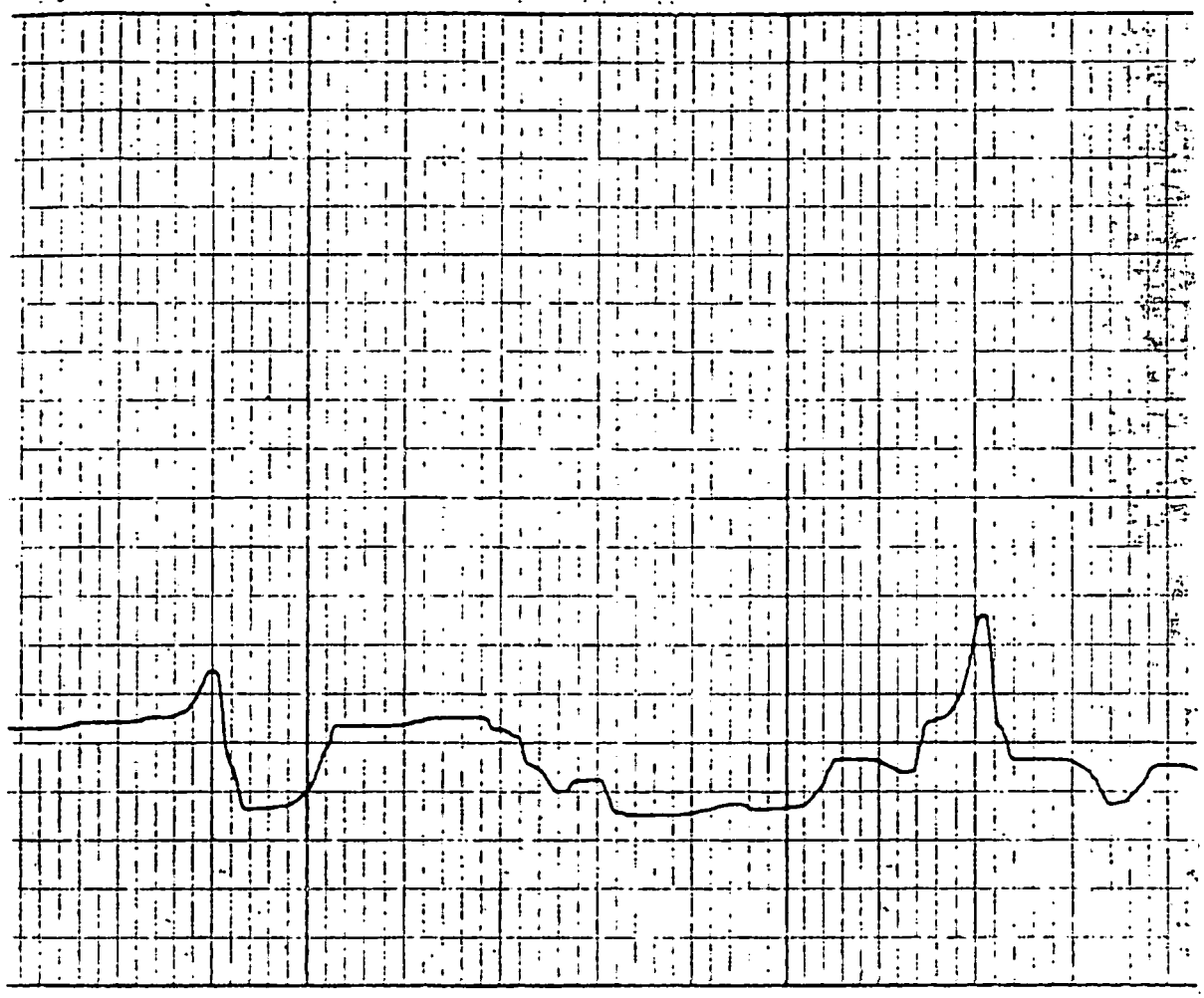
evious Completion Information

pth Control Log Yes No

forated No Yes From To

Cement Bond





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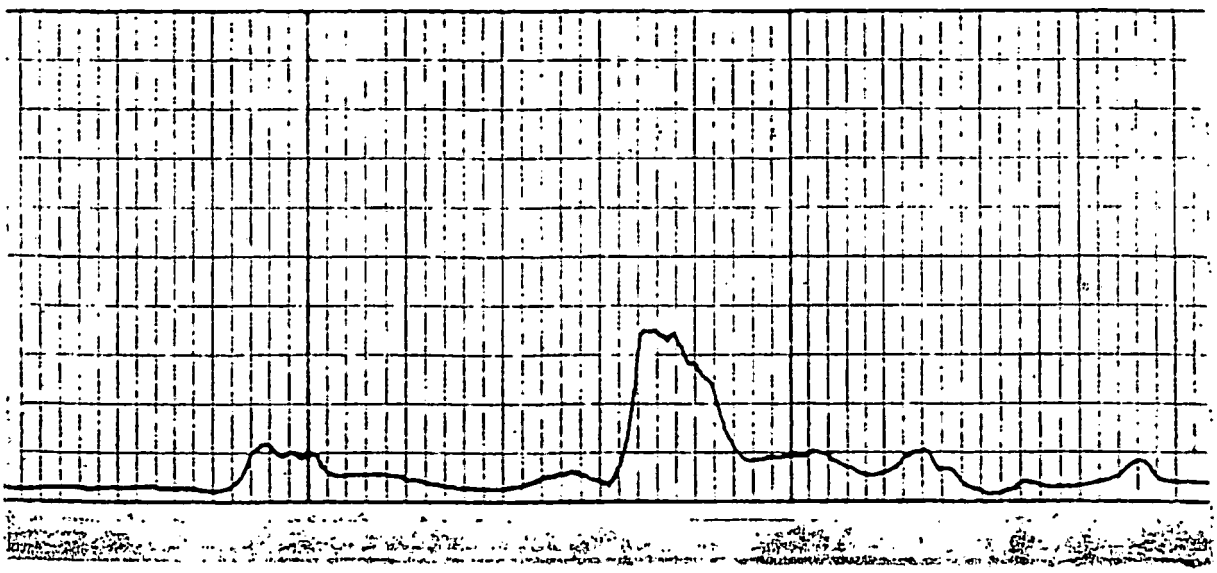

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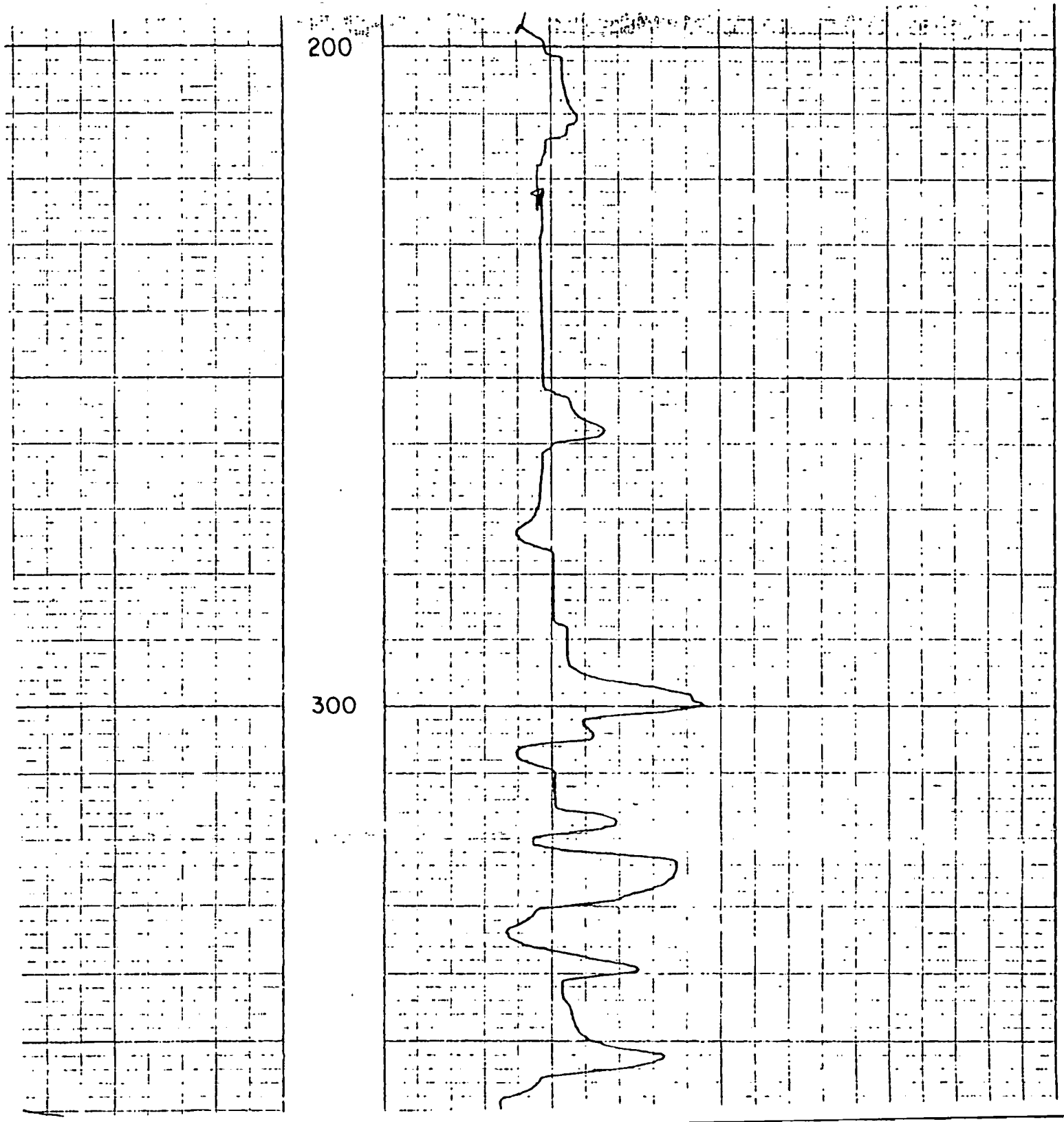

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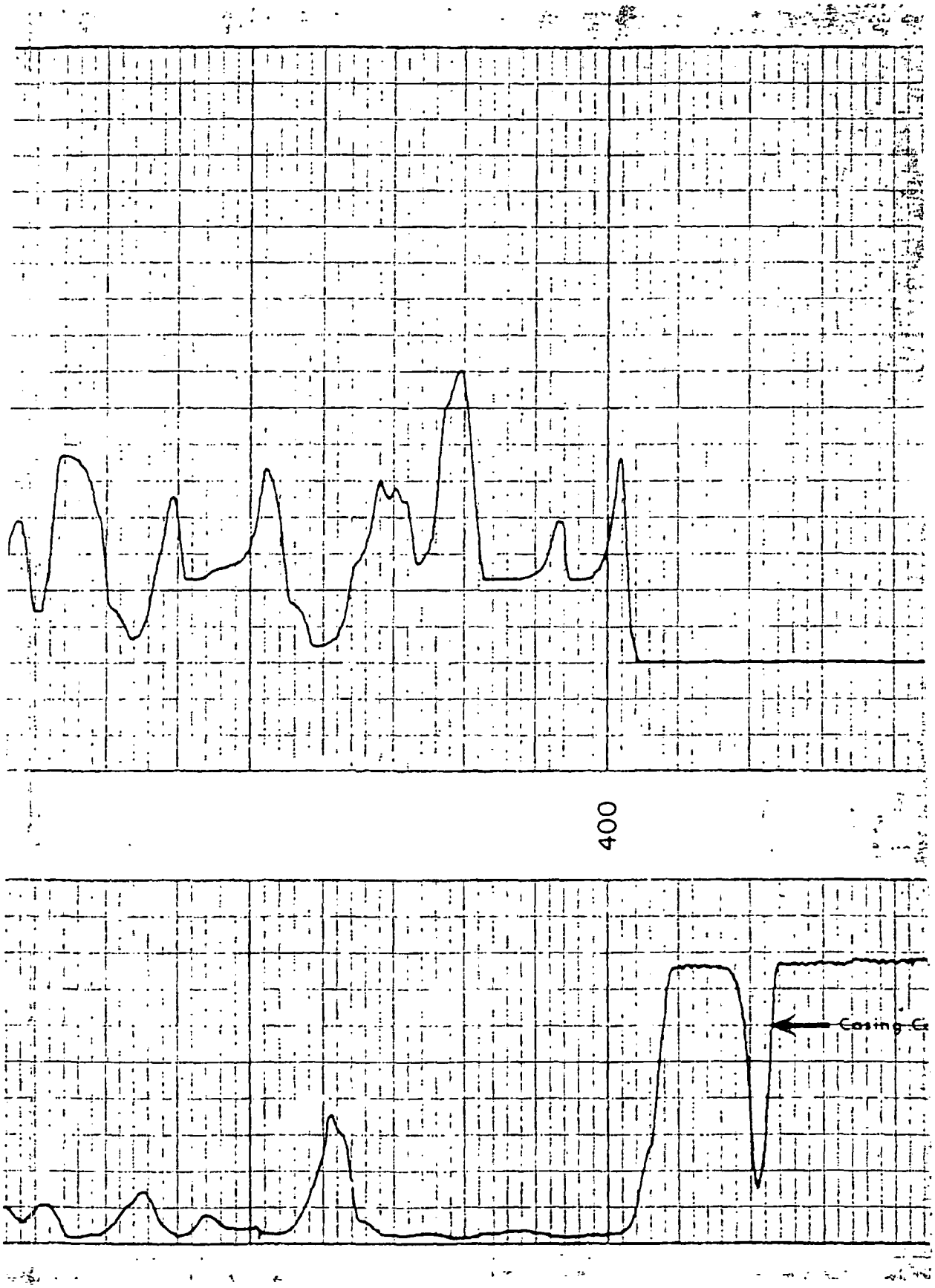
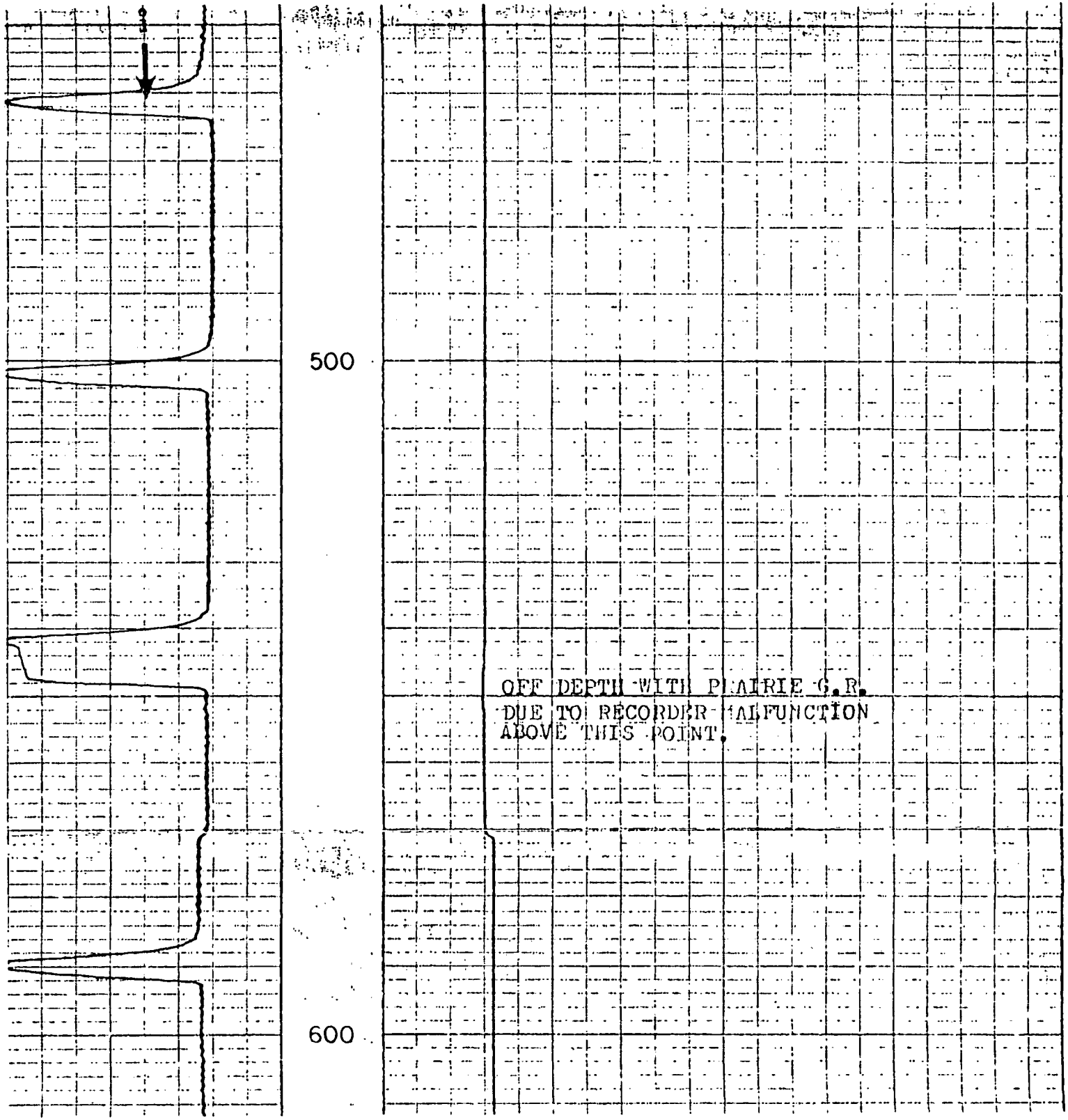
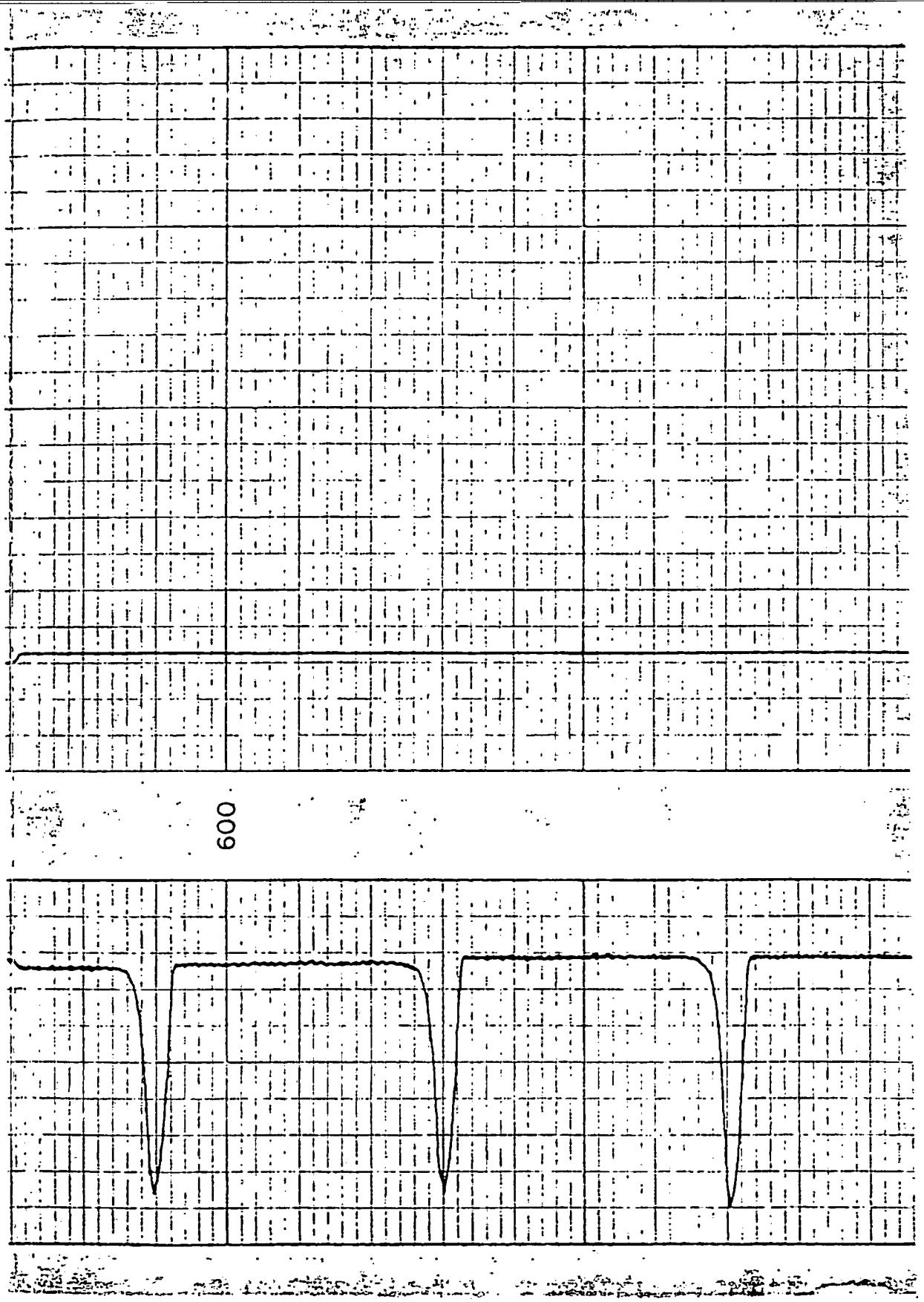


MAR02-1128


500
600
OFF DEPTH WITH PRAIRIE G.R.
DUE TO RECORDER MALFUNCTION
ABOVE THIS POINT.

MAR02-1129



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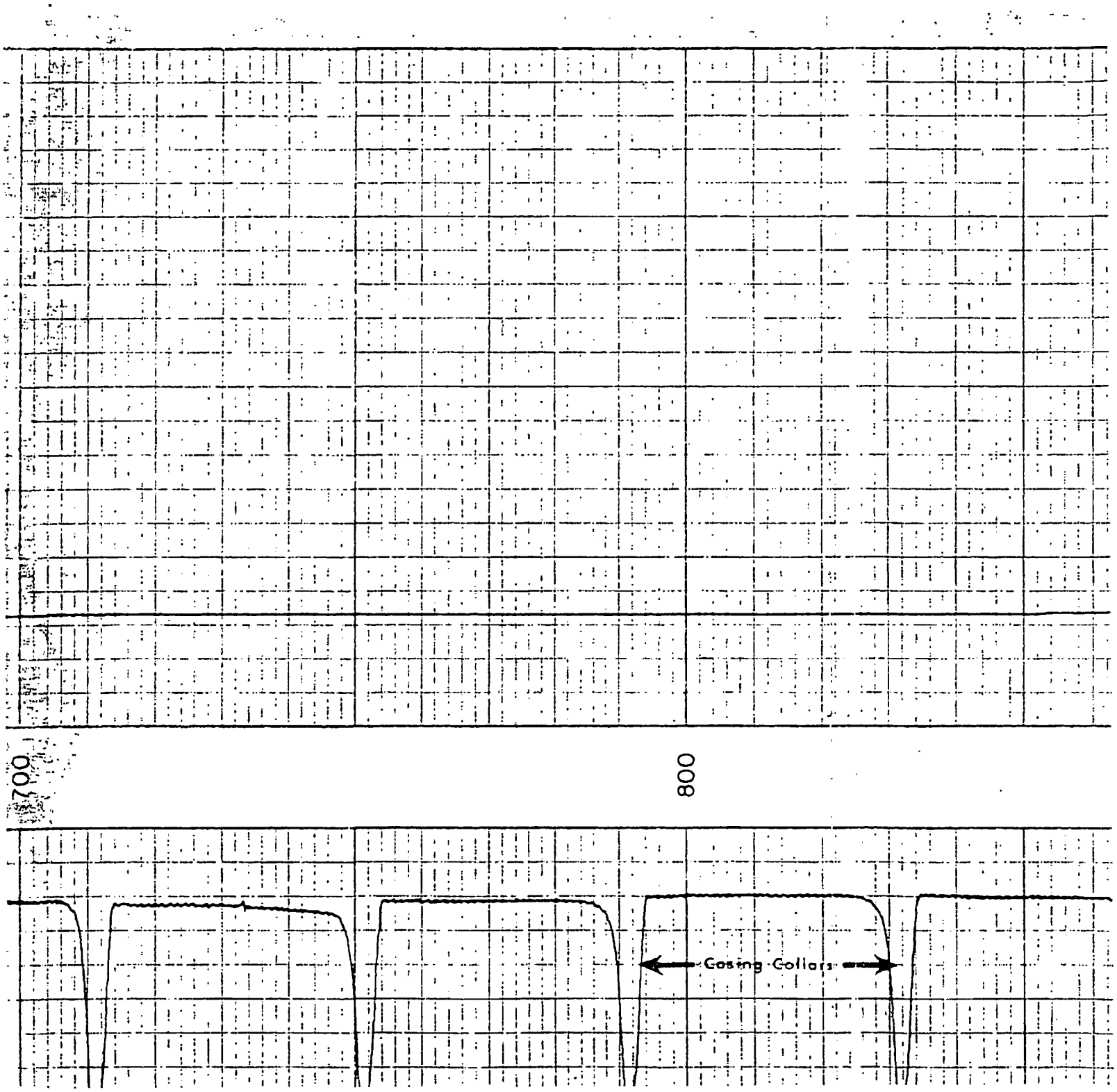

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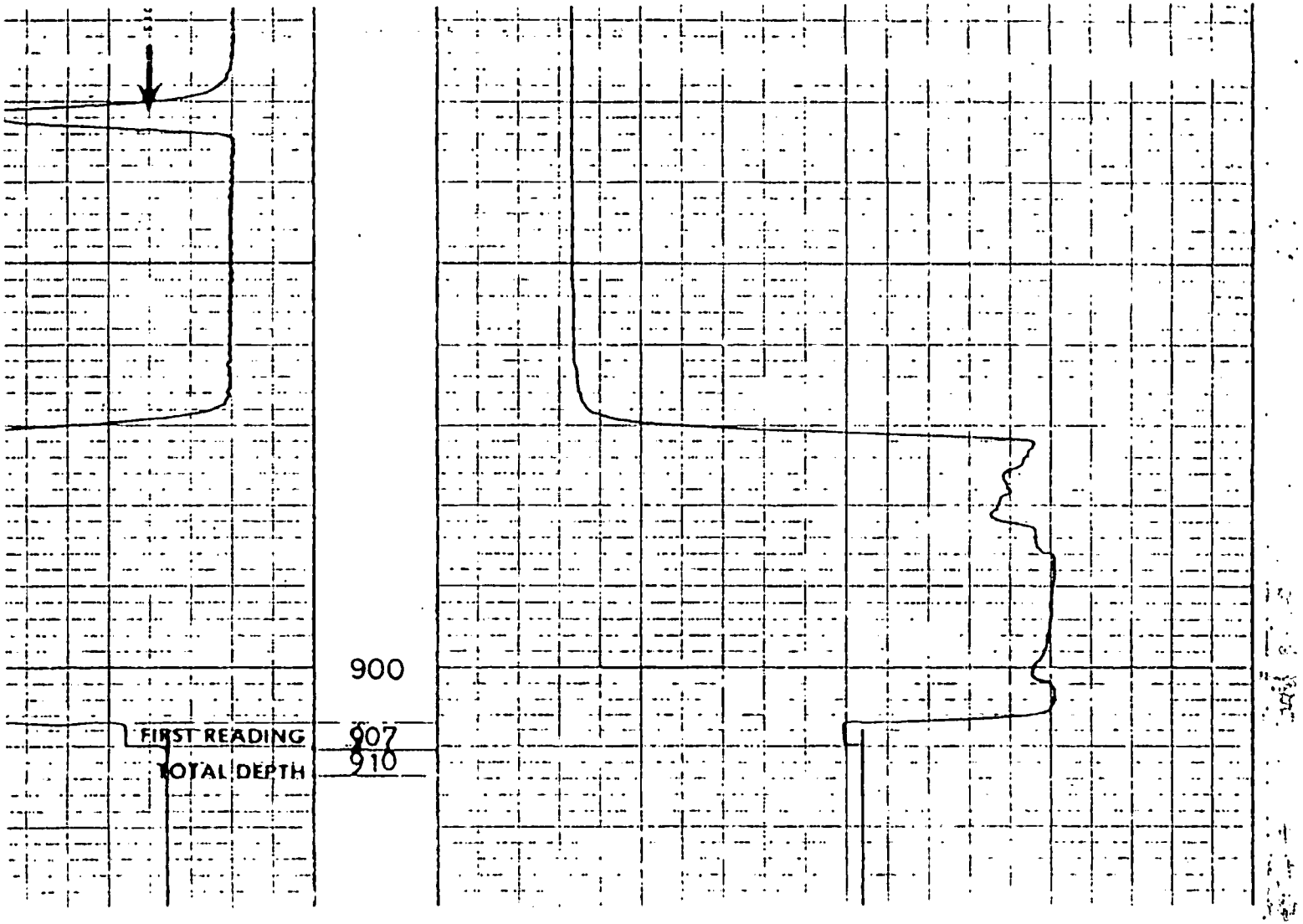


MAR02-1132

Schlumberger

CASING COLLAR LOG AND PERFORATING RECORD

COUNTY ROOSEVELT
FIELD or LOCATION EAST POPLAR SEC. 22-28N-51E
WELL BUCKLES NO.A-1
COMPANY TEXAS OIL & GAS

COMPANY TEXAS OIL & GAS CORPORATION

WELL BUCKLES NO.A-1

FIELD EAST POPLAR

COUNTY ROOSEVELT STATE MONTANA

Location: 1980' FNL 1980' FWL

Sec. 22 Twp. 28N Rge. 51E

Other Services:
CIS
GR-PDC

Permanent Datum: GL ; Elev.: 2085
Log Measured From KB , 12 Ft. Above Perm. Datum
Drilling Measured From KB

Elev.: K.B. 2097
D.F. ---
G.L. 2085

Date 5-1-81 | Run No. ONE

PLUG BACK TOTAL DEPTH | DRILLER- 5867 | LOGGER- 5868

DEPTHS BELOW RELATE TO: OPEN HOLE LOG MEASUREMENTS: ☒
: RADIOACTIVITY LOG MEASUREMENTS: ☒
: SCHLUMBERGER LINE MEASUREMENTS: ☐

CASING COLLARS		PERFORATING DATA				
		No.Shots	From	To	Gun Type	Gun Size
5807		17	5796	5800	HD	2-1/8
5765						
5723			SET	PACKER AT 5610		
5688						

BORE HOLE RECORD			CASING RECORD				
Hole Size	From	To	Size	Type	Weight	From	To
			5-1/2			SURF	TD
			2-7/8	TUBING		SURF	5610

HOLE FLUID DATA			
Type Fluid:	WATER	Opr. Rig Time:	1-1/2 HOURS
Density:	8.5#	Truck No.	5825
Fluid Level:	FULL	Location:	WLSTN-4105
		Recorded By:	SATTERFILLD
		Witnessed By:	PERIUS

MAR-836

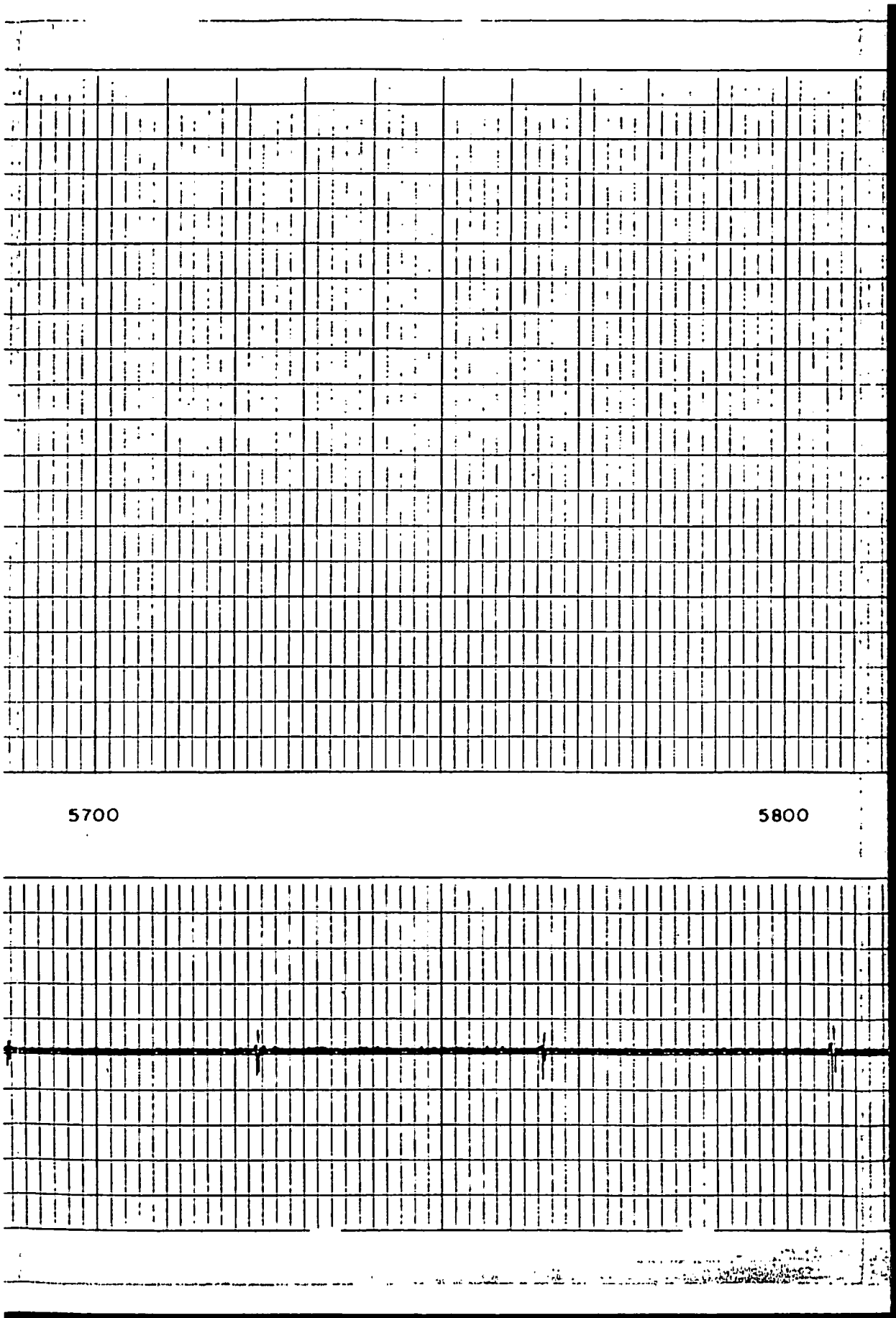
MAR02-1133

No.

er No. 146727

ASING COLLAR LOG EFORE PERFORATION	DEPTHS	CASING COLLAR LOG AFTER PERFORATION	RECORDING OF GUN POSITION BEFORE PERFORATION
Perforate TIE IN			
TAILPIPE BOTTOM			
	5700		

MAR02-1134



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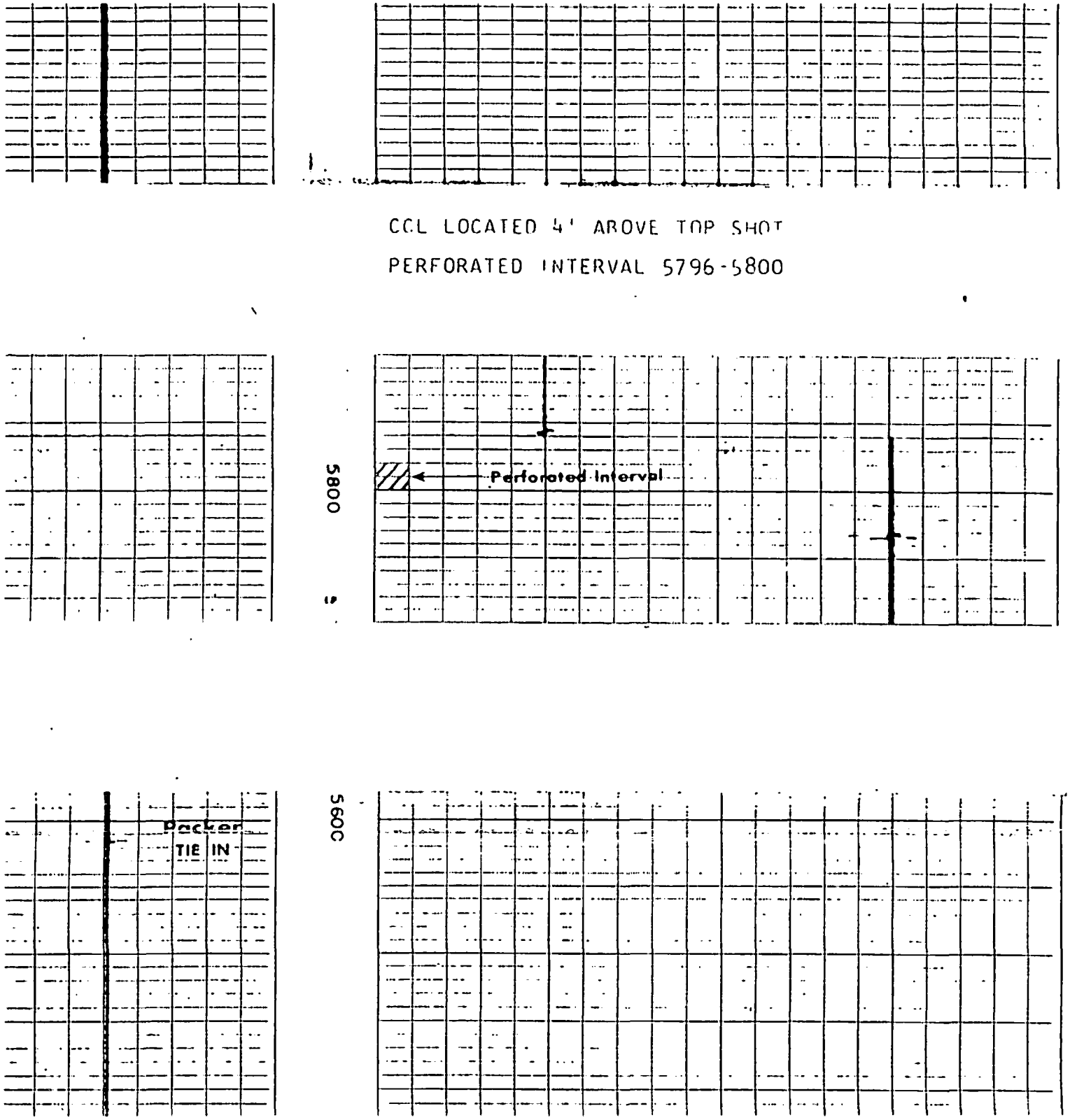
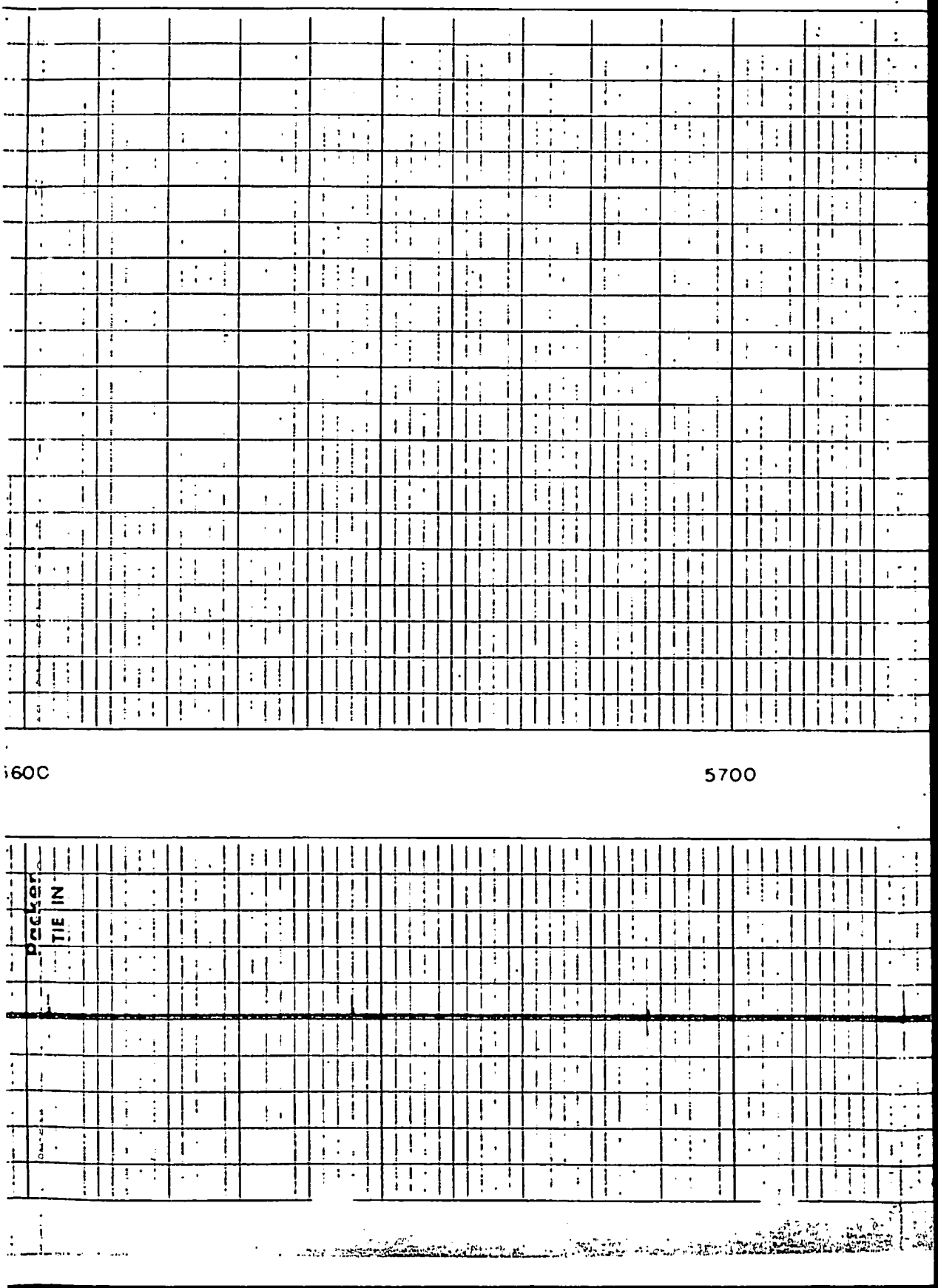
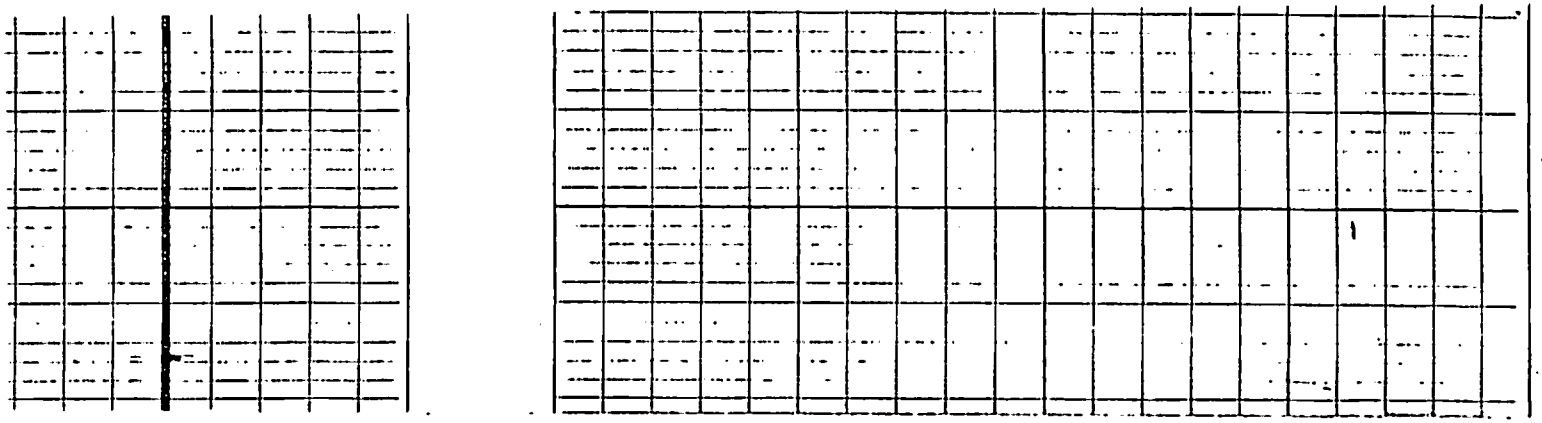

CCL LOCATED 4' ABOVE TOP SHOT
PERFORATED INTERVAL 5796-5800
5800
Perforated Interval
5600
Packer
TIE IN

MAR02-1136

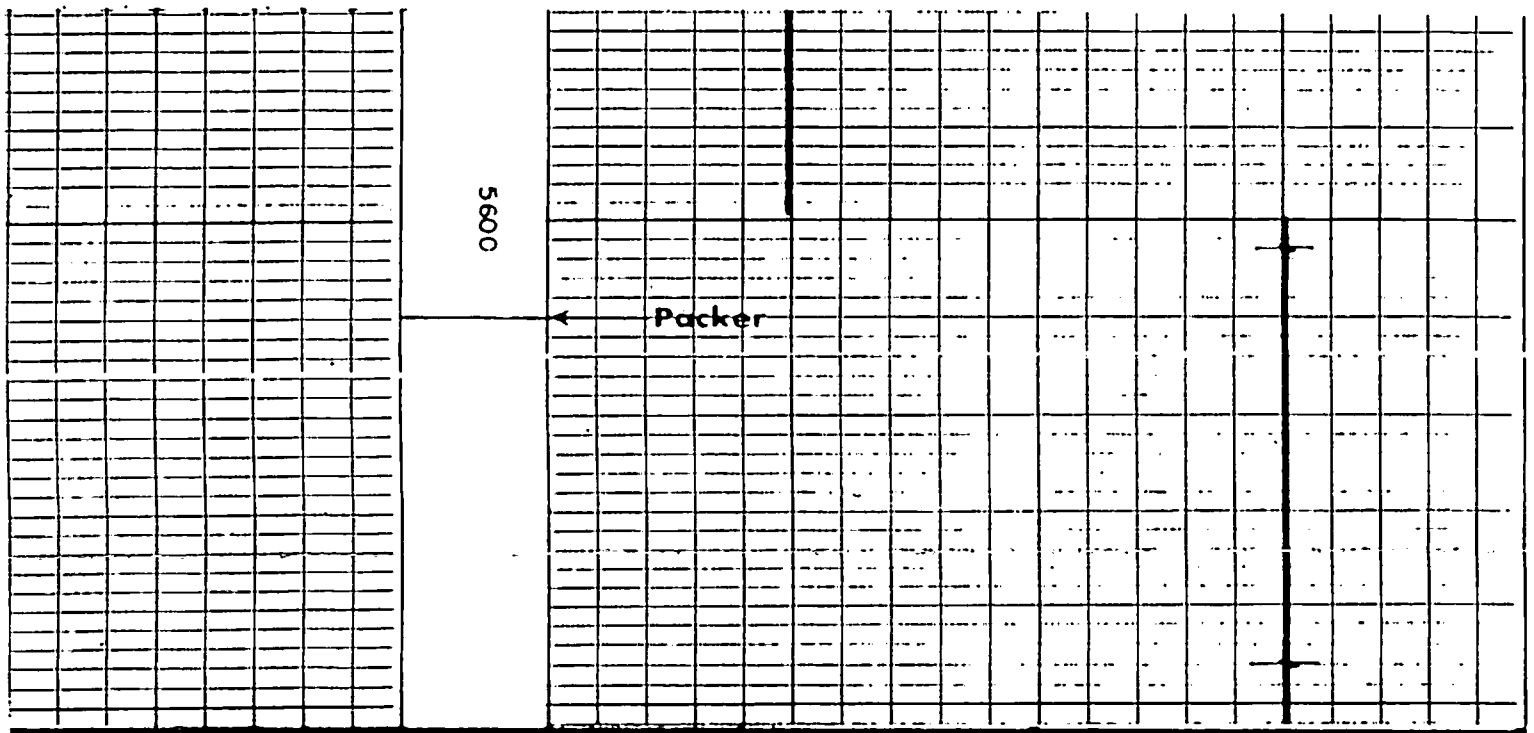


MAR02-1137



CCL LOCATED 10' ABOVE PACKER

PACKER SET AT 5610



ASING COLLAR LOG :FORE PERFORATION	DEPTHS	CASING COLLAR LOG AFTER PERFORATION	RECORDING OF GUN POSITION BEFORE PERFORATION

MPANY TEXAS OIL & GAS CORPORATION

SCHL. TD 5868

MAR02-1138

CASING COLLAR LOG BEFORE PERFORATION	DEPTHS	CASING COLLAR LOG AFTER PERFORATION	RECORDING OF GUN POSITION BEFORE PERFORATION

COMPANY TEXAS OIL & GAS CORPORATION

WELL BUCKLES NO. A-1

FIELD EAST POPLAR

COUNTY ROOSEVELT STATE MONTANA

SCHL. TD 5868
DRLR TD 5867

Elev:
KB 2097
DF ---
GL 2085

MAR02-1139

PRAIRIE

Temperature Survey

FILE NO.	
COMPANY	TEXAS OIL AND GAS CORPORATION
WELL	BUCKLES SALTWATER DISPOSAL #1
FIELD	EAST POPLAR
County	ROOSEVELT State MONTANA
LOCATION:	1803FNL 1853FWL SEC. 22 TWP. 28N RGE. 51E
OTHER SERVICES	GAMMA RAY CEMENT BOND

PERMANENT DATUM G.L. ELEV. 2085
LOG MEASURED FROM EIGHT FT. ABOVE PERM. DATUM
DRILLING MEASURED FROM K.B.

ELEV.: K.B. 2093
G.L. 2085

		Shot Density	No. of Shots	Perforating From	Interval To
DATE	MAY 29, 1981				
RUN NO.	THREE				
TYPE LOG	TEMP. SURVEY				
DEPTH - DRILLER	961				
DEPTH - LOGGER	910				
LOGGED INTER.	909				
TOP LOGGED INTER.	0				
FLUID IN HOLE	WATER				
LEVEL	FULL				
TRUCK NO.	THREE				
OPER. RIG TIME	1 HOUR				
RECORDED BY	ONEIL				
WITNESSED BY	CROFT				

Gun Type and Size

CASING RECORD

Size in.	Weight	From	To
7	17	SURF	920

COLLAR LOCATION

Casing	Tubing

OTHER SERVICES

Service	Type	Size	Depth

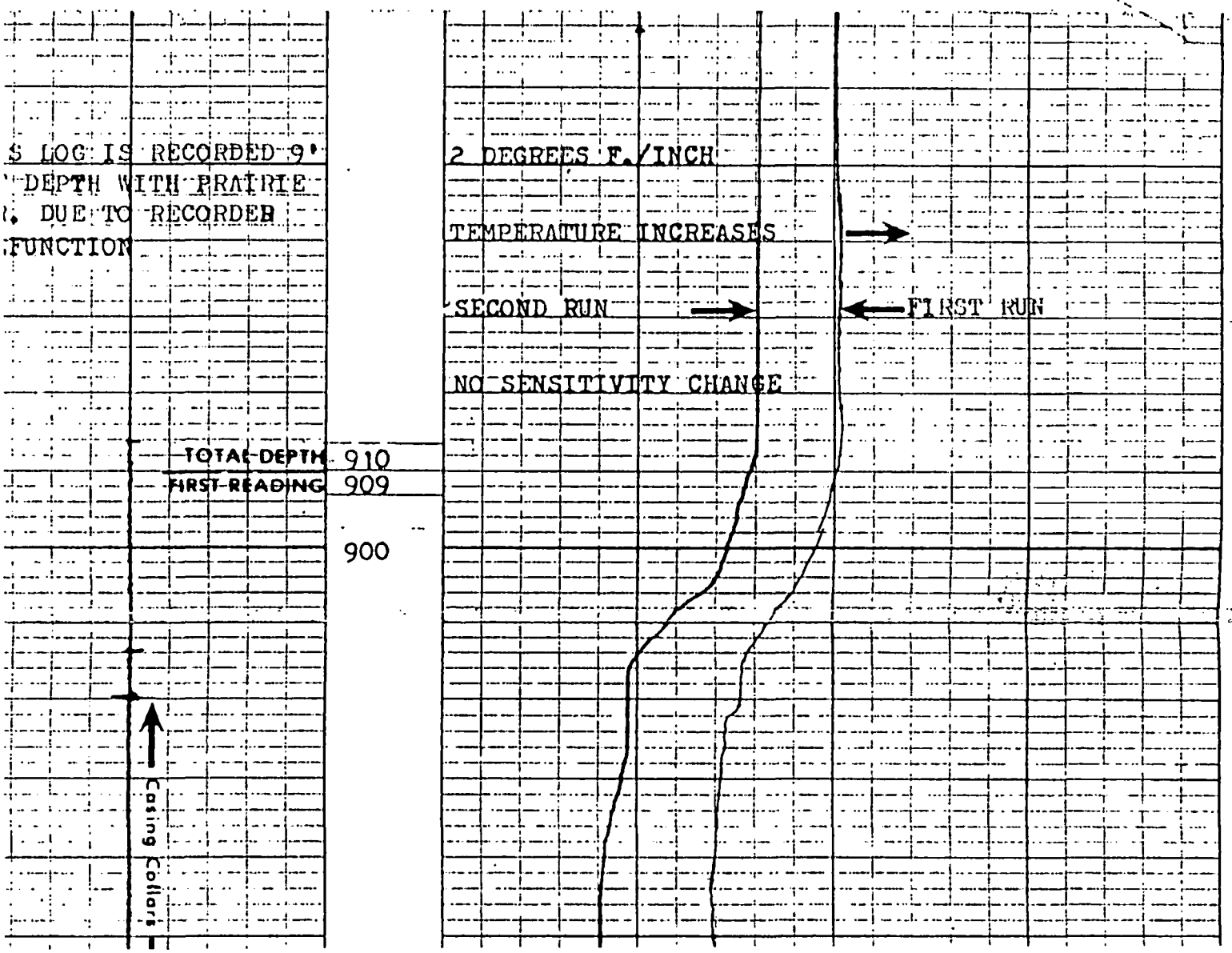
Remarks:

MAR-837

MAR02-1140

vious Completion Information	
pth Control Log Yes No	
forated No Yes From To	

Temperature Survey



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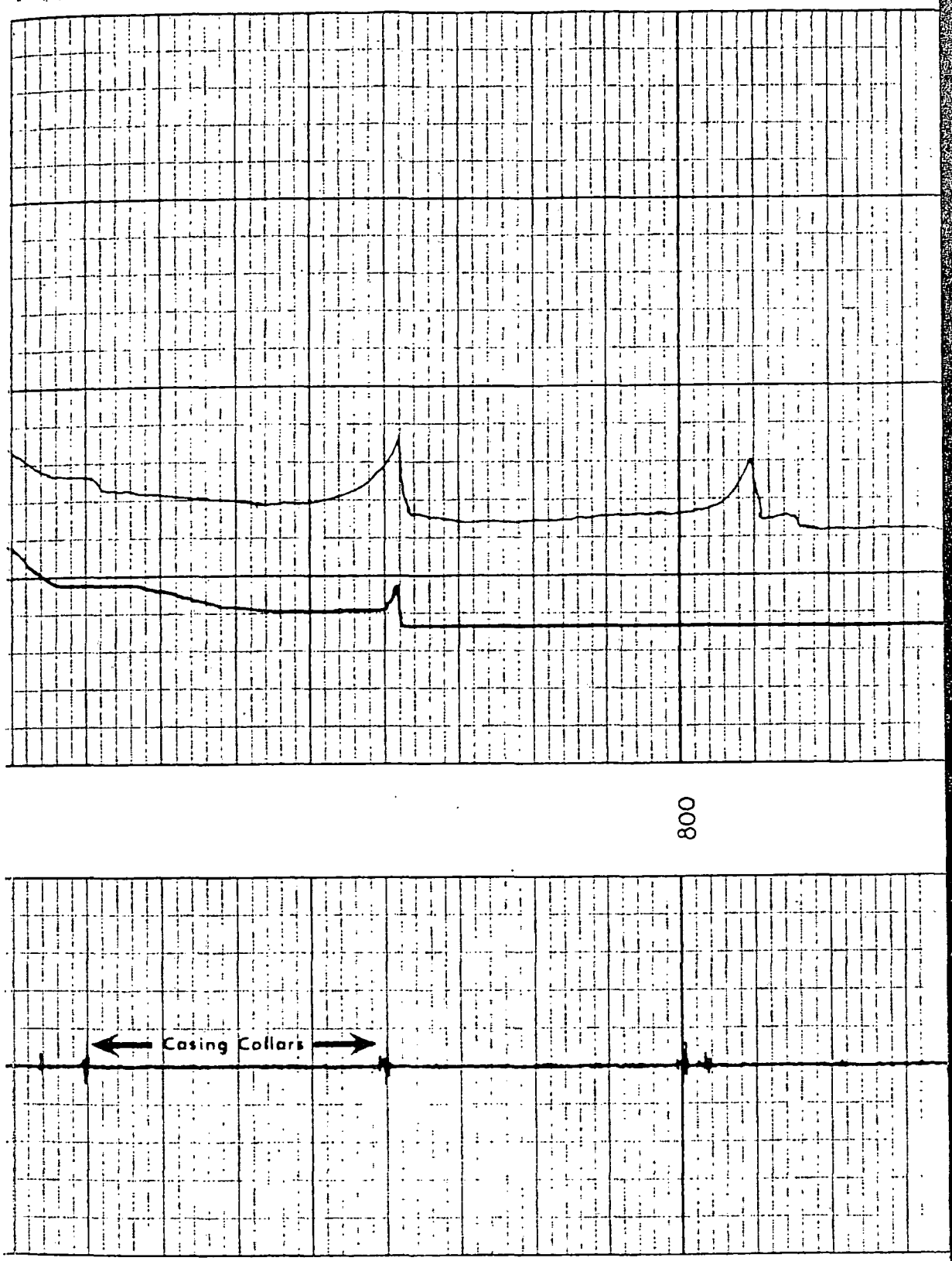

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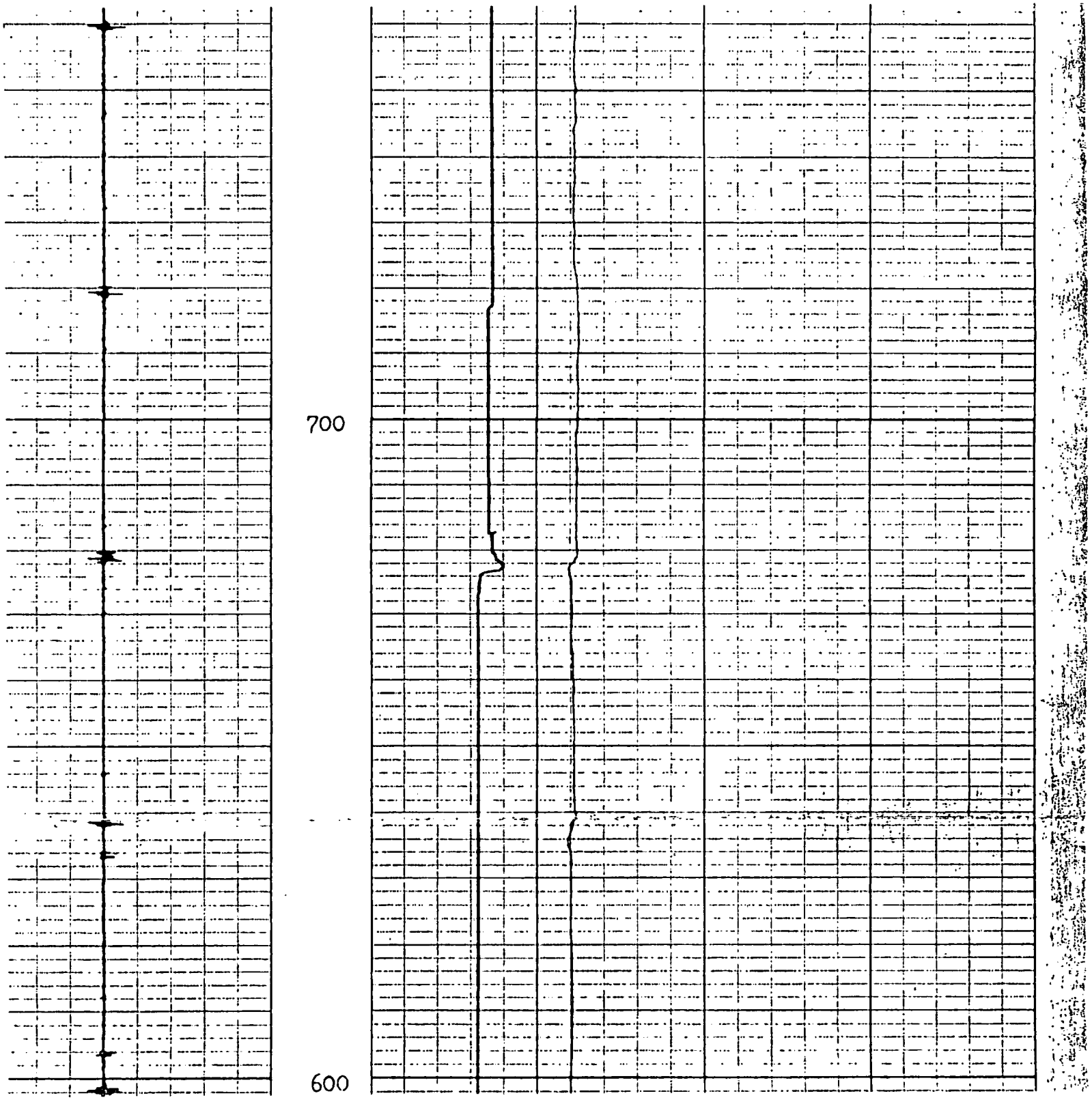

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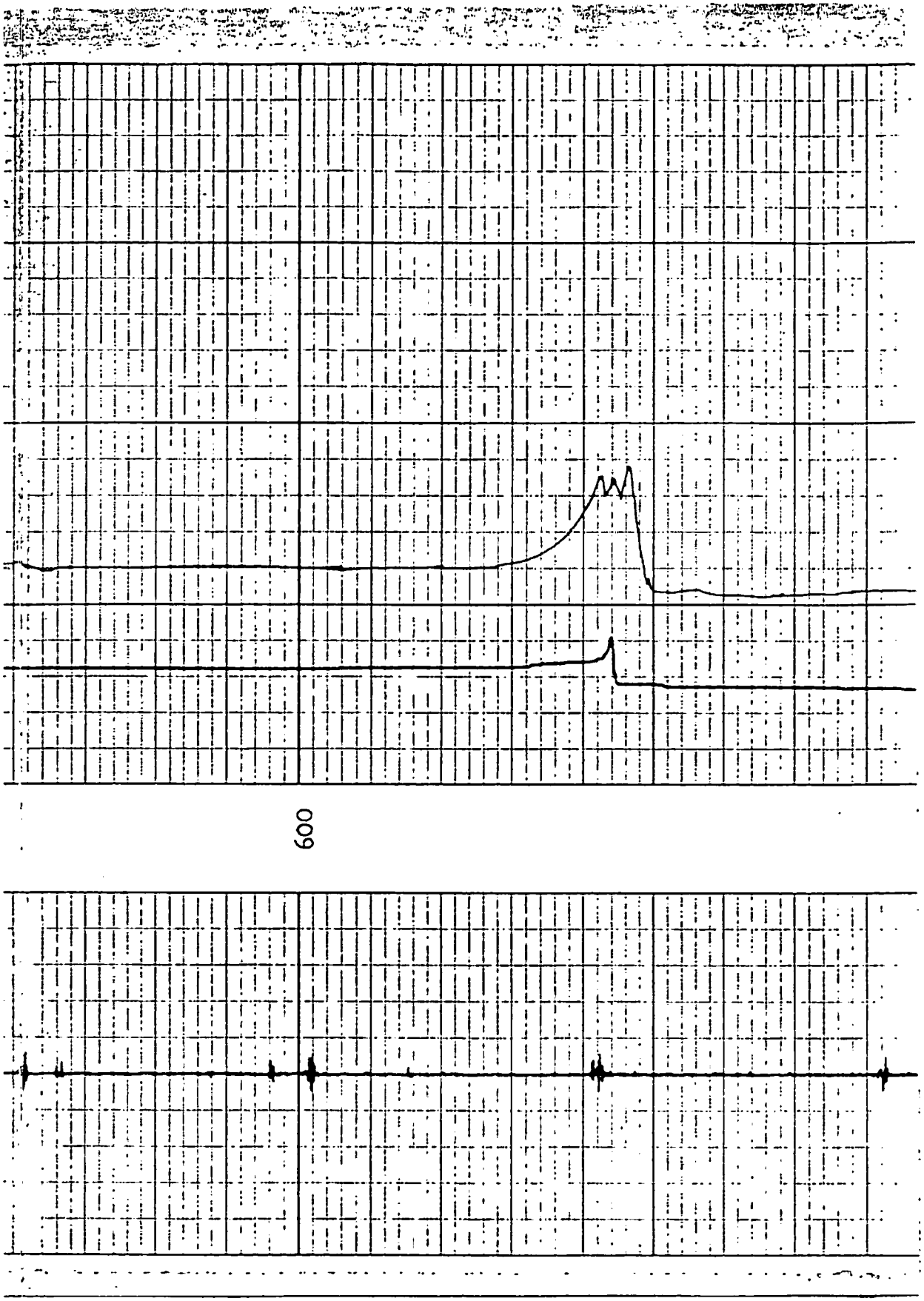

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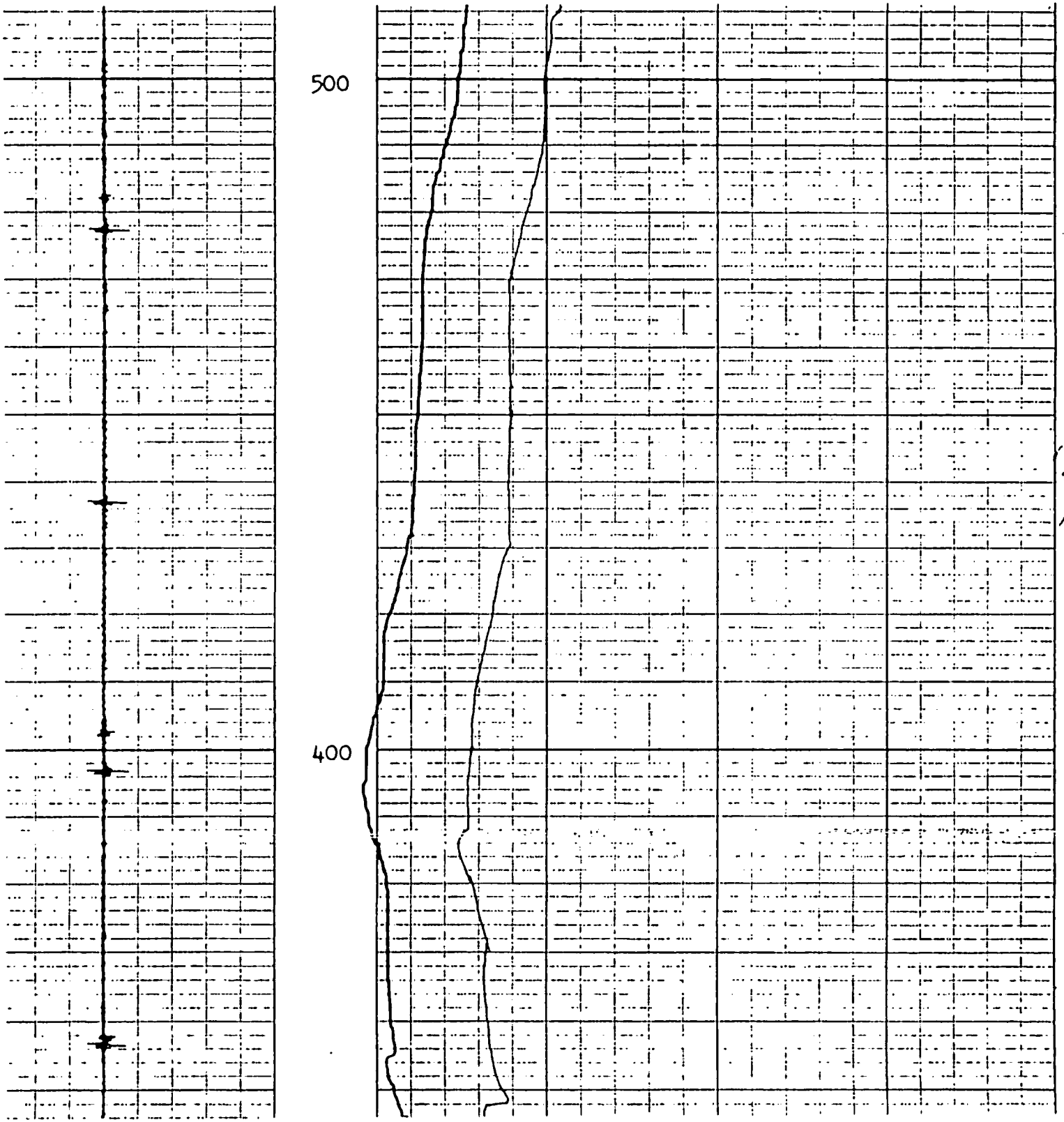

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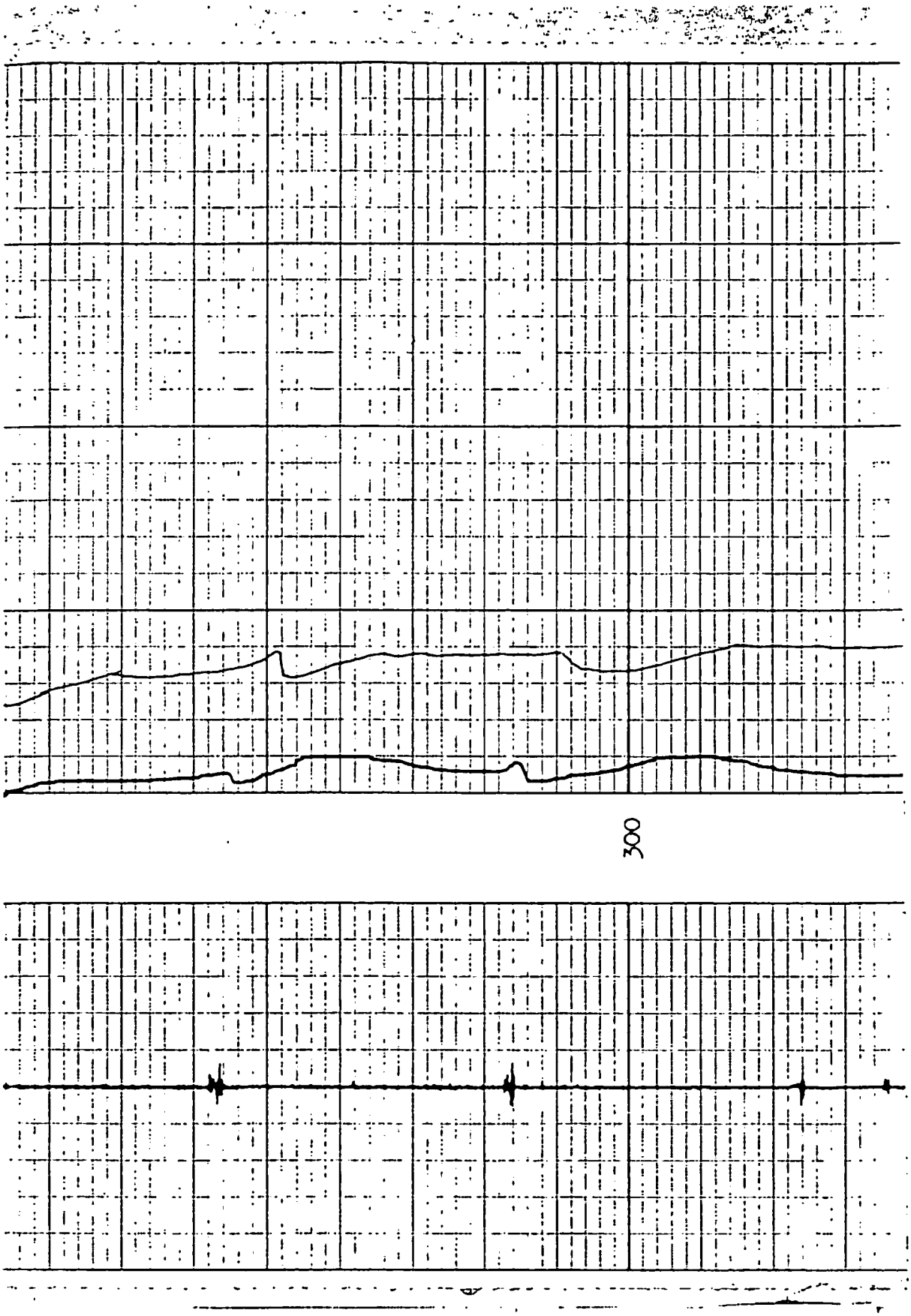

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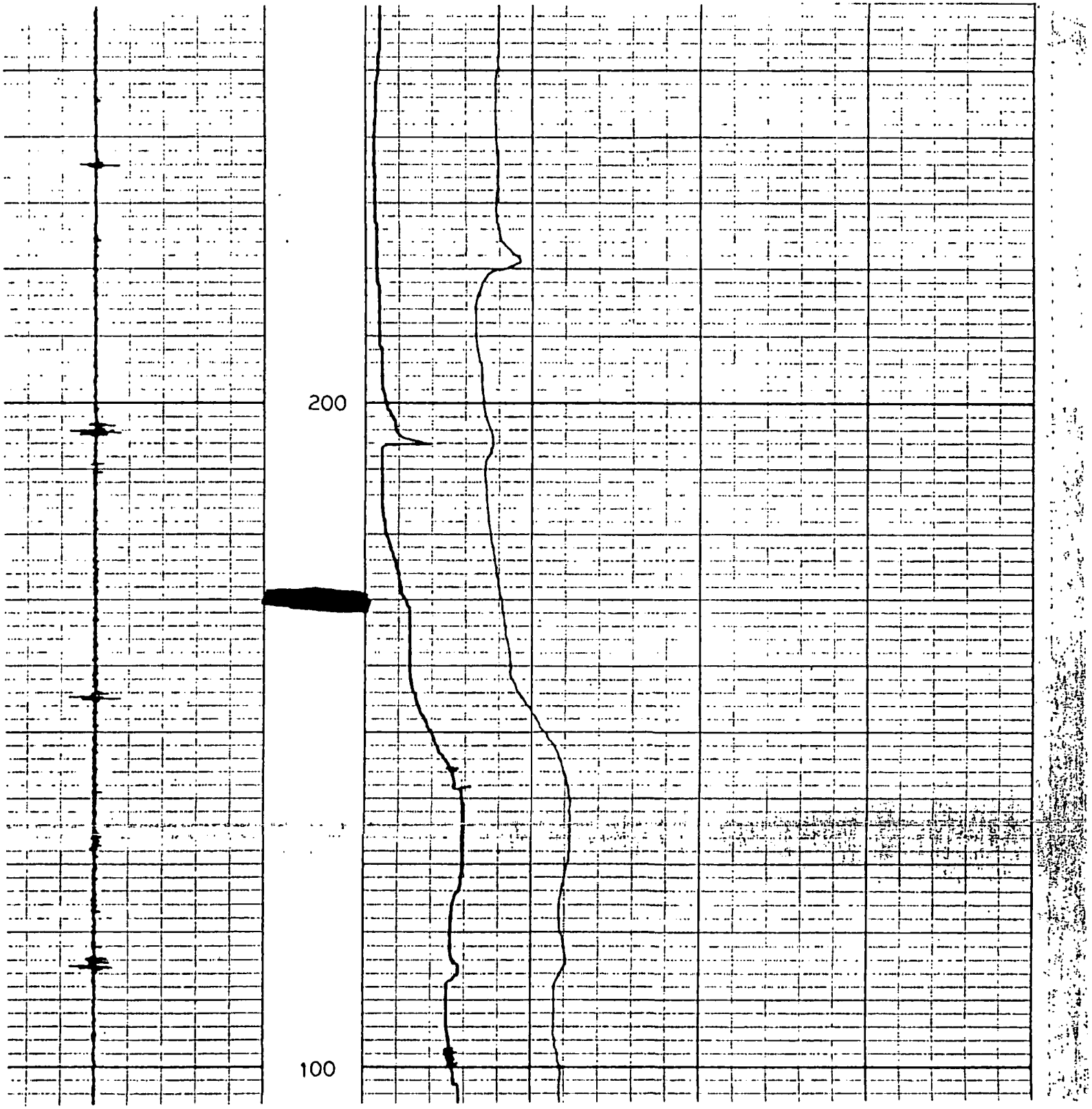

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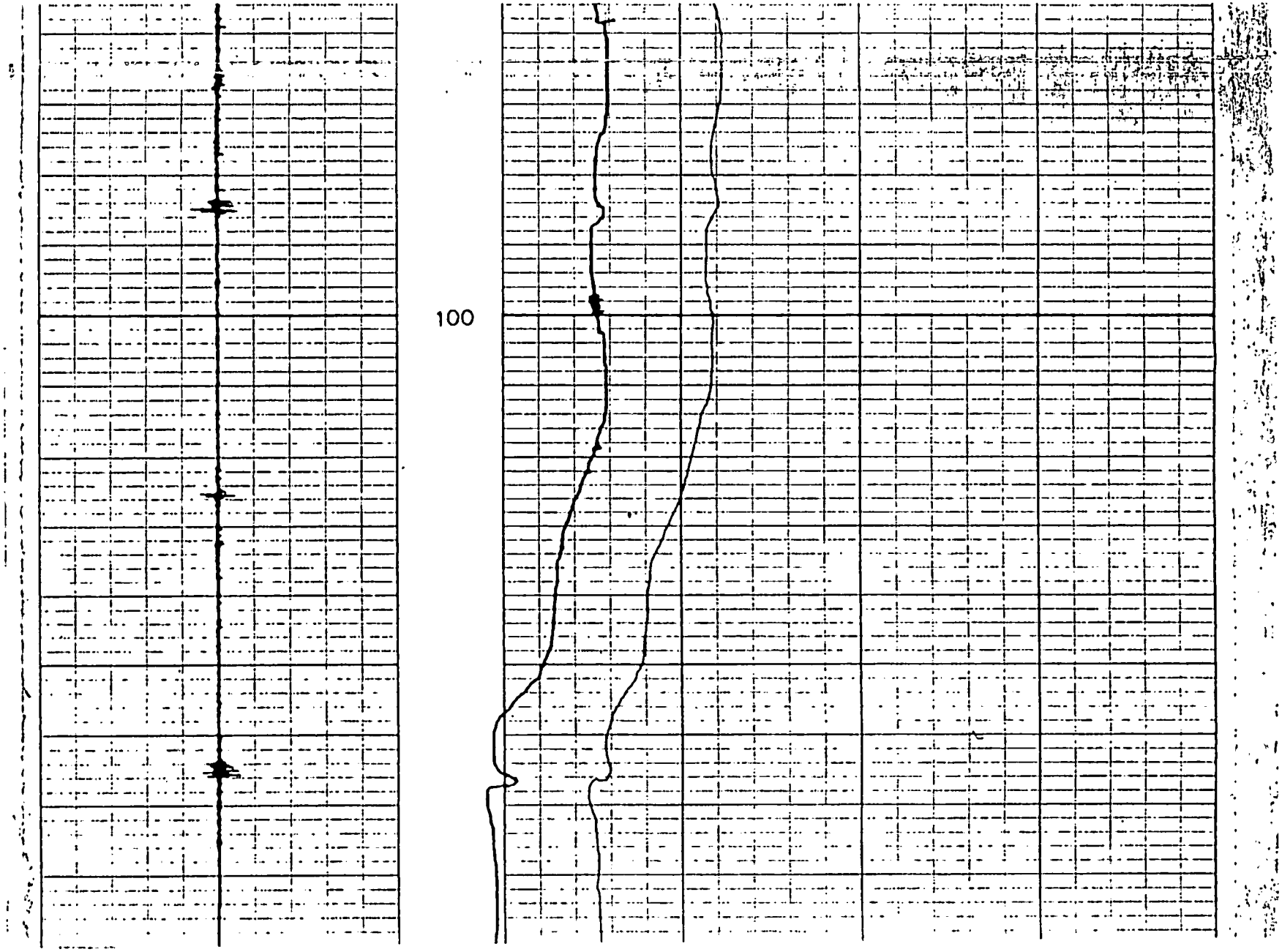


MAR02-1148

Schlumberger

SIMULTANEOUS

COMPENSATED NEUTRON-FORMATION DENSITY

COUNTY ROOSEVELT
FIELD EAST POPLAR
LOCATION SEC.22-28N-51E
WELL BUCKLES NO. A-1
COMPANY TEXAS OIL & GAS

COMPANY TEXAS OIL AND GAS CORP.
PRODUCTION DEPT.
WELL BUCKLES NO. A-1
FIELD EAST POPLAR
COUNTY ROOSEVELT STATE MONTANA

LOCATION 1980'FNL - 1980'FWL

API SERIAL NO.	SEC.	TWP.	RANGE
	22	28N	51E

Other Services:
DLL/MSFL/GR
INT/BHC/GR

Permanent Datum: GL ; Elev.: 2095
Log Measured From KB, 12 Ft. Above Perm. Datum
Drilling Measured From KB

Elev.: K.B. 2097
D.F. ---
G.L. 2085

Date		4-16-81								
Run No.		ONE								
Depth—Driller		5938								
Depth—Logger		5944								
Btm. Log Interval		5942								
Top Log Interval		SEE REMARKS								
Casing—Driller		8-5/8@ 1214		@		@		@		
Casing—Logger		1220								
Bit Size		7-7/8								
Type Fluid in Hole		SALT-LOW SOLIDS								
Dens.	Visc.	11.3	41							
pH	Fluid Loss	6.4	6 ml		ml		ml			ml
Source of Sample		MUD TANK								
Rm @ Meas. Temp.		.056 @ 68 °F		@	°F	@	°F	@		°F
Rmf @ Meas. Temp.		.049 @ 68 °F		@	°F	@	°F	@		°F
Rmc @ Meas. Temp.		.084 @ 68 °F		@	°F	@	°F	@		°F
Source: Rmf	Rmc	M	C							
Rm @ BHT		.022 @ 188 °F		@	°F	@	°F	@		°F
TIME: Circulation Stopped		4-16-0600								
TIME: Logger on Bottom		4-16-1200								
Max. Rec. Temp.		198 °F			°F		°F			°F
Equip.	Location	8135	WLSTN-4109							
Recorded By		SACHAU								
Witnessed By		WALEN - PERIUS								

MAR-838

MAR02-1149

The well name, location and borehole reference data were furnished by the customer.

	ONE			
er No.	213161			
	FULL			
A CL.	130000			
M.	30			
NT DATA				
	NLM-BC-439			
	PGC-G-105			
	PDH-E-219			
	PGS-EC-230			
	GSR-J-5076			
ator	SFT-106-1309			
	NLM-BC-439			
	CNC-A-1339			
	NSR-FA-2028			
ator	CNB-AB-1634			
	SGC-JC-2250			
Panel	CPU-CAA-535			
ler (TTR)	MTU-D-2745			
ler (DRE)	OMU-CAA-362			
heel (CPW)	CMD-BAB-195			
Type	ECC.			
No.	1			
one S. O. — Inches	---			
ION DATA				
BKG. CPS	SEE CALIBRATION SUMMARY LISTING:			
Source CPS	"		"	
Sens. - Cal	"		"	
T. C. - Cal	"		"	
acing - Before Log	"		"	
acing - Before Log	"		"	
acing - After Log	"		"	
acing - After Log	"		"	
ore Log	"		"	
ore Log	"		"	
r Log	"		"	
r Log	"		"	

SCALE CHANGES:

Type Log	Depth	UPHOLE	DOWNHOLE
GR	5200	0-200	0-100
ØN	4902	45/-15	30/-10
ØD	4902	45/-15	30/-10
ØN	1503	60/0	45/-15
GR	1168	0-100	0-200

REMARKS:

FDC LR @ 3909'

CNL - GR LOGGED FROM 1503' - 4'

LOGGING DATA

PTH	CNP			FDC				GR			
Bottom	Porosity Scale	Matrix	Auto Corr. or Hole Size Setting	Porosity Scale	Grain Density	Liquid Density	Hole Fluid	Sens. Logged	D.C.	Zero. Div. Left	Scale Per 100 Div.
TD	30/-10	L.S.	AUTO	30/-10	2.71	1.1	LIQ	100	1	0	100
5200	30/-10	L.S.	AUTO	30/-10	2.71	1.1	LIQ	200	1	0	200
4902	45/-15	L.S.	AUTO	45/-15	2.71	1.1	LIQ	200	1	0	200
1503	60/0	L.S.	AUTO	45/-15	2.71	1.1	LIQ	200	1	0	200
1168	60/0	L.S.	AUTO	45/-15	2.71	1.1	LIQ	100	1	0	100

pretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any inter-
ns, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or
d by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our General Terms and

MAR02-1150

LOGGING DATA

DEPTH		CNP			FDC				GR			
Top	Bottom	Porosity Scale	Matrix	Auto Corr. or Hole Size Setting	Porosity Scale	Grain Density	Liquid Density	Hole Fluid	Sens. Logged	D.C.	Zero. Div. Left	Scale Per 100 Div.
5200	TD	30/-10	L.S.	AUTO	30/-10	2.71	1.1	LIQ	100	1	0	100
4902	5200	30/-10	L.S.	AUTO	30/-10	2.71	1.1	LIQ	200	1	0	200
3909	4902	45/-15	L.S.	AUTO	45/-15	2.71	1.1	LIQ	200	1	0	200
1168	1503	60/0	L.S.	AUTO	45/-15	2.71	1.1	LIQ	200	1	0	200
4	1168	60/0	L.S.	AUTO	45/-15	2.71	1.1	LIQ	100	1	0	100

All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretations, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our General Terms and Conditions as set out in our current Price Schedule

AFTER SURVEY TOOL CHECK SUMMARY

PERFORMED: 81/04/16
PROGRAM FILE: ISN (VERSION 18.2 80/08/23)

CNTA TOOL CHECK

	JIG BEFORE	JIG AFTER
NRAT	2.180	2.145

POROSITY CHANGE (LIME): -0.004

PGTE TOOL CHECK

	JIG BEFORE	JIG AFTER	UNITS
FFDC	333	333	CPS

FILE

7

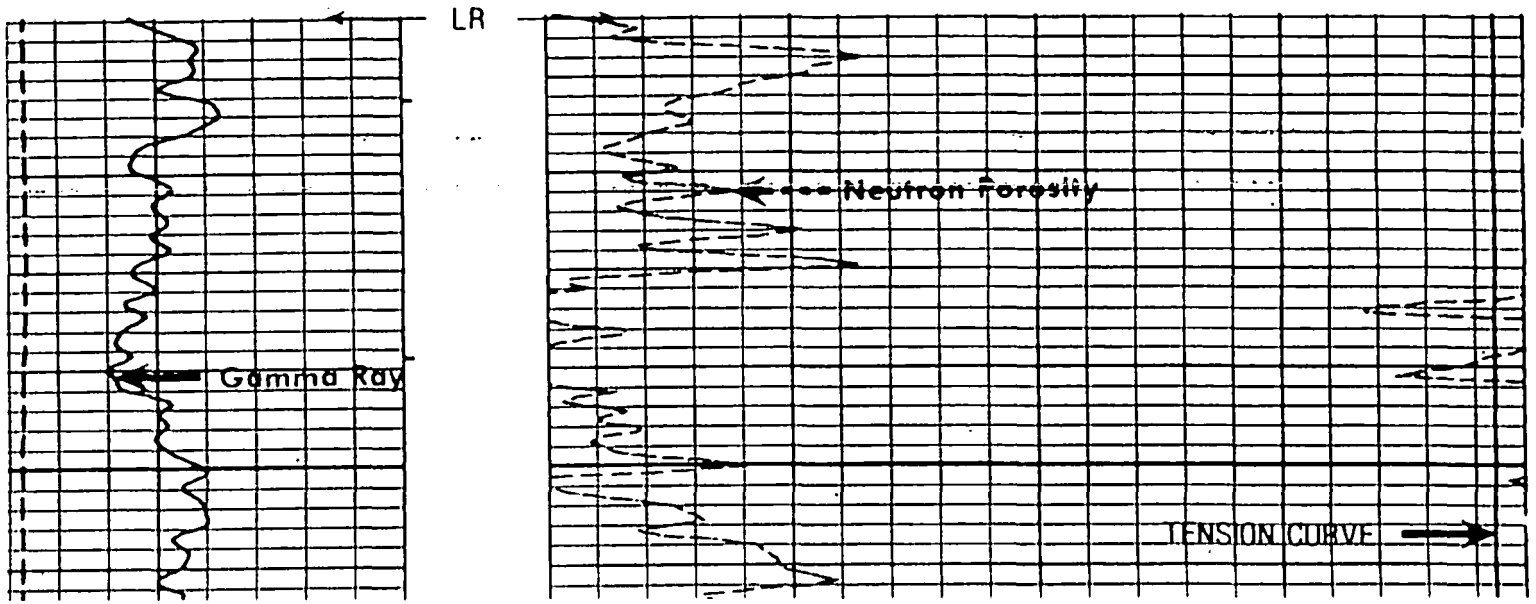
PARAMETERS

AME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
C		CALI	PSNR		2.210	BS	INCH	7.875
DEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
HF		WATE						
D		0.0	BHS		CASE	FPHI		PHIX

CALI(IN) 0 16.00			TENS(LB) 10000. 0.0
GR (GAPI) 100.0			
CALI(IN) 0 26.00		NPHI( ) LIMESTONE 0.6000 0.0	

FILE

5



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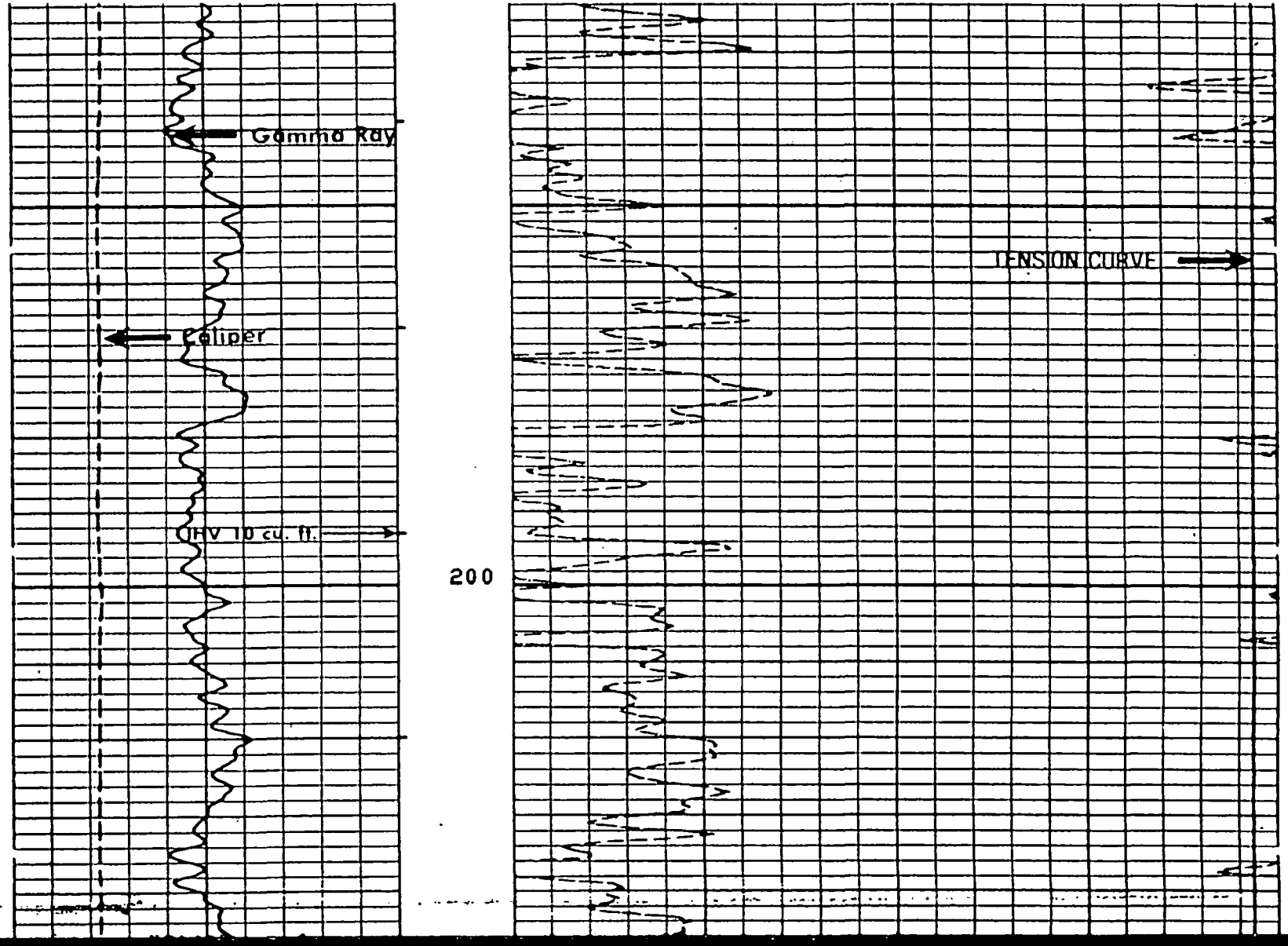

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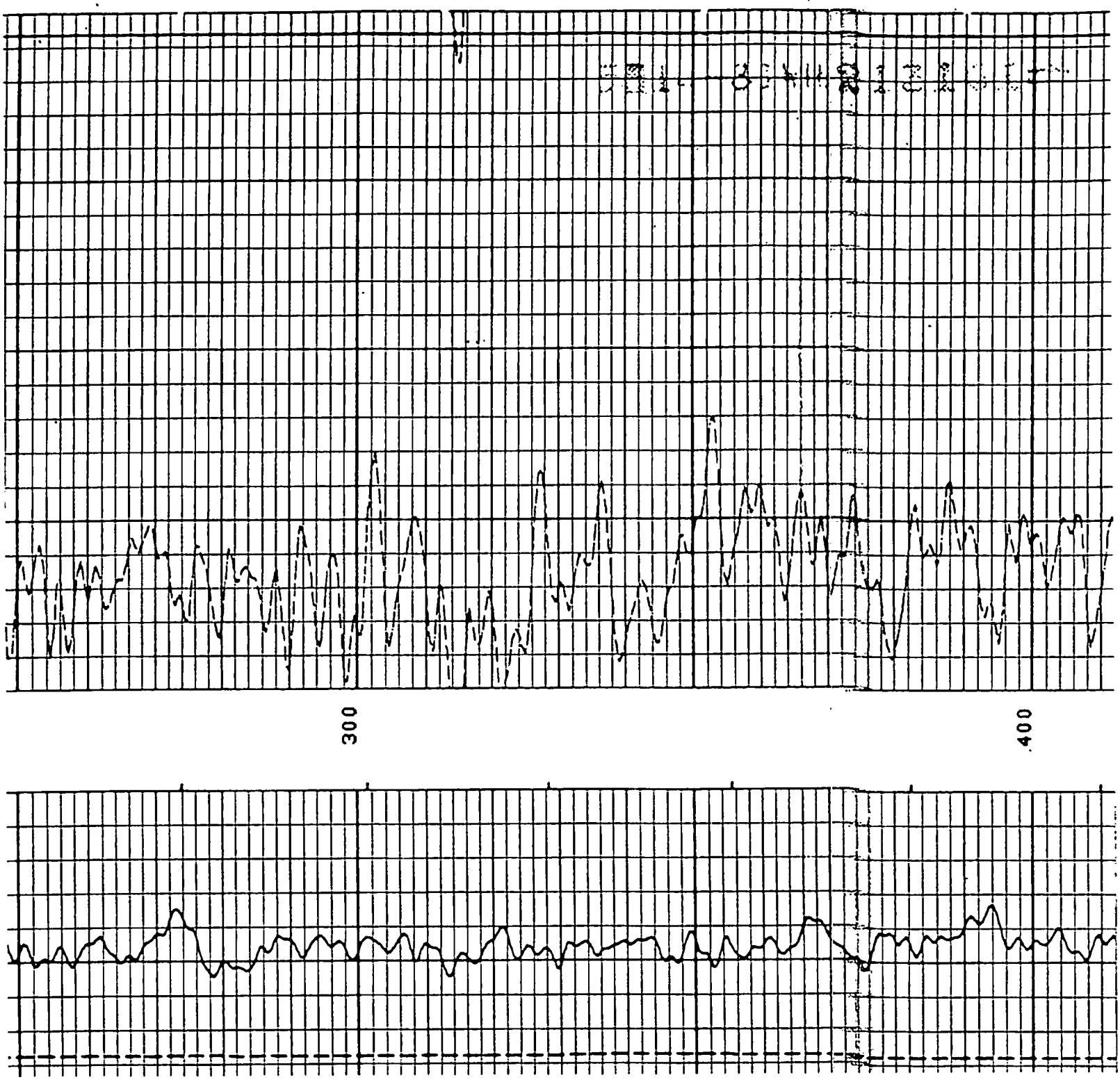

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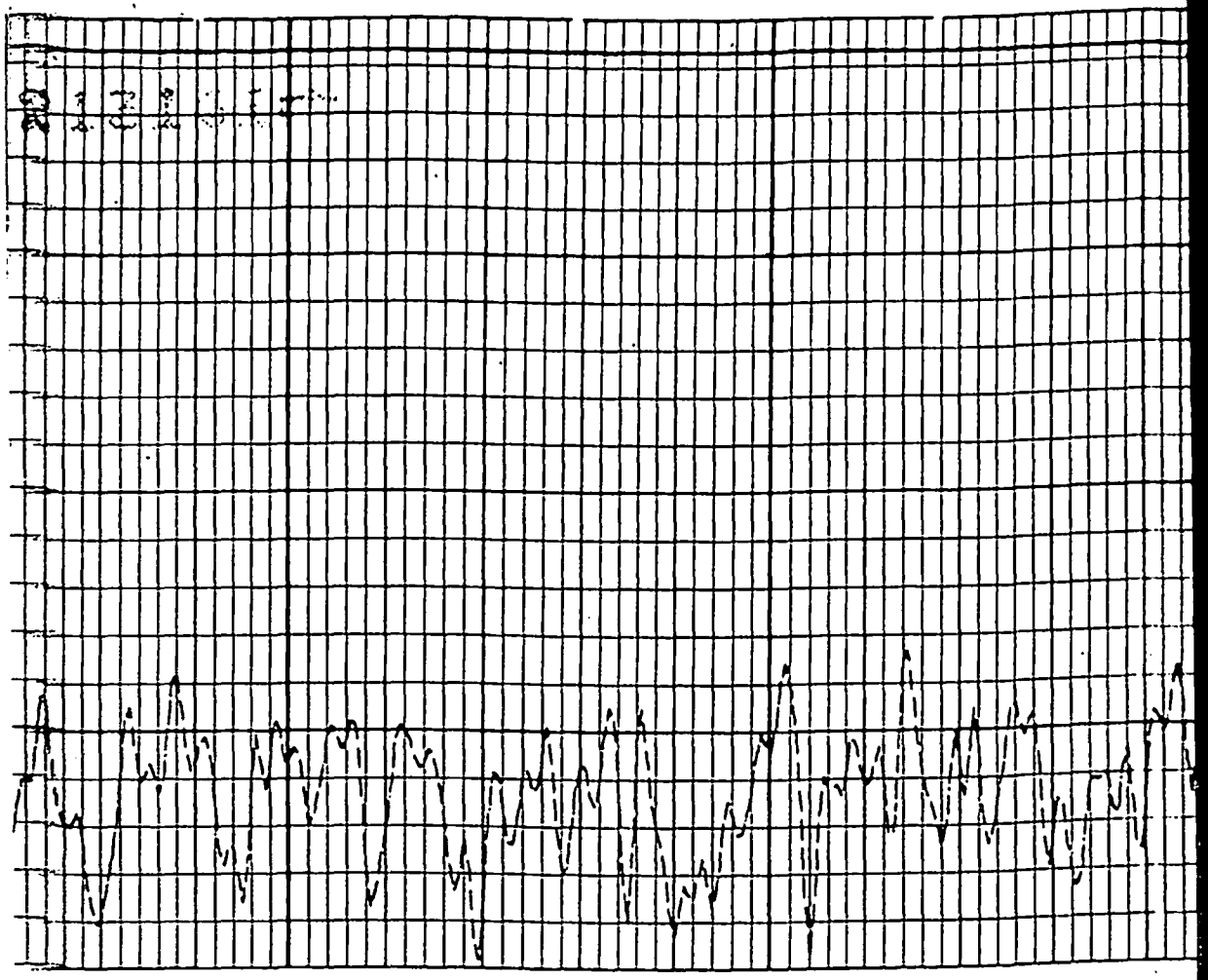

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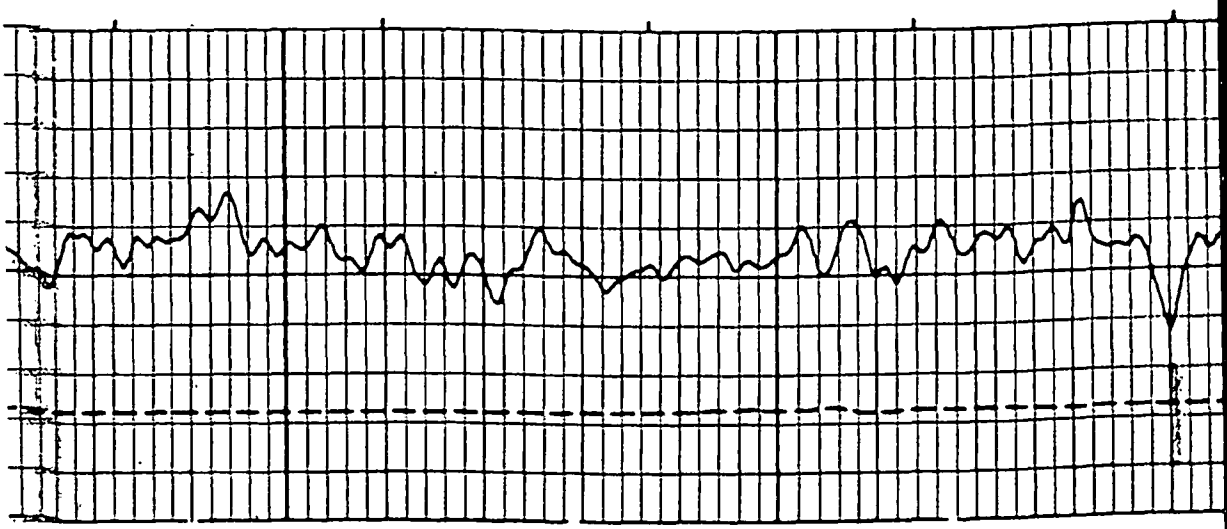
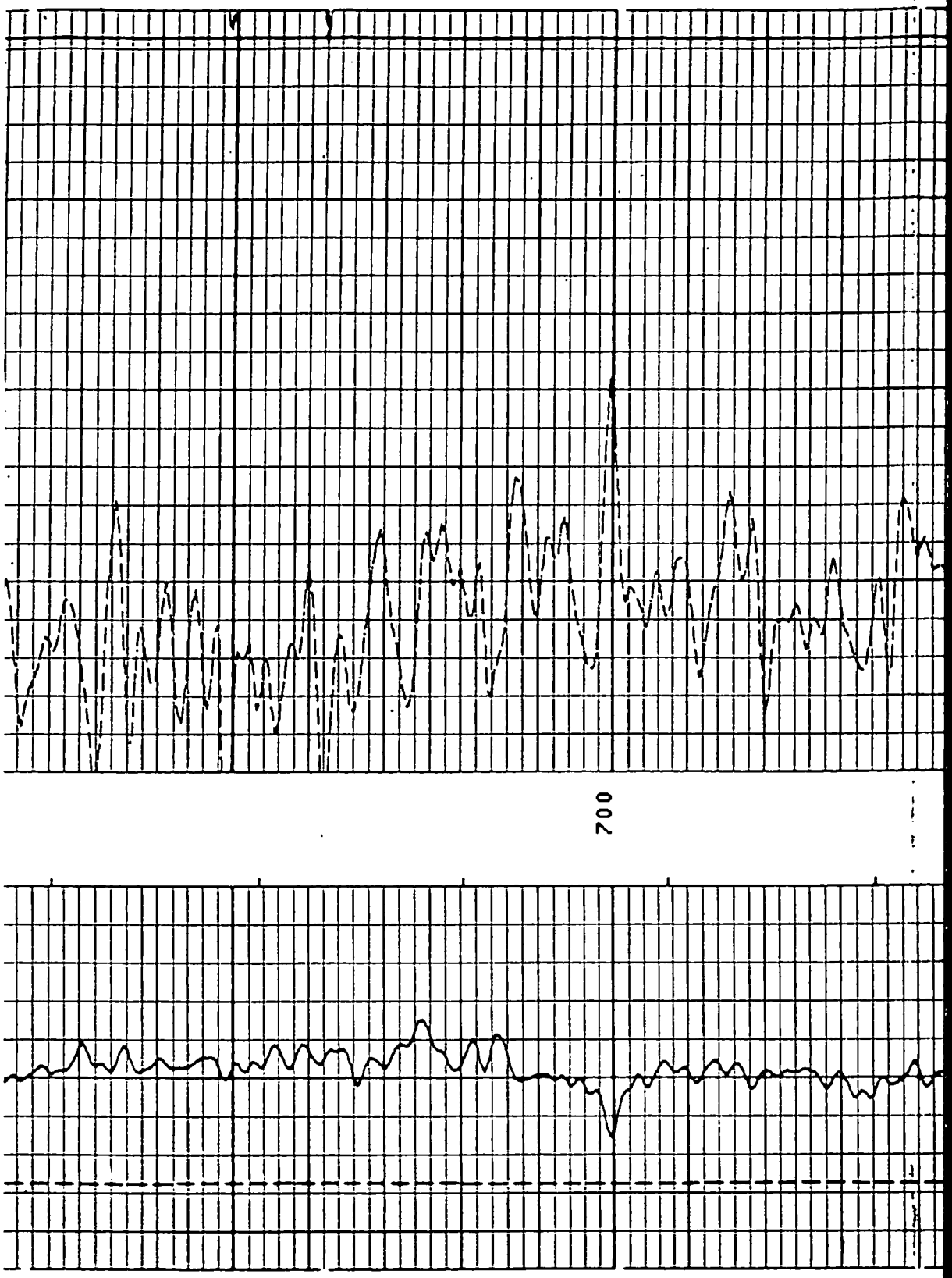


MAR02-1155

MAR02-1156



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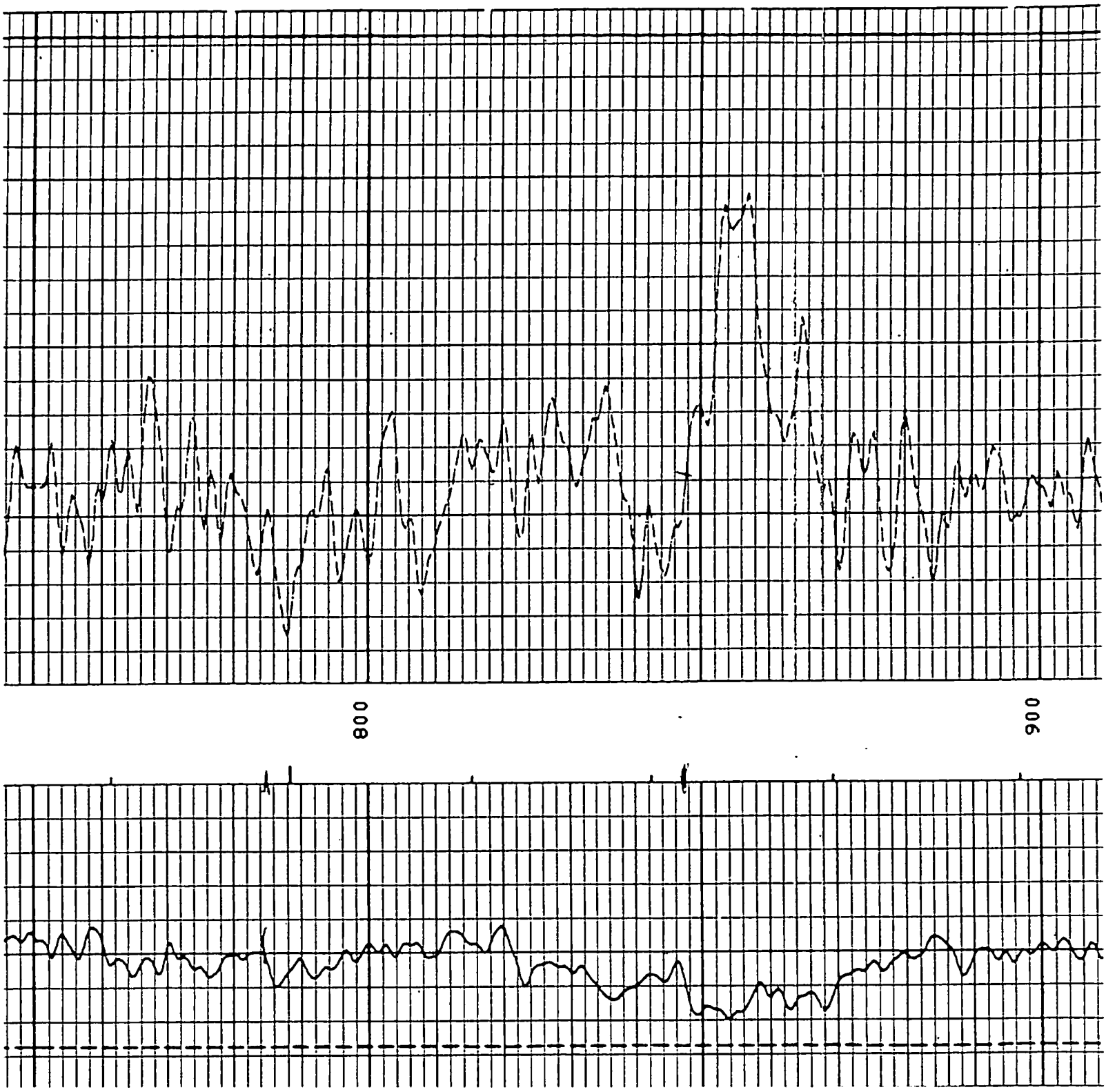

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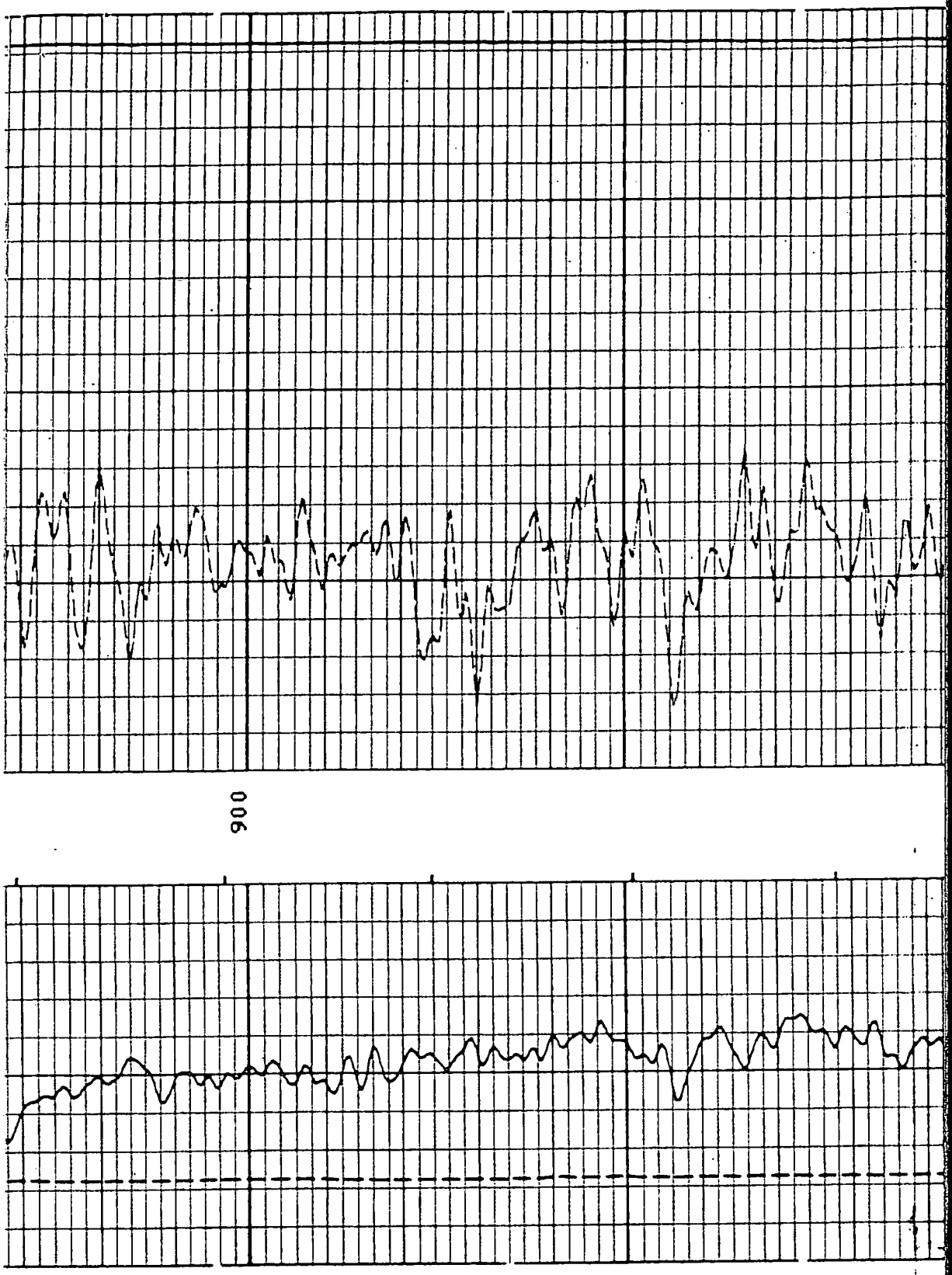
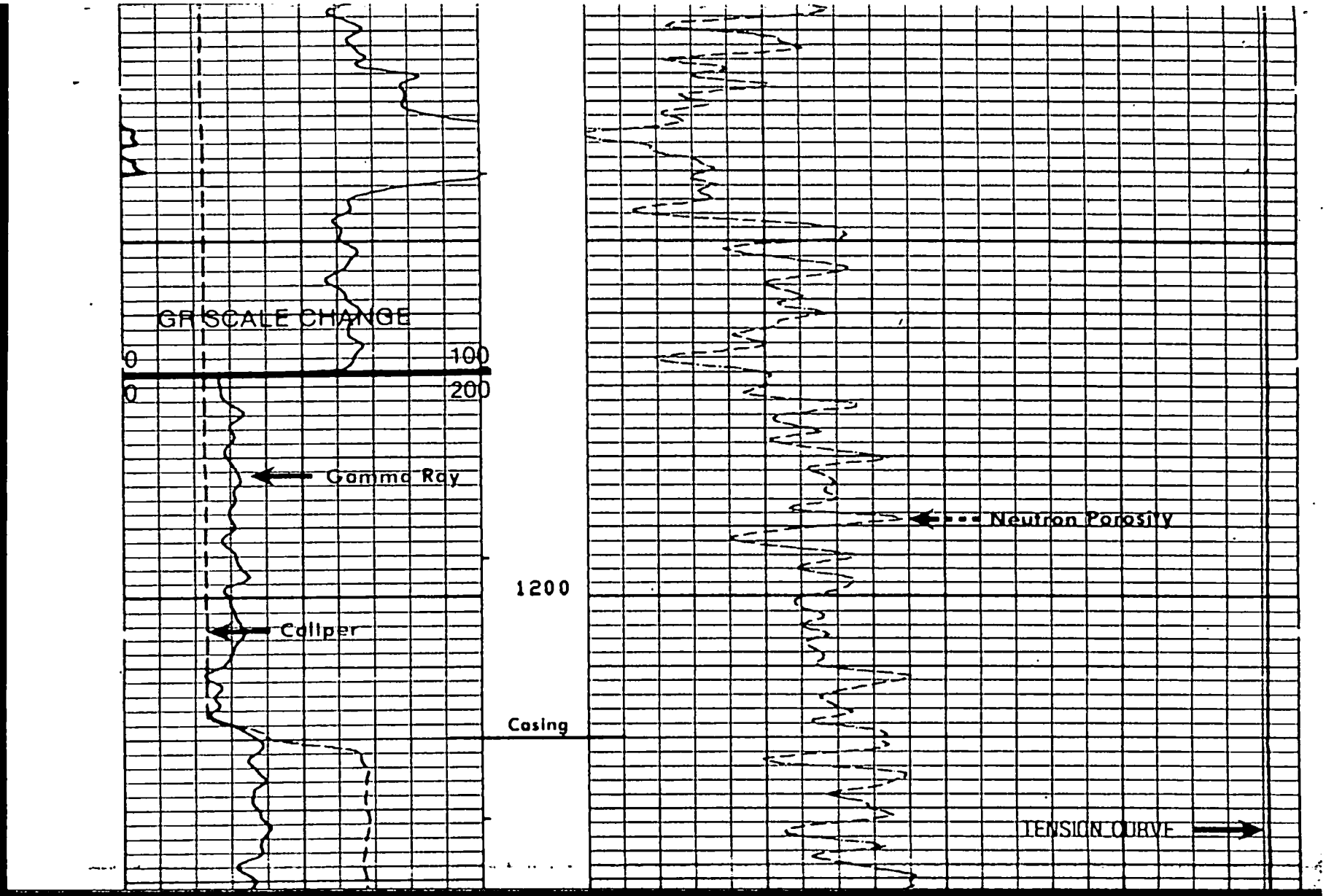
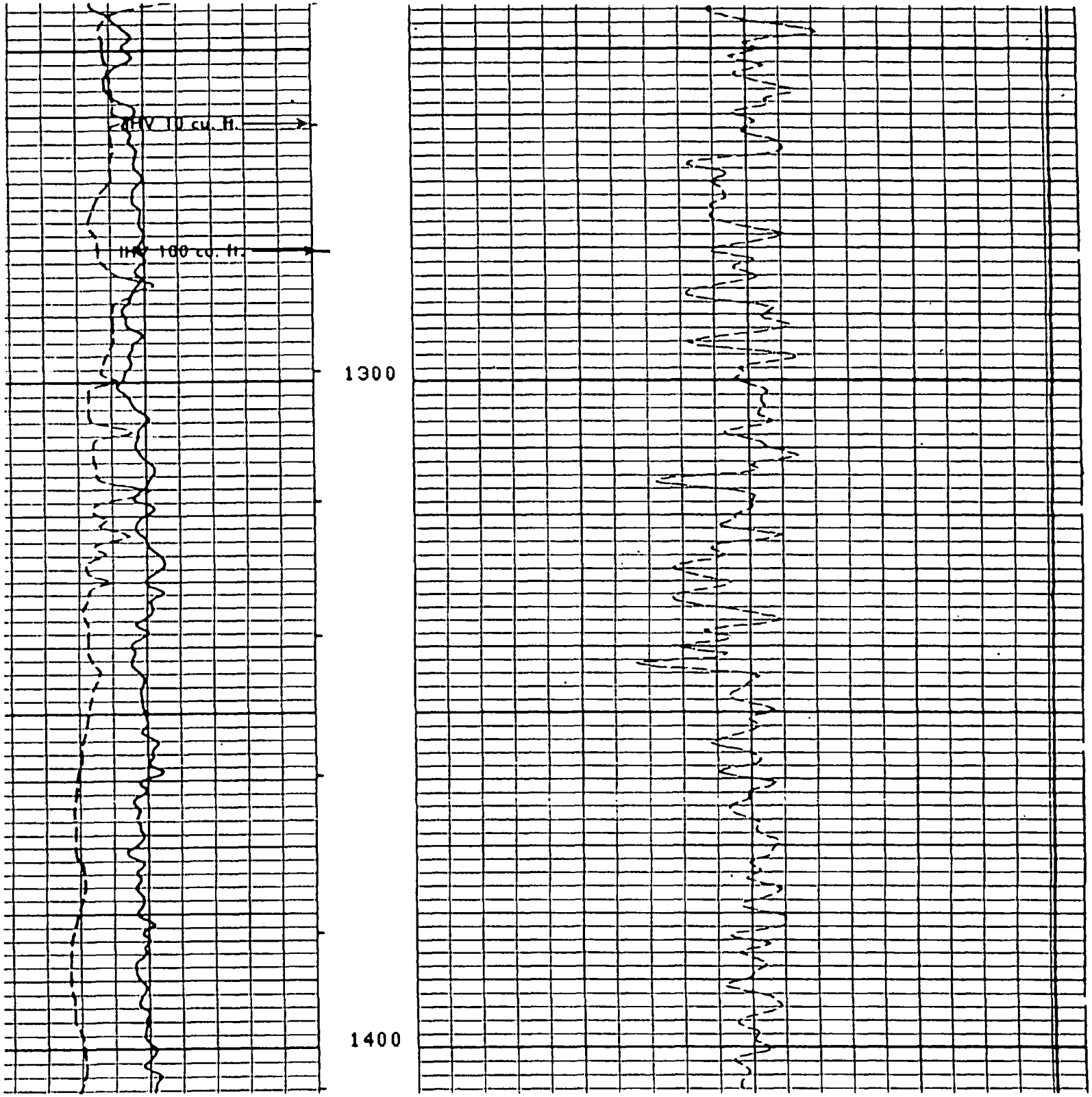


MAR02-1159

MAR02-1160


GR SCALE CHANGE
0
100
0
200
Gamma Ray
Neutron Porosity
1200
Caliper
Casing
TENSION CURVE

MAR02-1161



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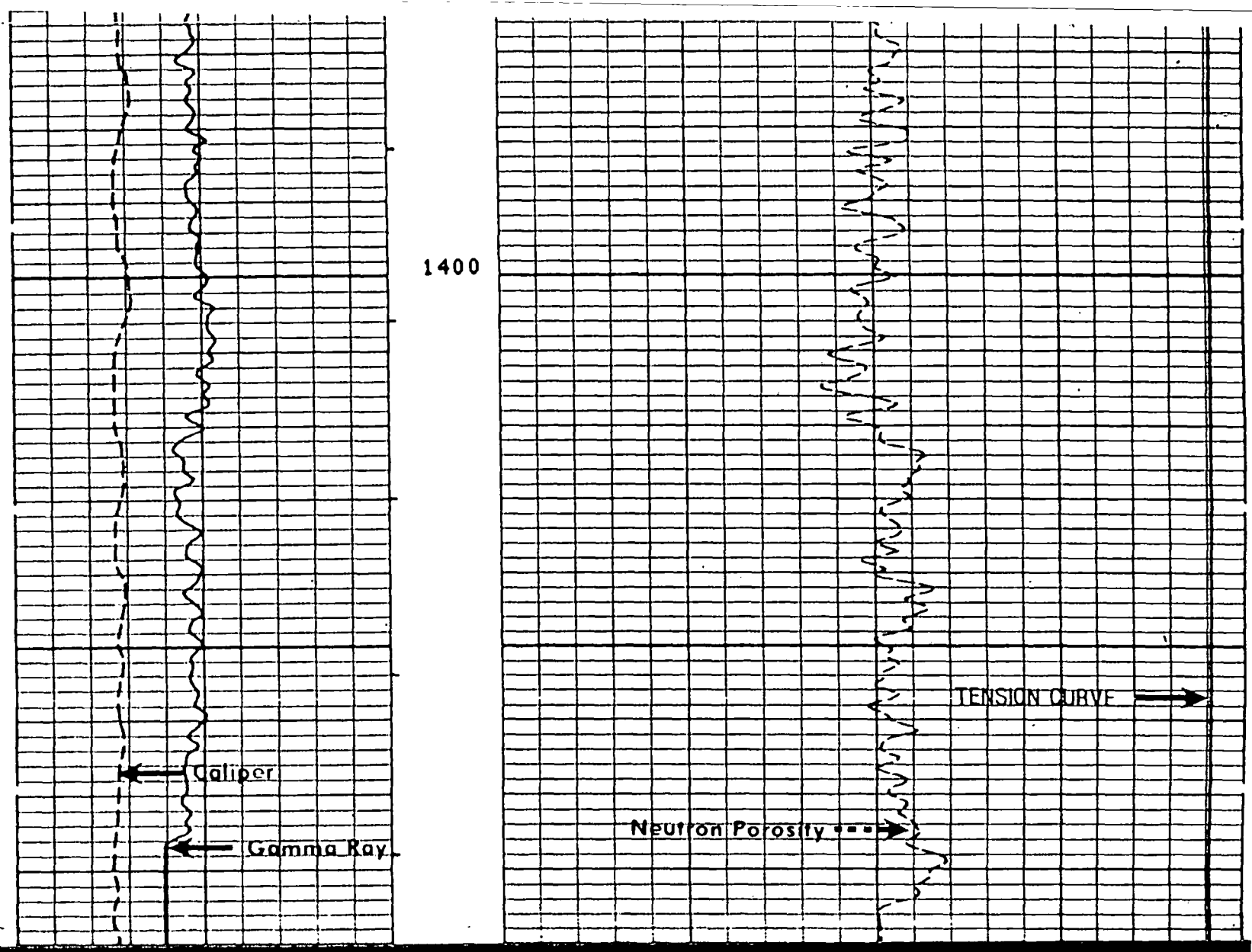


MAR02-1163

1500

FILE

5

SECTION NOT LOGGED

CALI(IN)			TENS(LB)
5.000	16.00		10000. 0.0
GR (GAPI)			
1.0	200.0		
CALI(IN)		NPHI( ) LIMESTONE	
6.00	26.00	0.6000	0.0

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

Neutron Porosity SCALE CHANGE

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

CALI(IN)			TENS(LB)
5.000	16.00		10000. 0.0
GR (GAPI)		DPHI( ) LIMESTONE	

MAR02-1164

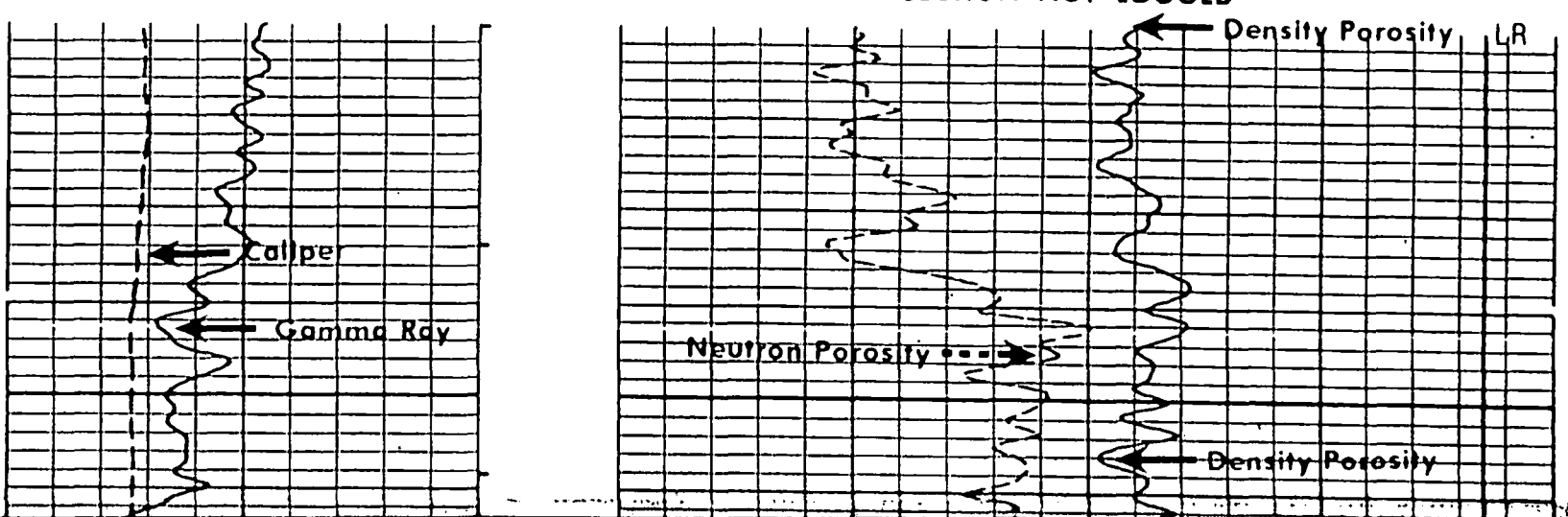
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

CALI(IN) 6.000 16.00		TENS(LB) 10000. 0.0
GR (GAPI) 0.0 200.0		DPHI( ) LIMESTONE 0.4500 -0.150
CALI(IN) 16.00 26.00		NPHI( ) LIMESTONE 0.4500 -0.150

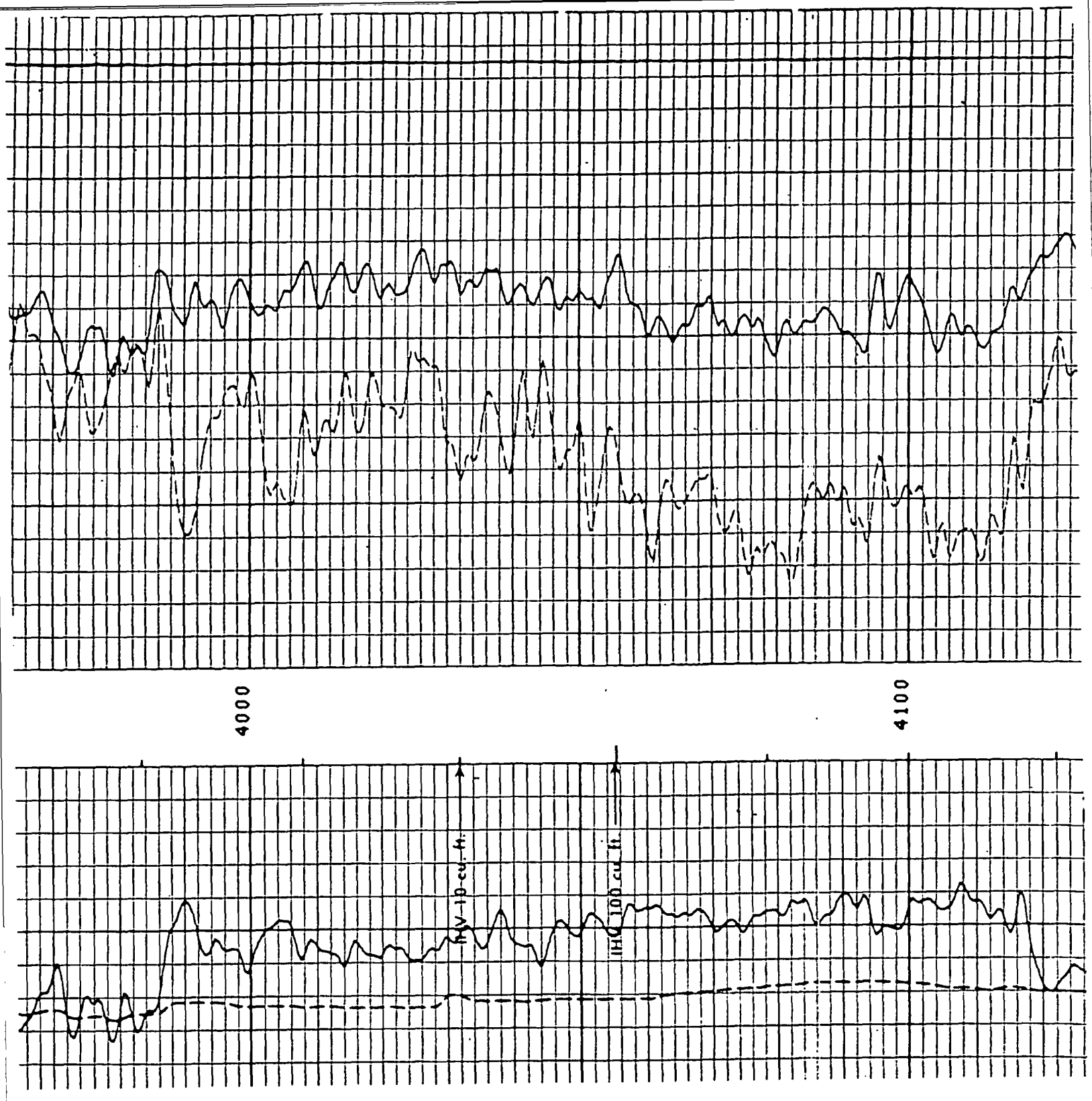
FILE

4

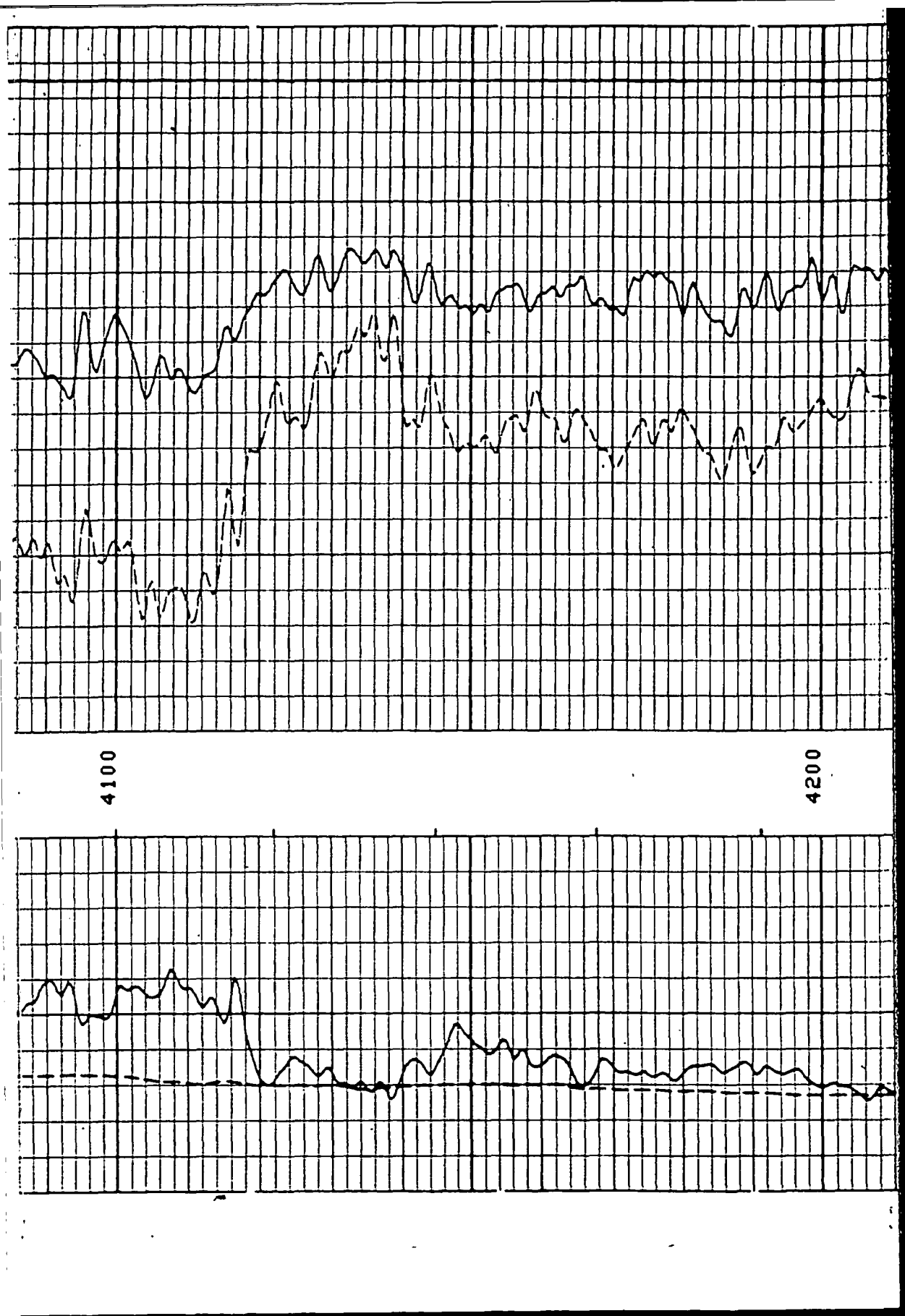
SECTION NOT LOGGED



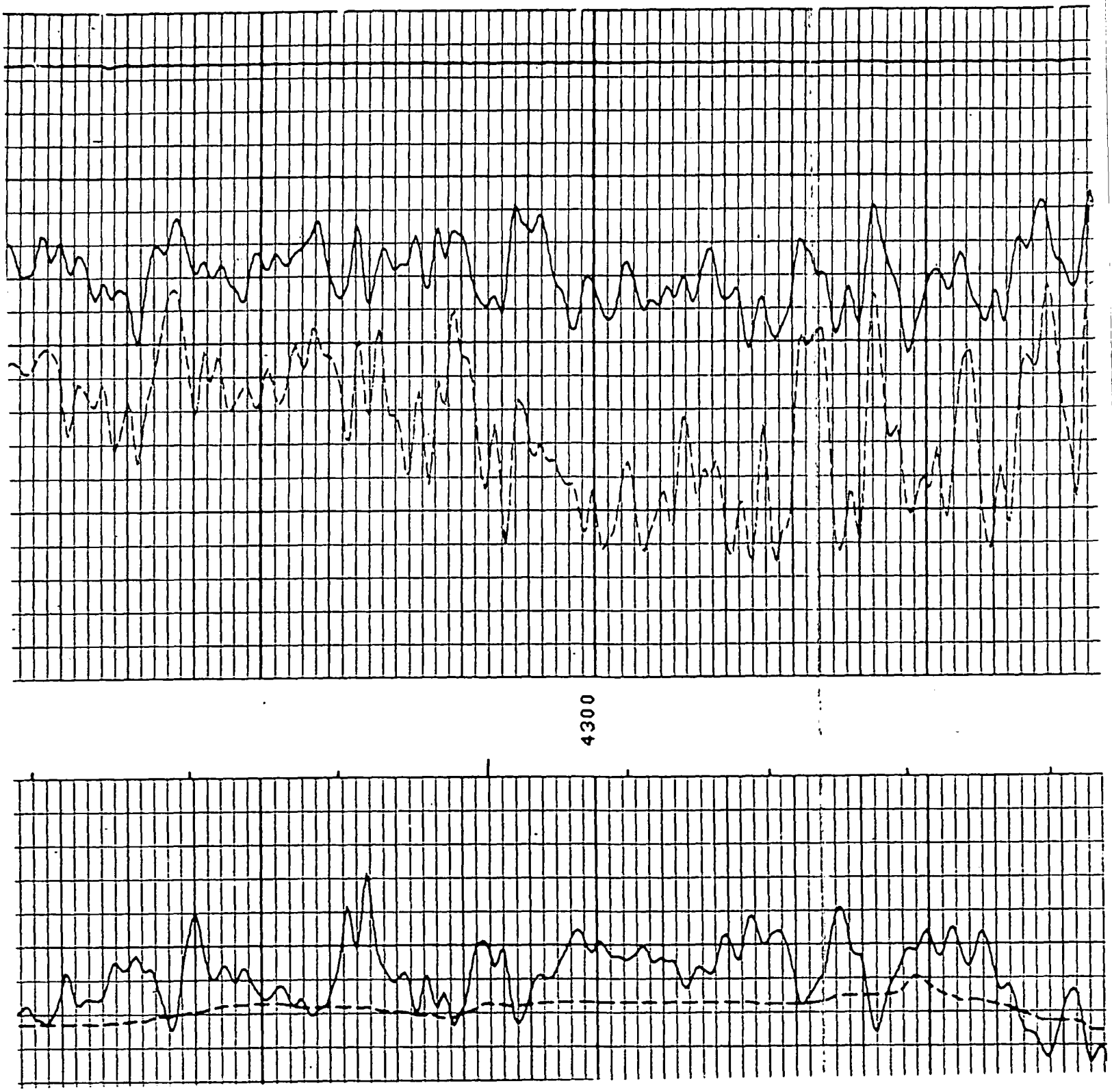
MAR02-1165



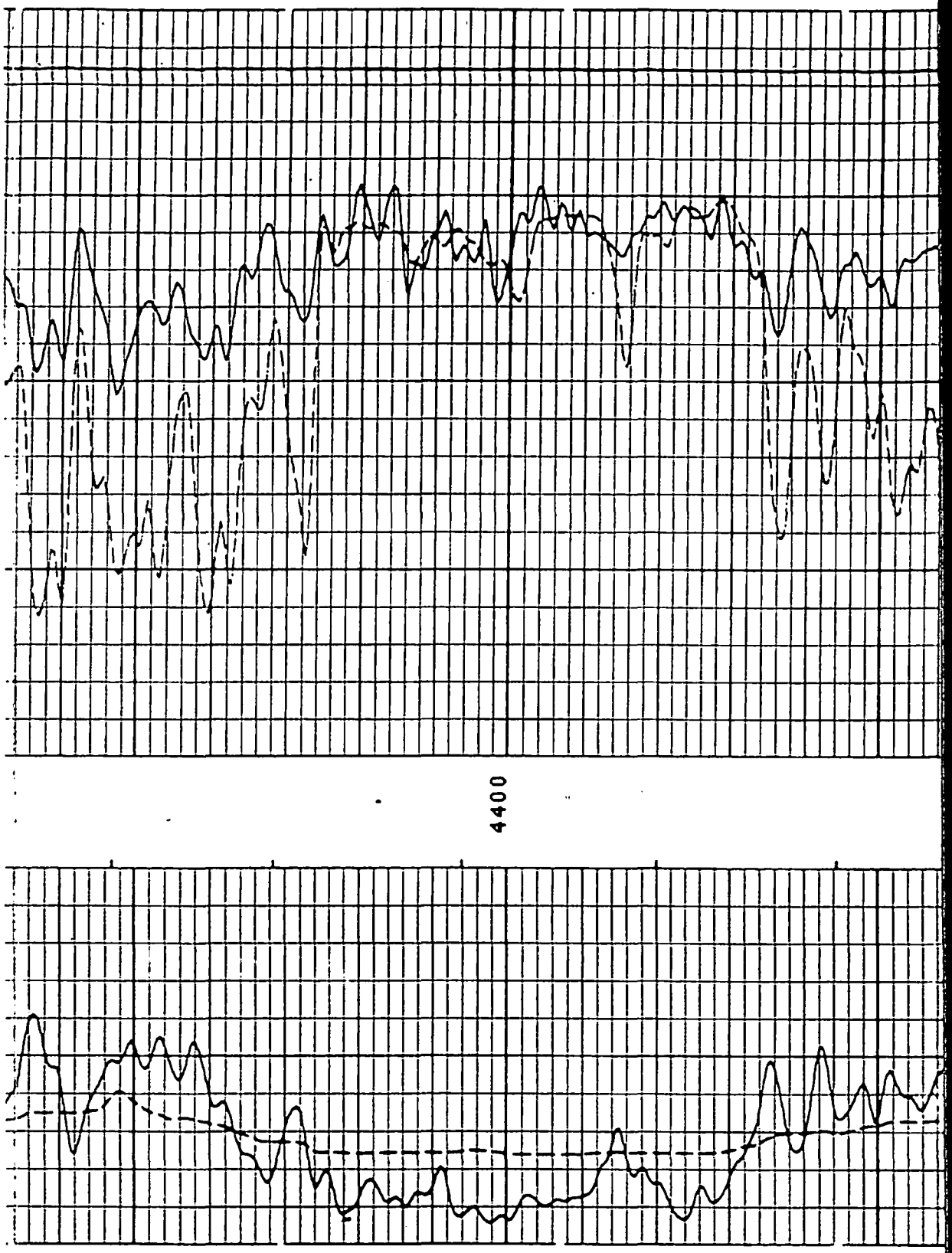
MAR02-1166



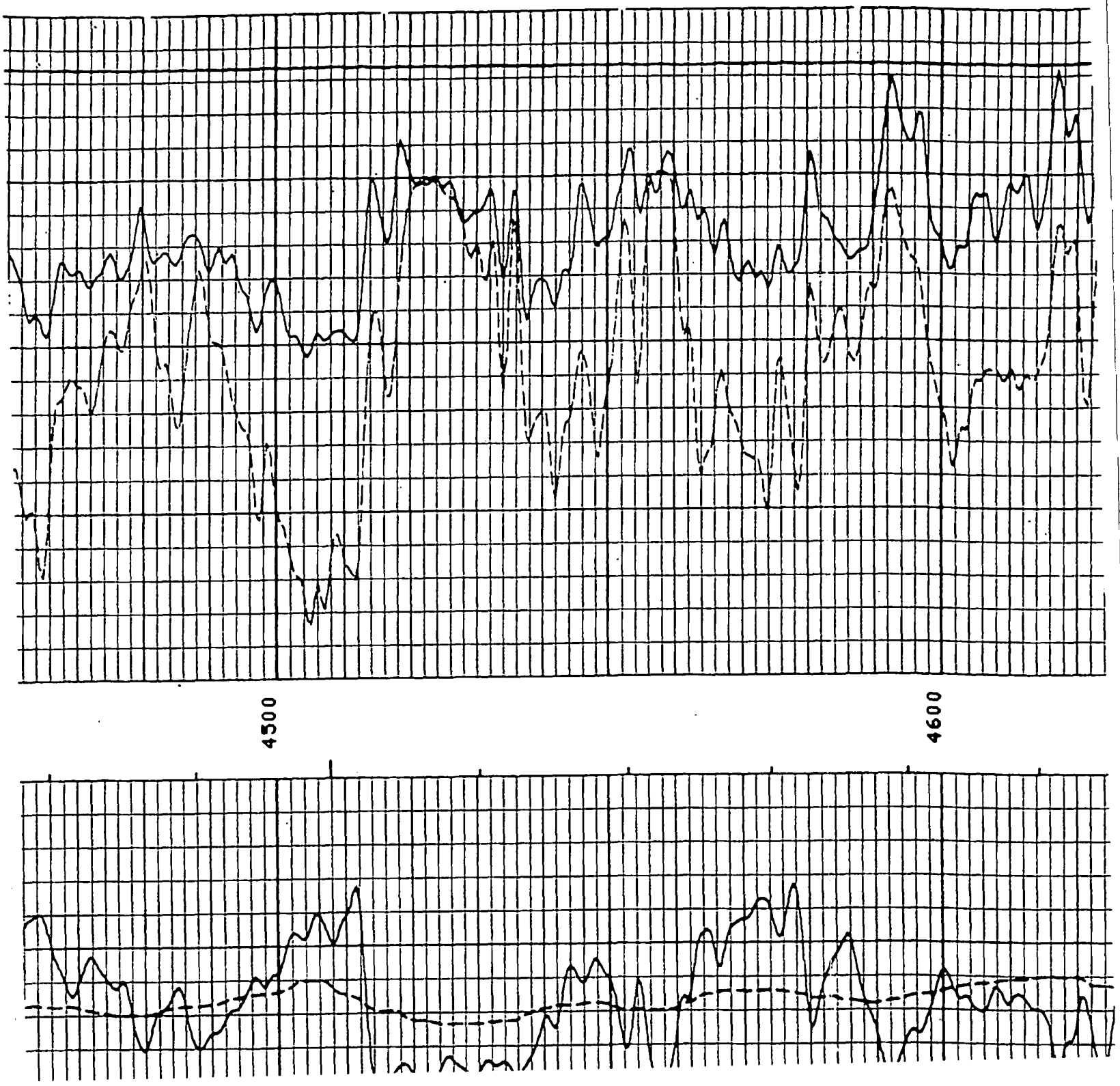
MAR02-1167



MAR02-1168

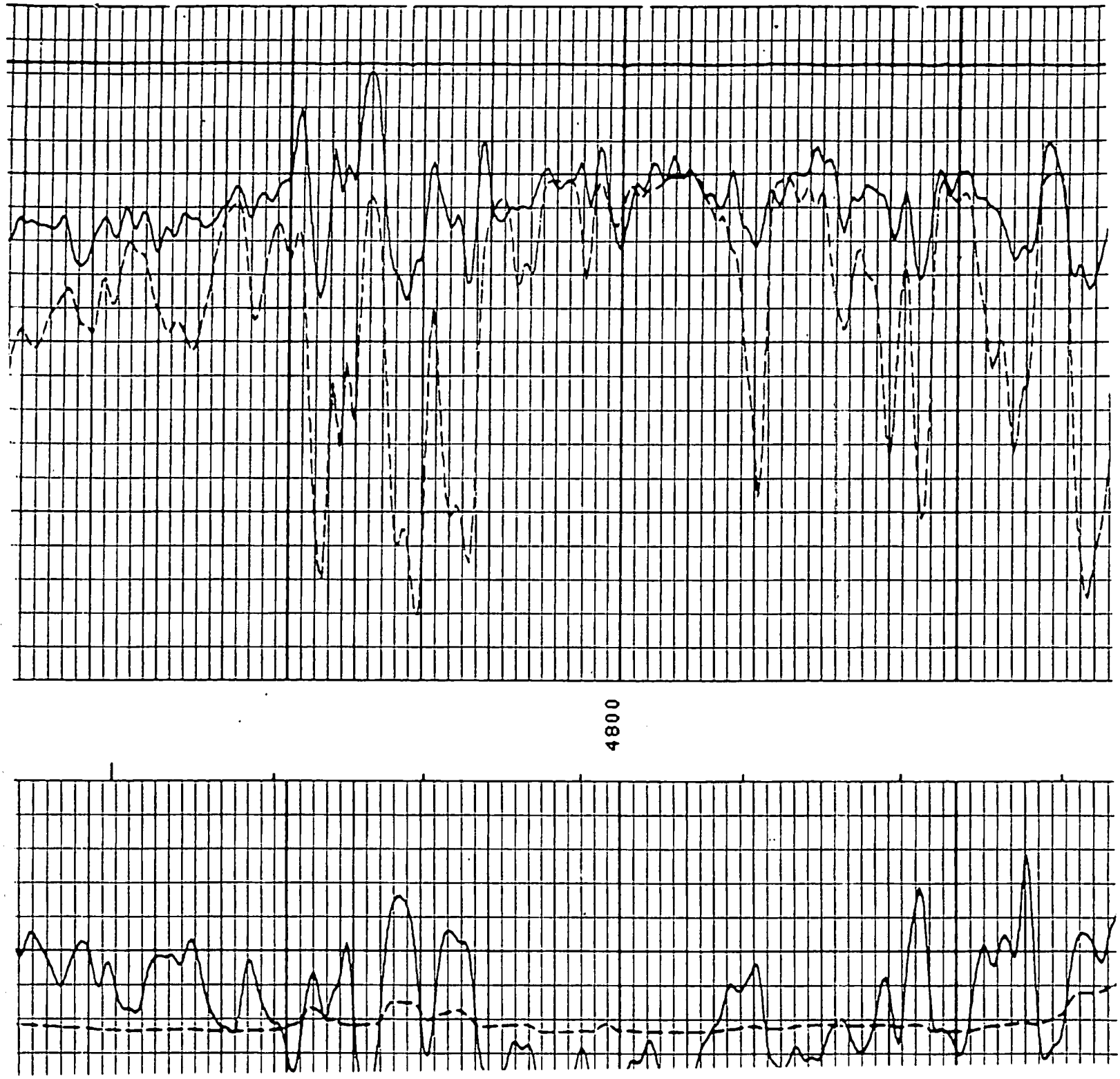


MAR02-1169

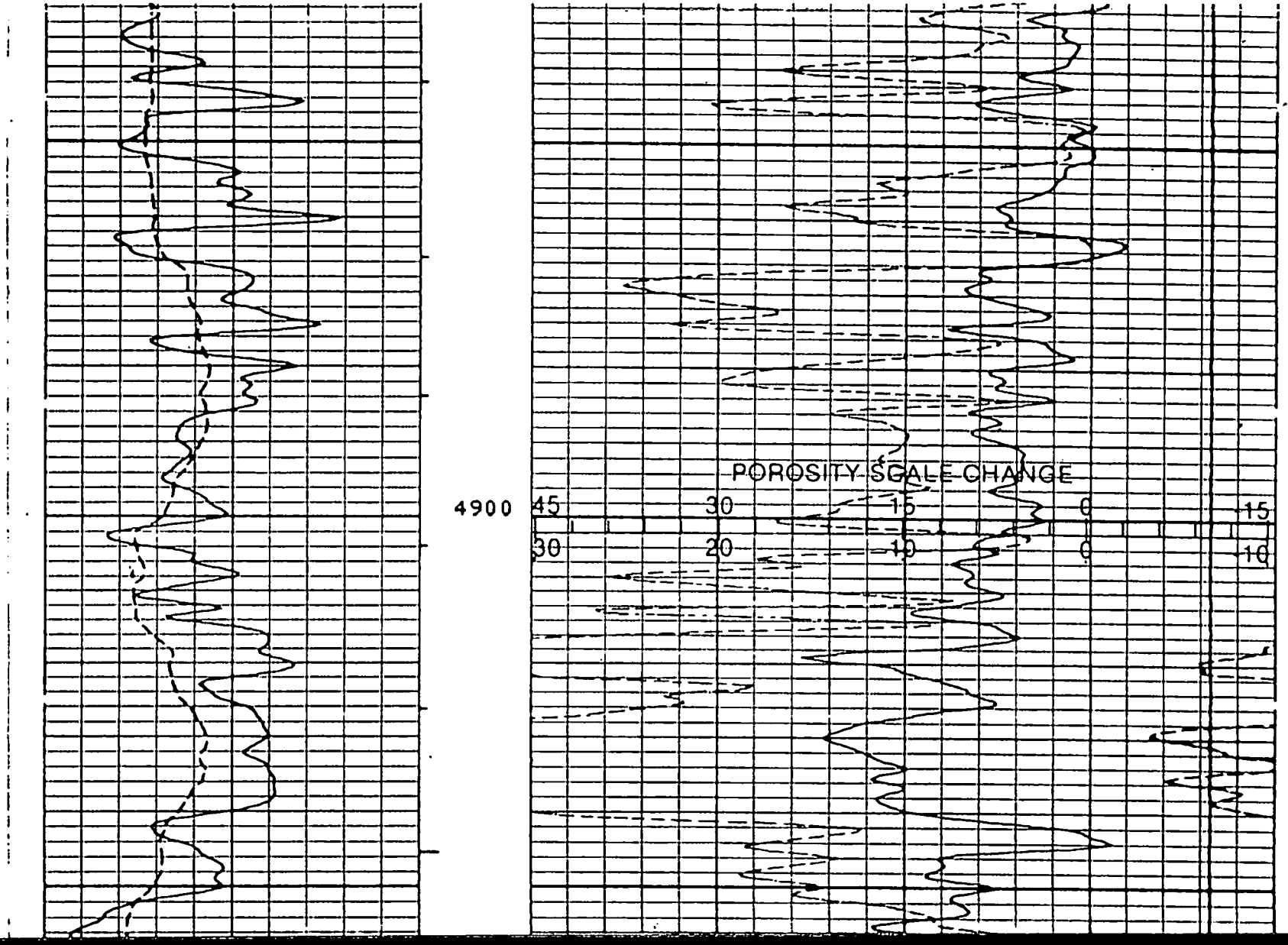


MAR02-1170

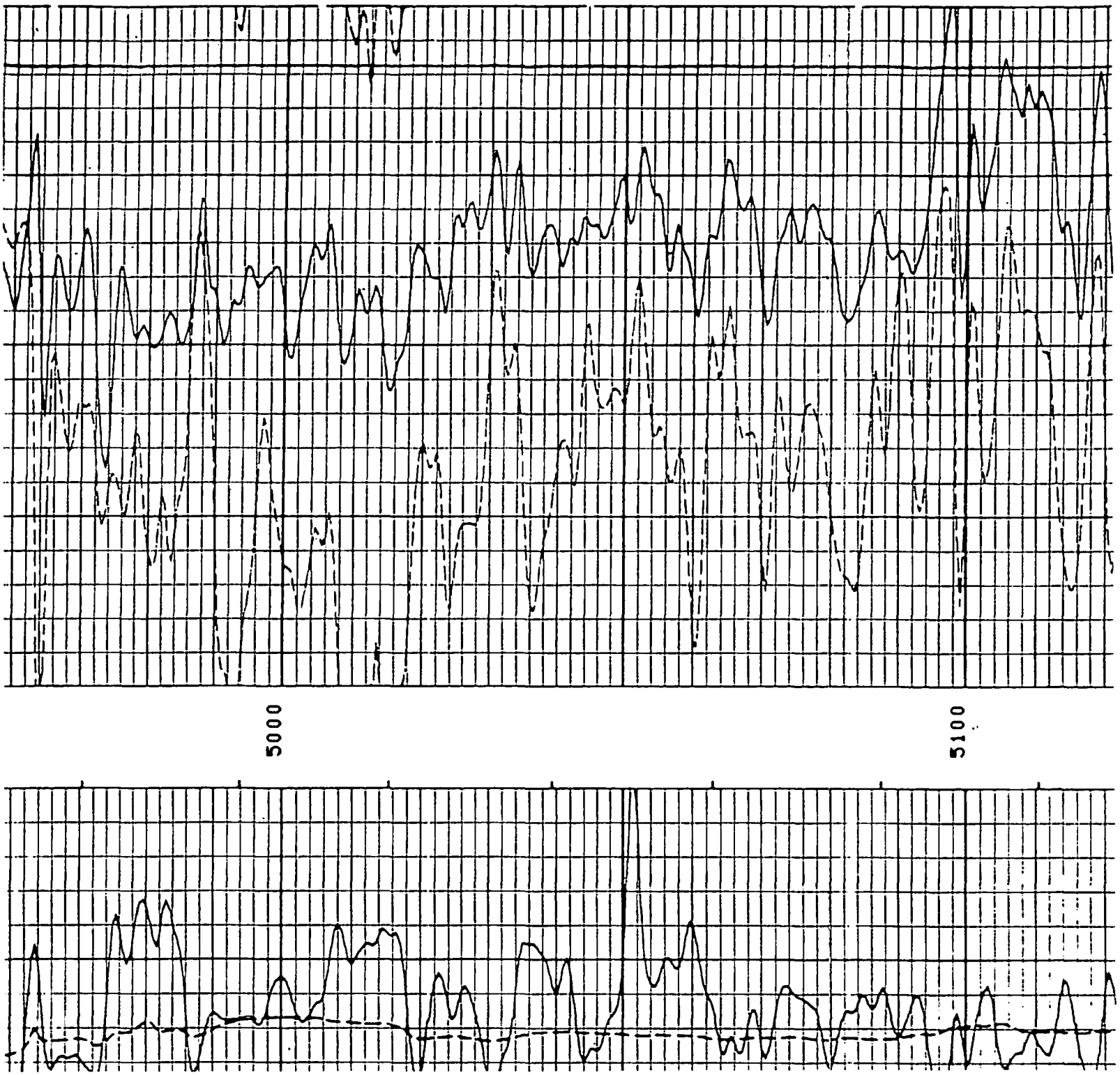
MAR02-1171



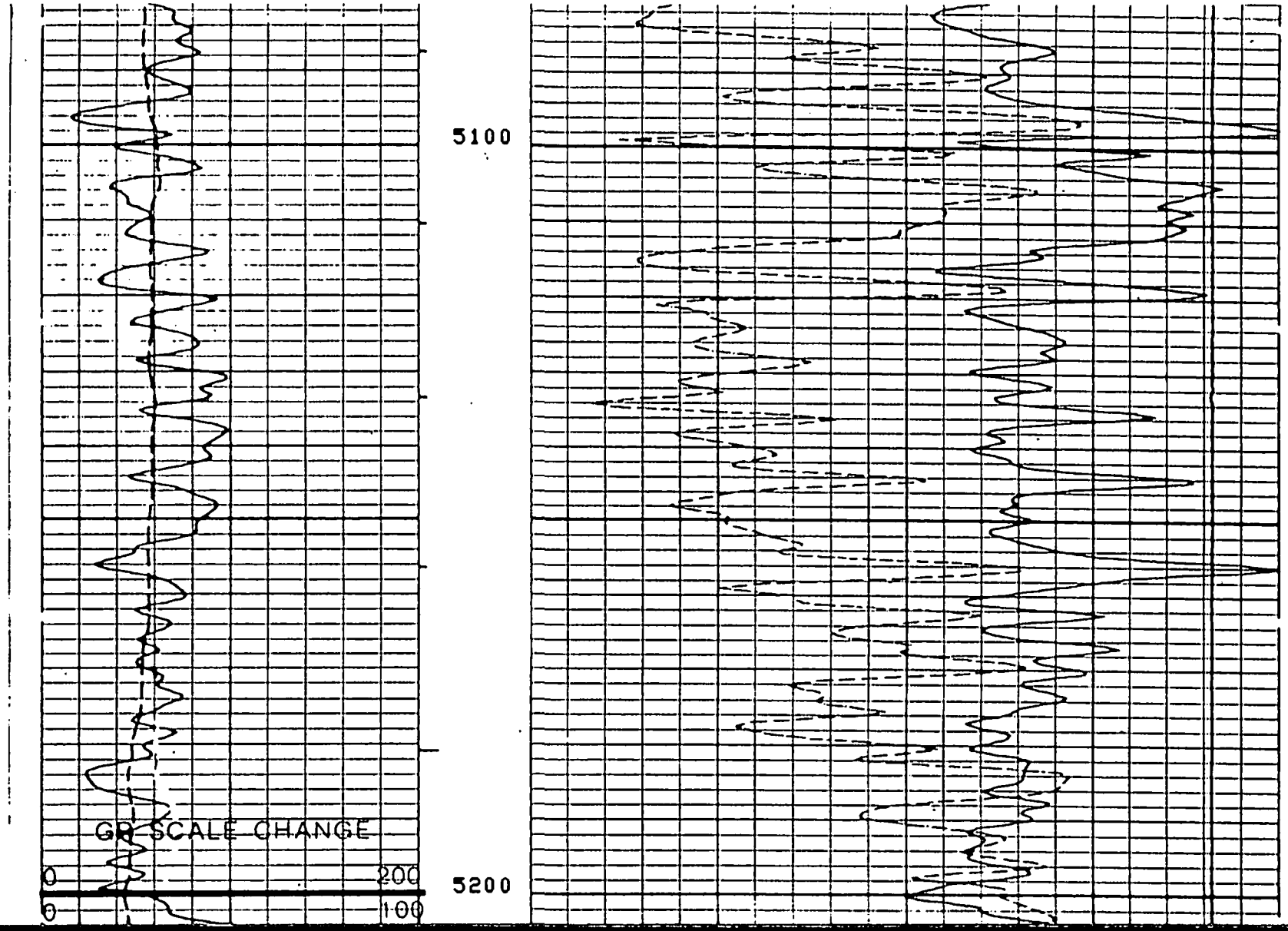
MAR02-1172



MAR02-1173

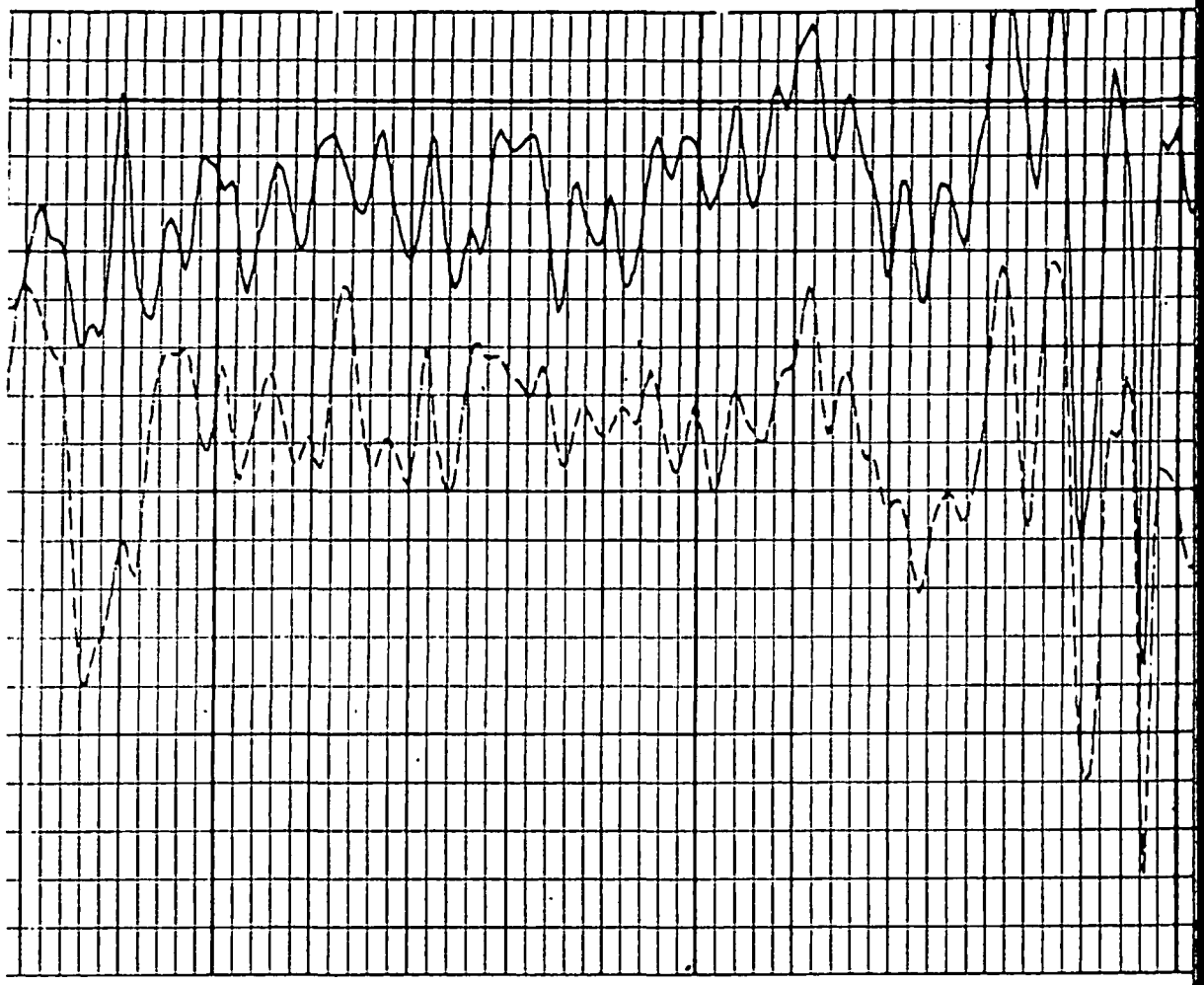


MAR02-1174



MAR02-1175

MAR02-1176



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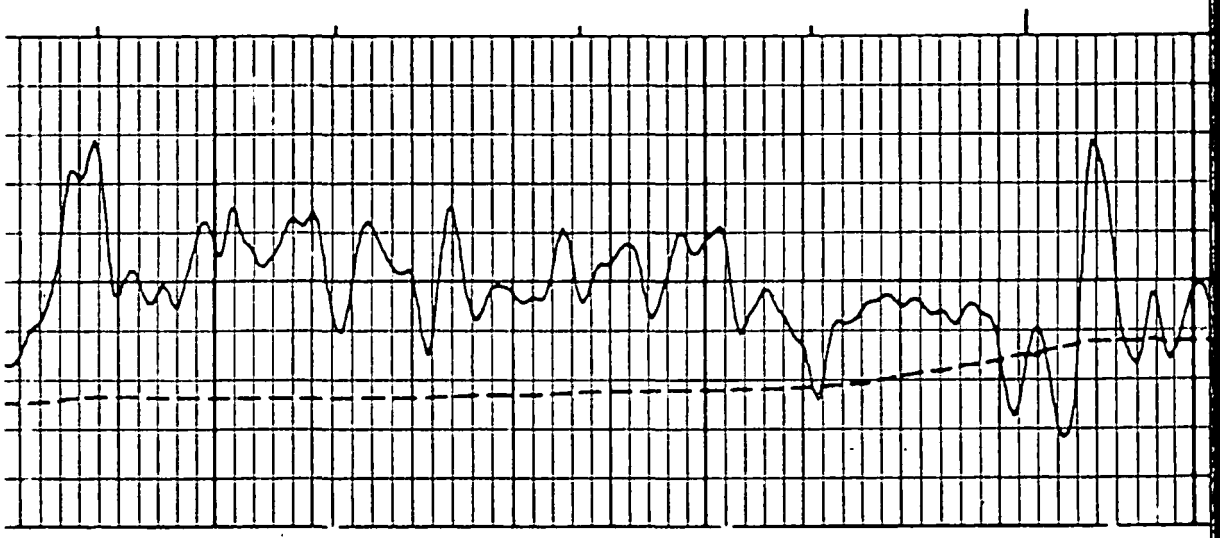
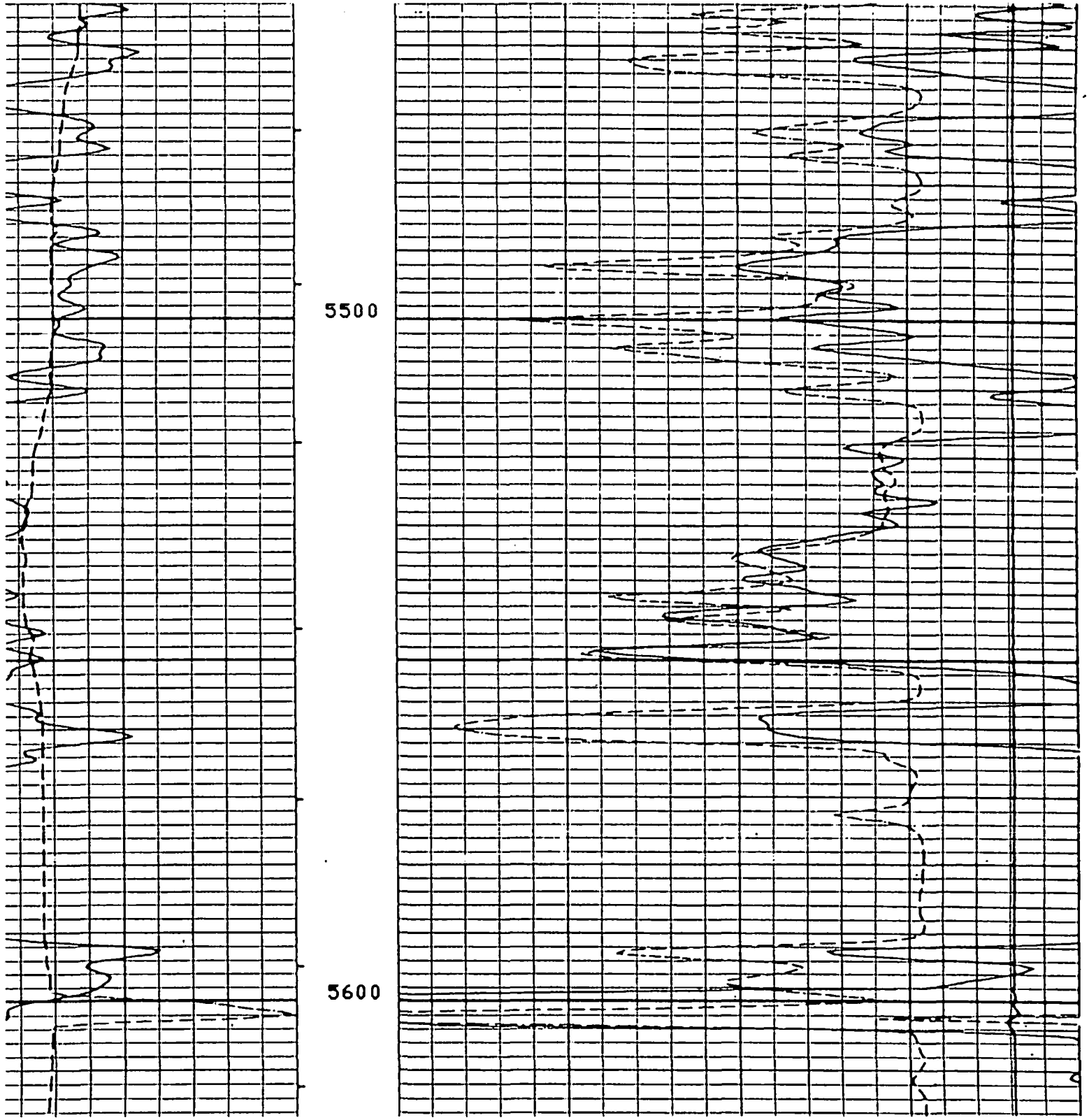
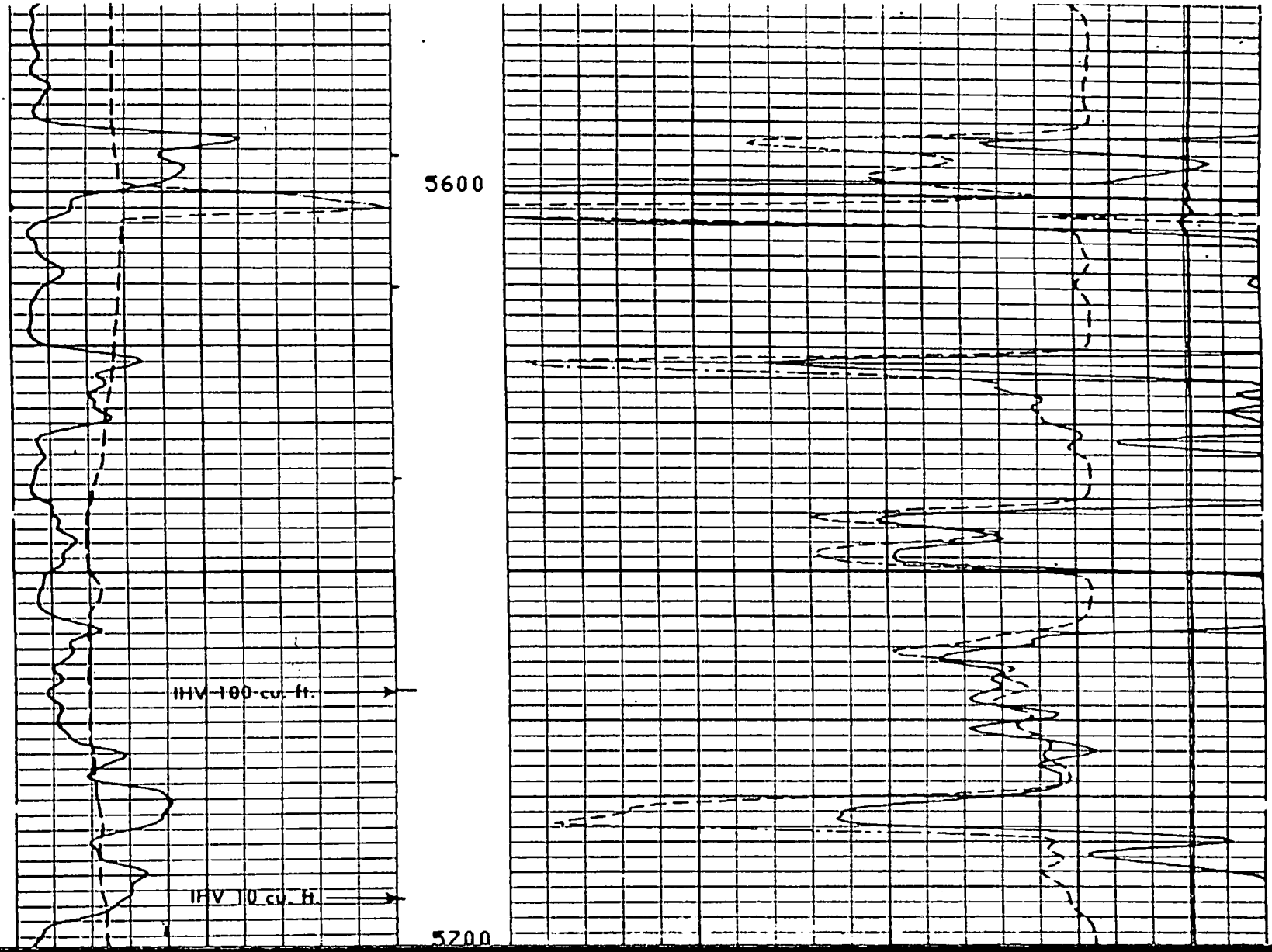


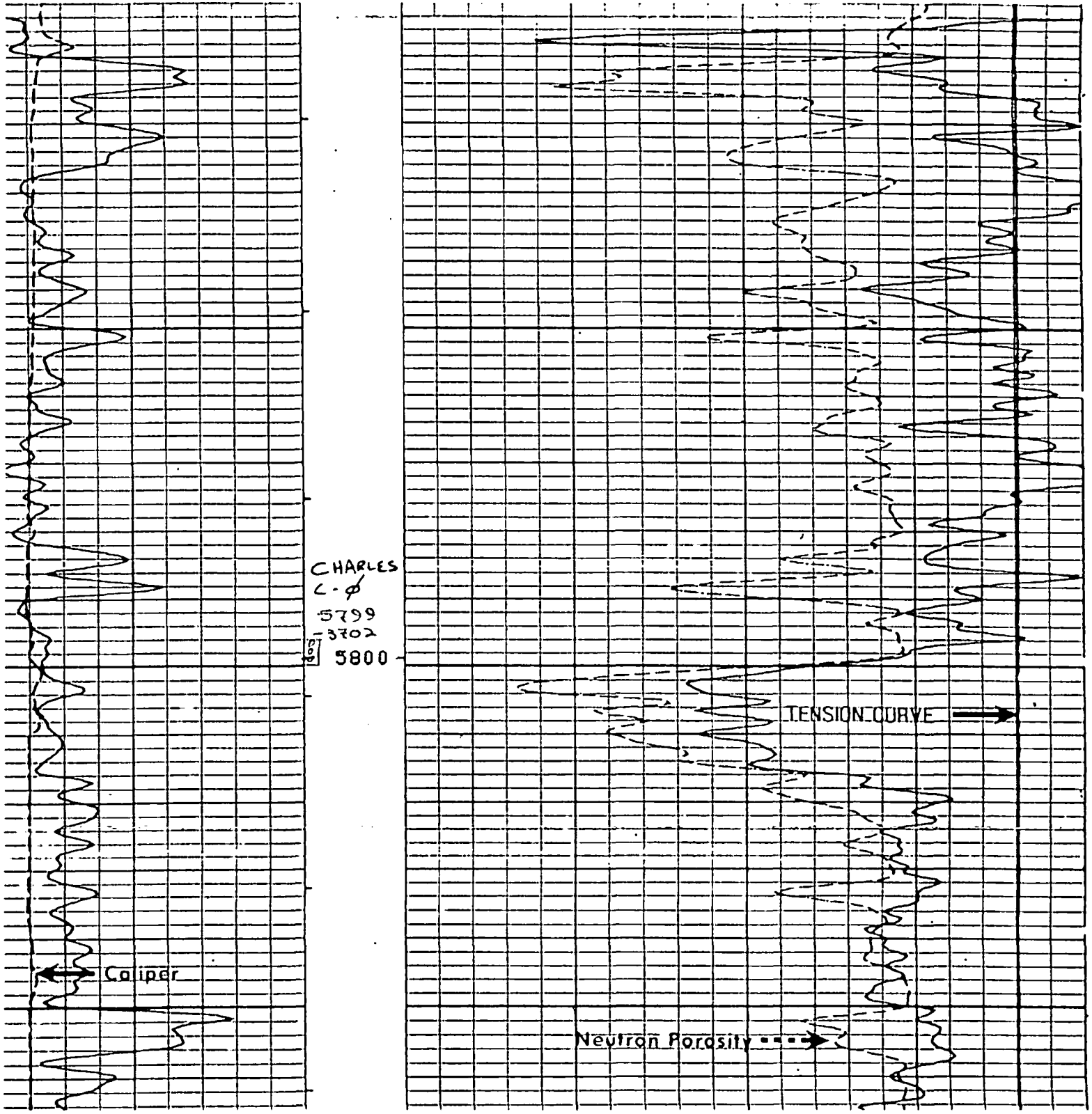
MAR02-1177



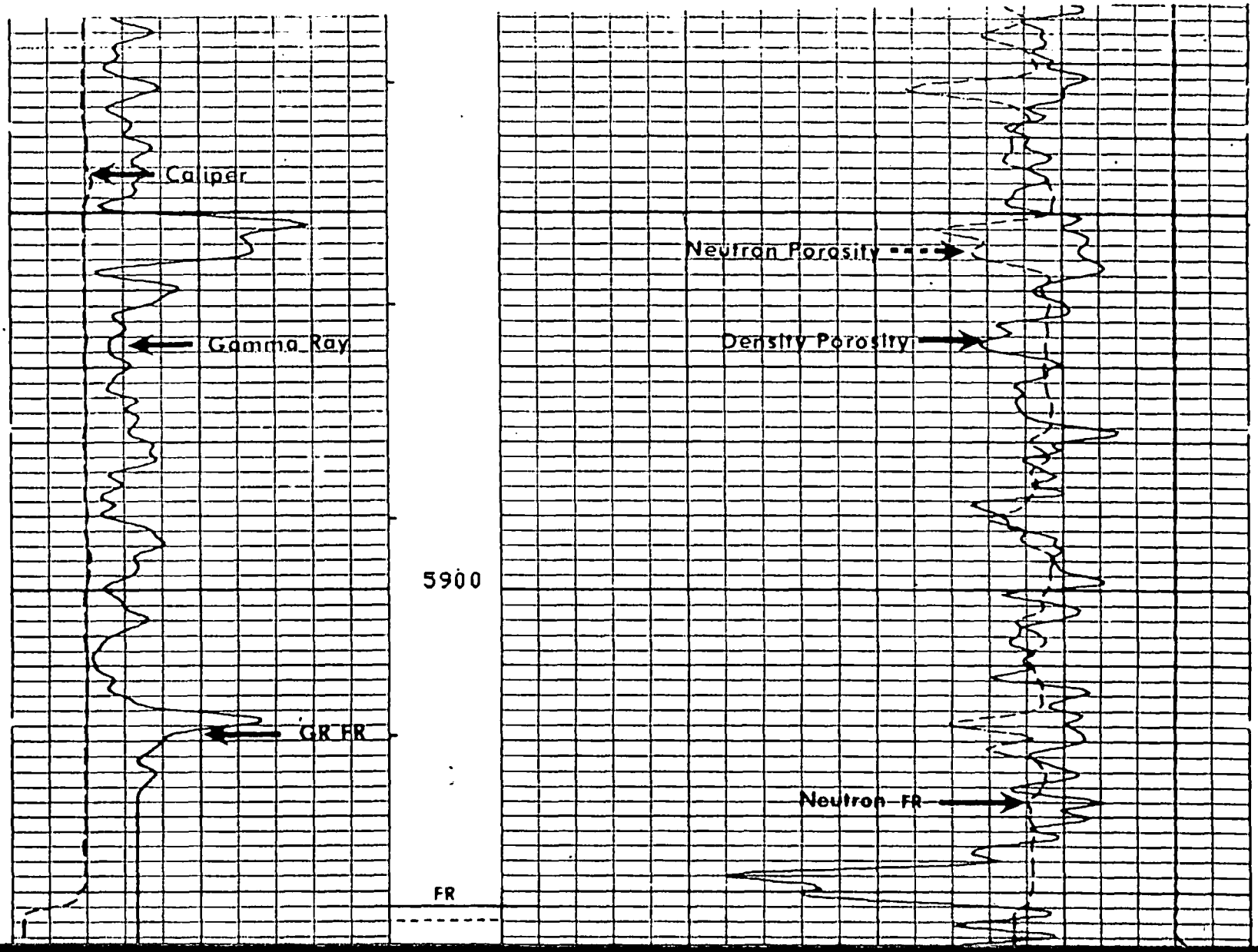
MAR02-1178



MAR02-1179


CHARLES
C-Ø
5799
-3702
5800
TENSION CURVE
Caliper
Neutron Porosity

MAR02-1180


Caliper
Gamma Ray
GR FR
5900
FR
Neutron Porosity
Density Porosity
Neutron FR

MAR02-1181

FILE

4

CALI(IN)			TENS(LB)
000	16.00		10000. 0.0
GR (GAPI)			DPHI( ) LIMESTONE
0	100.0	0.3000	-0.100
CALI(IN)			NPHI( ) LIMESTONE
5.00	26.00	0.3000	-0.100

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

CALI(IN)			TENS(LB)
.000	16.00		10000. 0.0
GR (GAPI)			DPHI( ) LIMESTONE
.0	100.0	0.3000	-0.100
CALI(IN)			NPHI( ) LIMESTONE
5.00	26.00	0.3000	-0.100

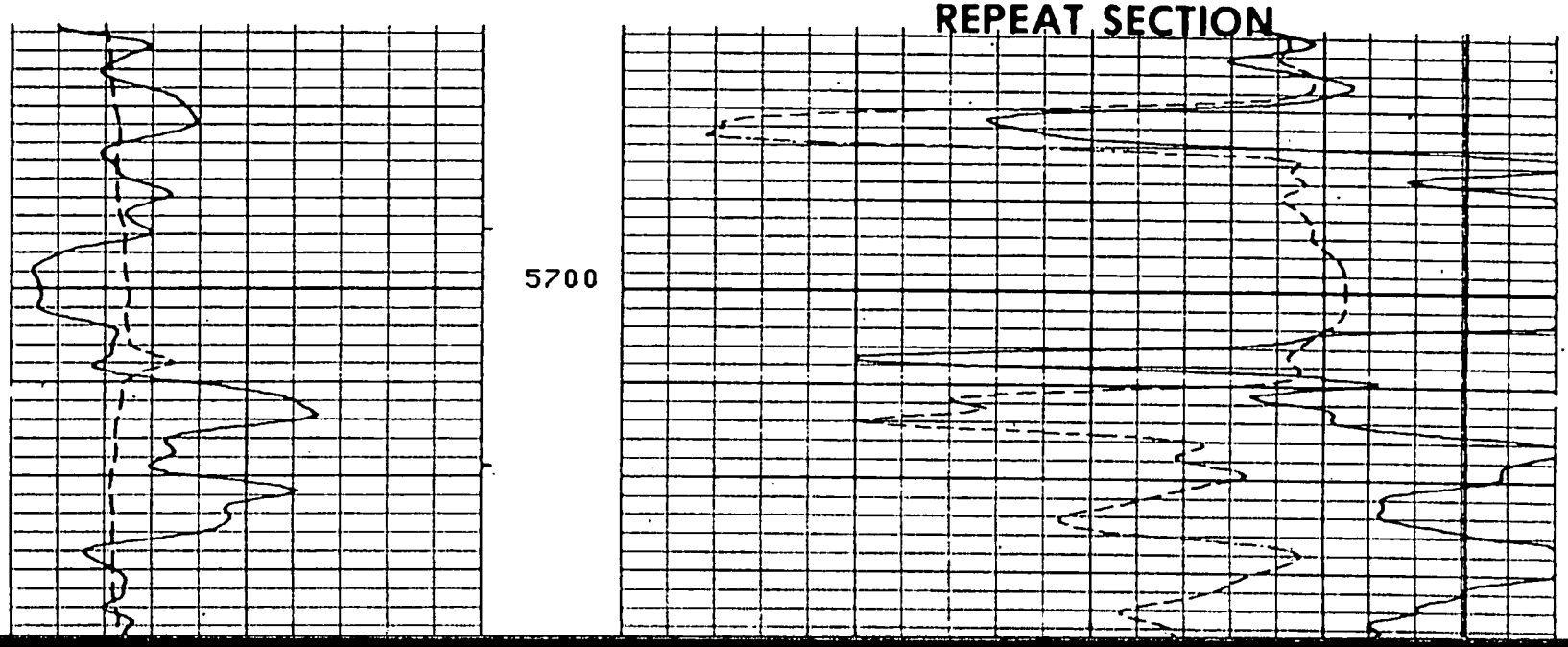
BHF	WATE				
DO	0.0	BHS	OPEN	FPHI	PHIX

CALI(IN)			TENS(LB)
6.000	16.00		10000. 0.0
GR (GAPI)			DPHI( ) LIMESTONE
0.0	100.0		0.3000 -0.100
CALI(IN)			NPHI( ) LIMESTONE
16.00	26.00		0.3000 -0.100

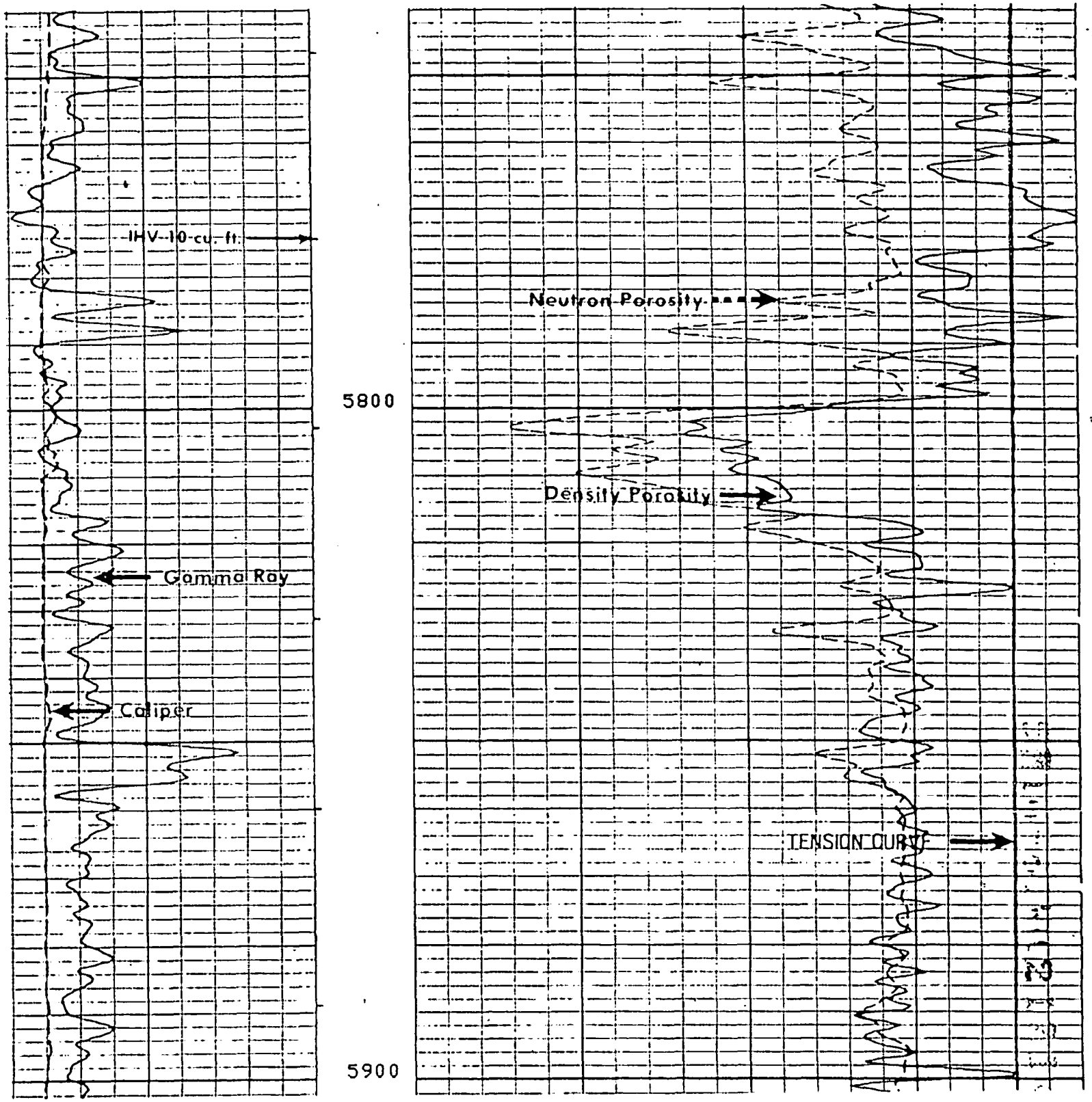
FILE

3

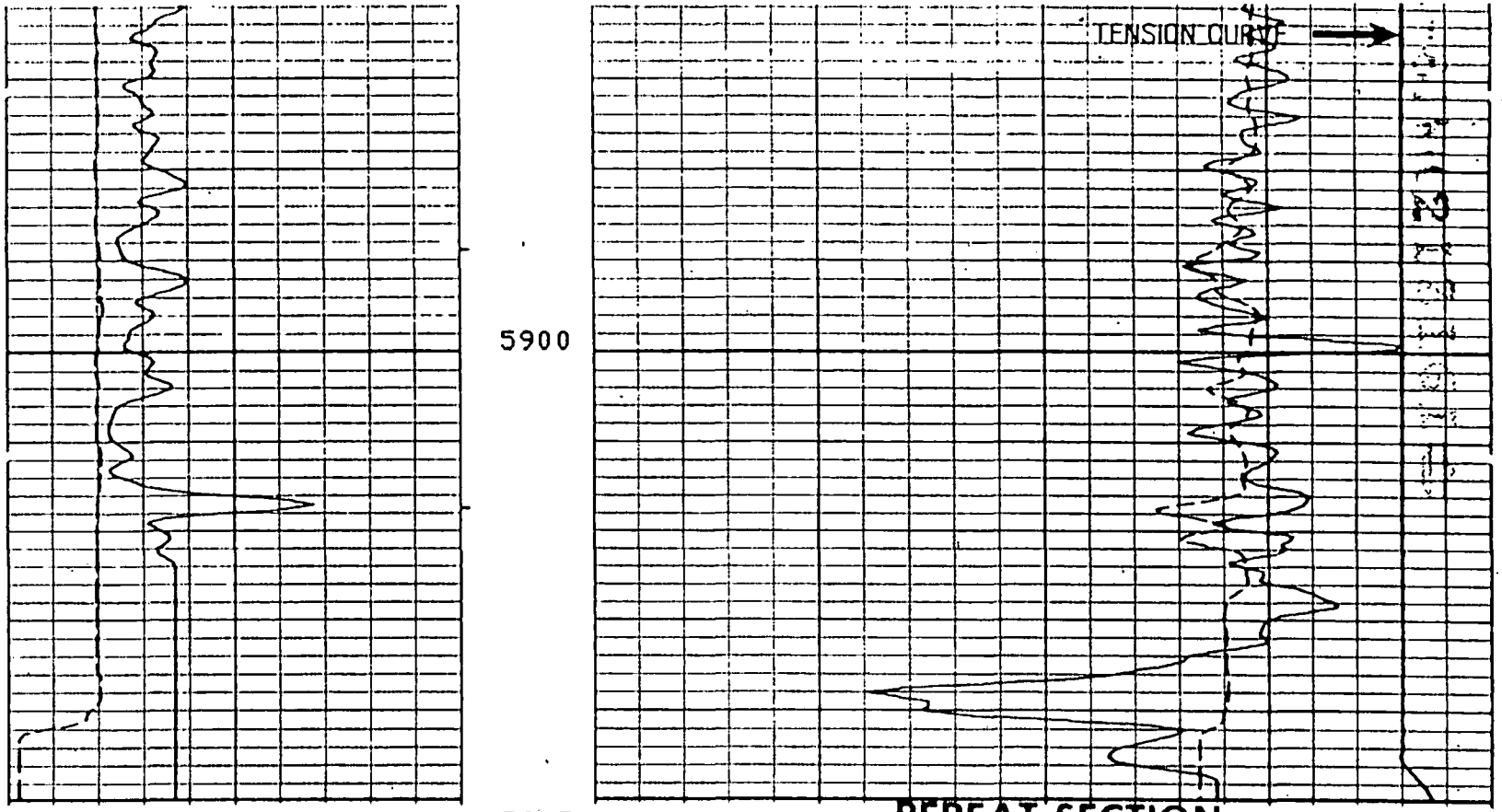
REPEAT SECTION



MAR02-1183


IHV-10-cu. ft.
Gamma Ray
Caliper
5800
5900
Neutron Porosity
Density Porosity
TENSION CURVE

MAR02-1184



CALI(IN)			TENS(LB)
6.000	16.00		10000. 0.0
GR (GAPI)			DPHI( ) LIMESTONE
0.0	100.0	0.3000	-0.100
CALI(IN)			NPHI( ) LIMESTONE

MAR02-1185

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

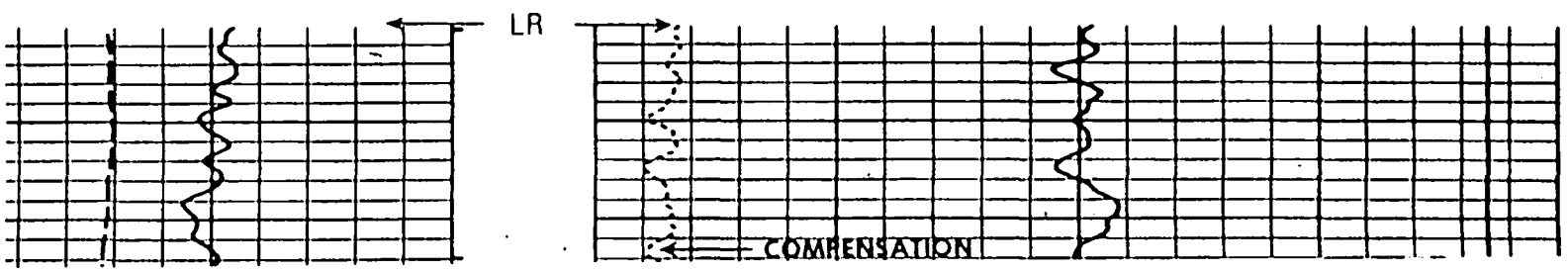
PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

CALI(IN)			
.000 16.00			
GR (GAPI)		DRHO(G/C3)	TENS(LB)
.0 200.0		-0.050 0.4500	10000. 0.0
CALI(IN)		RHOB(G/C3)	
6.00 26.00		2.000 3.000	

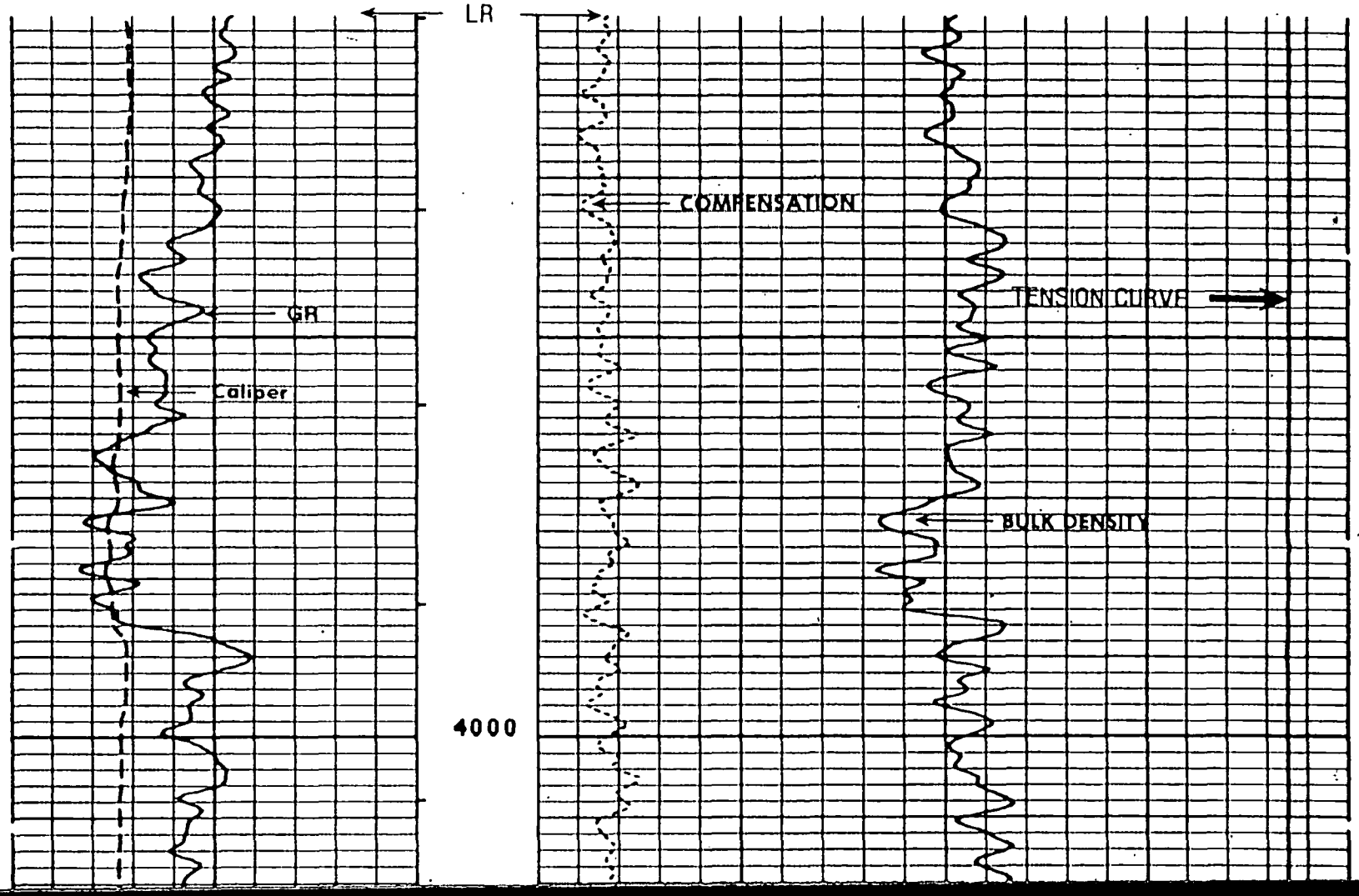
FILE

4

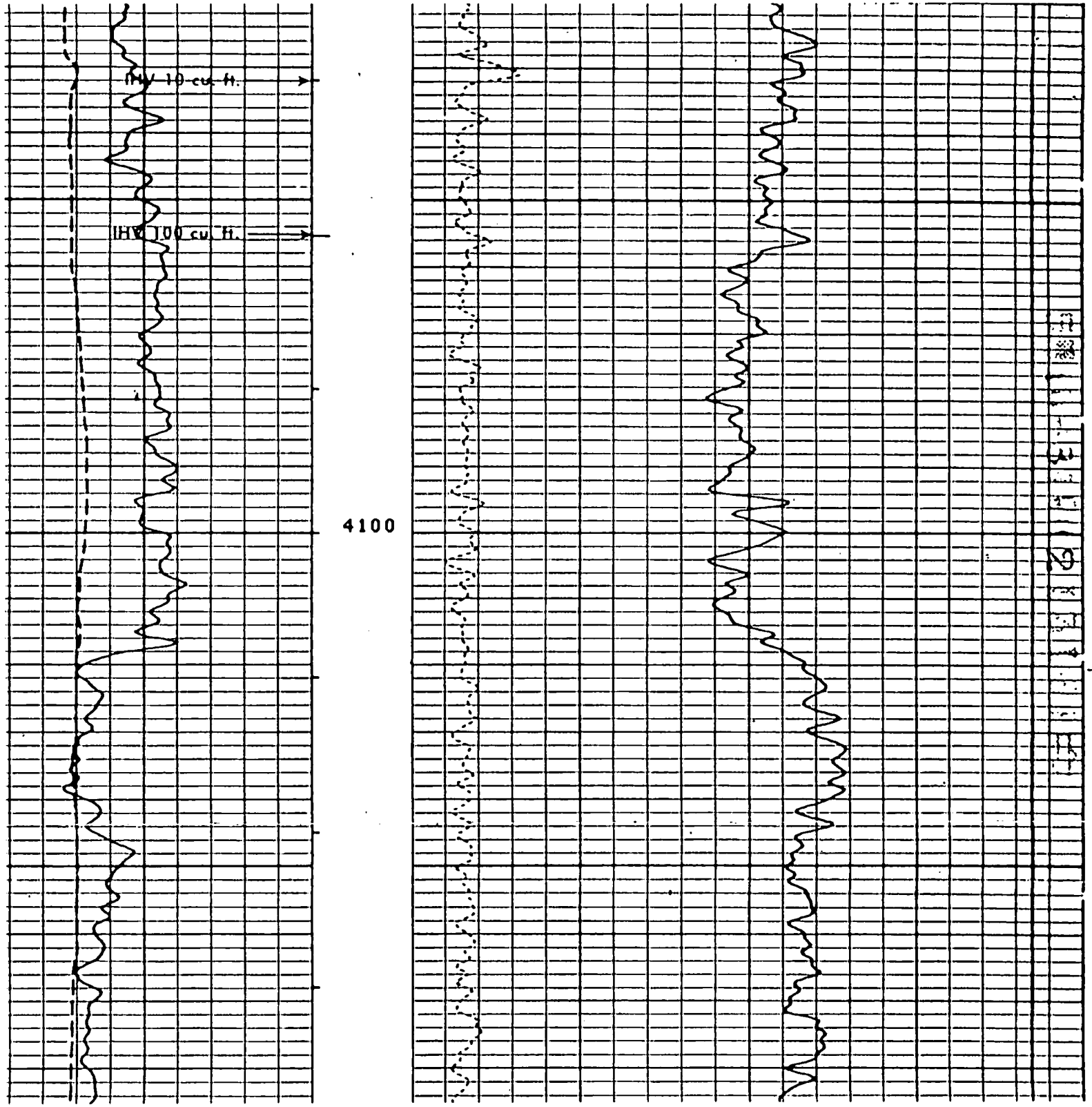


FILE

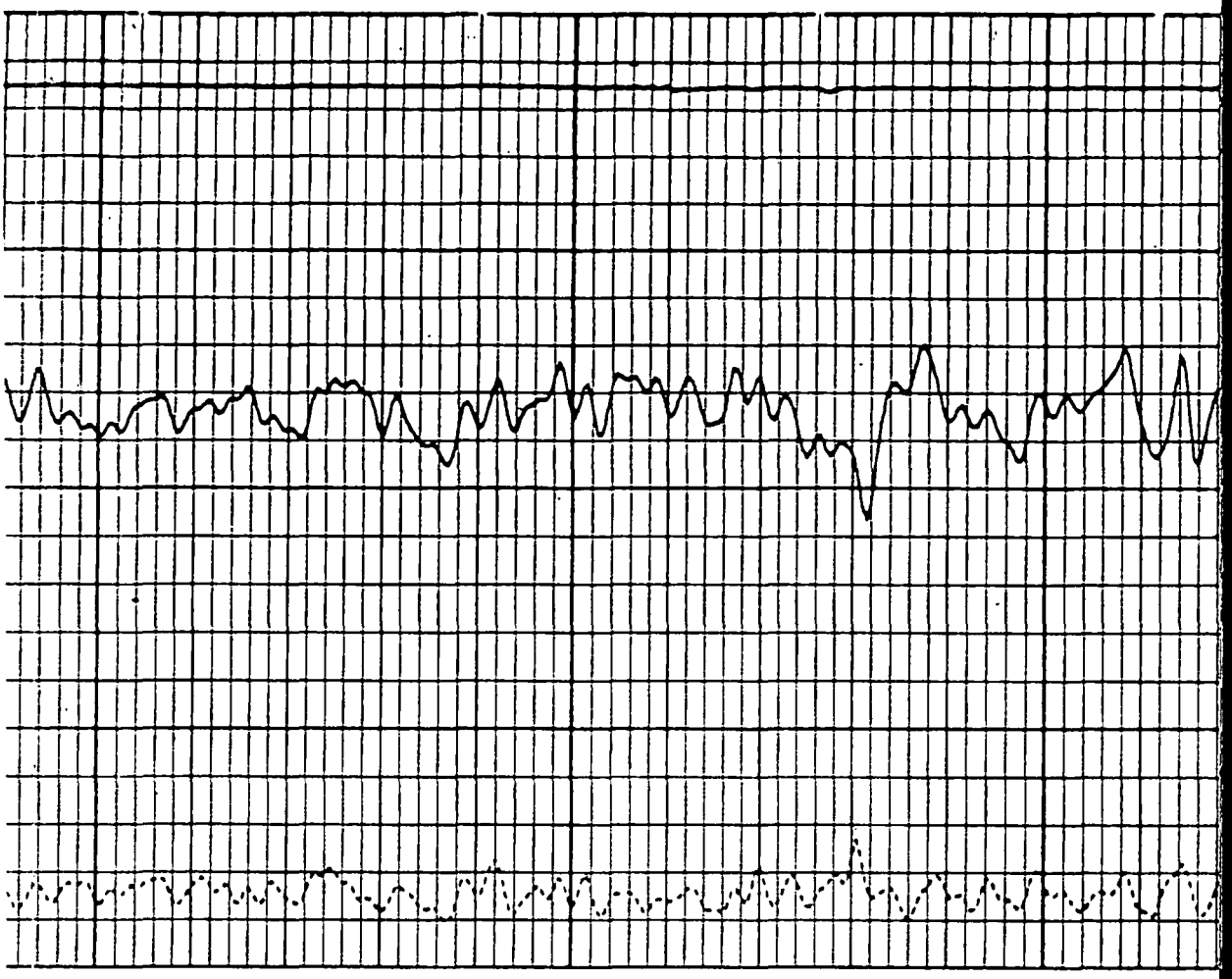
4



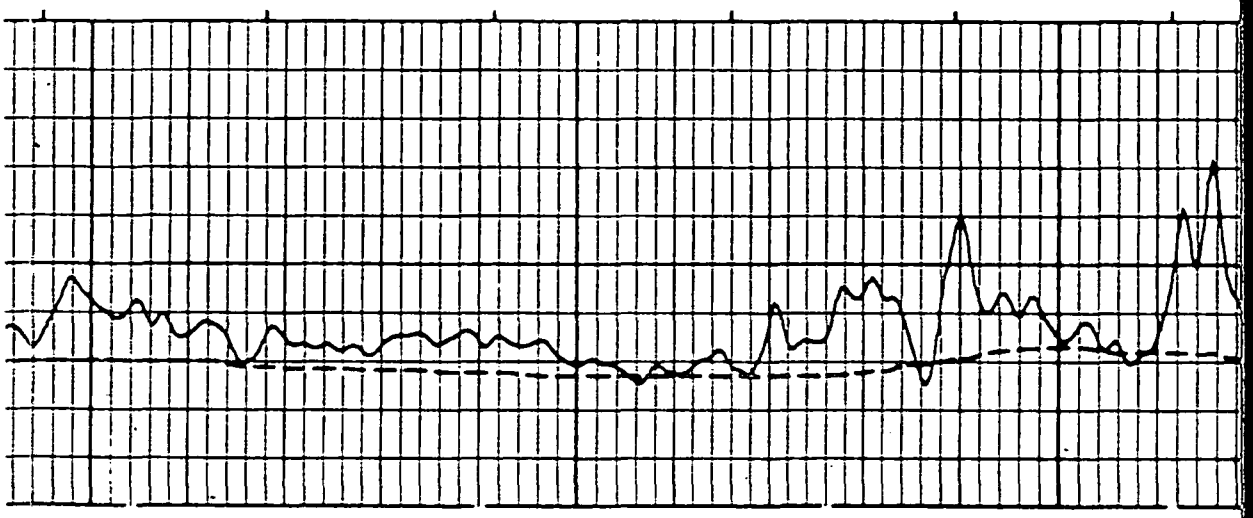
MAR02-1187



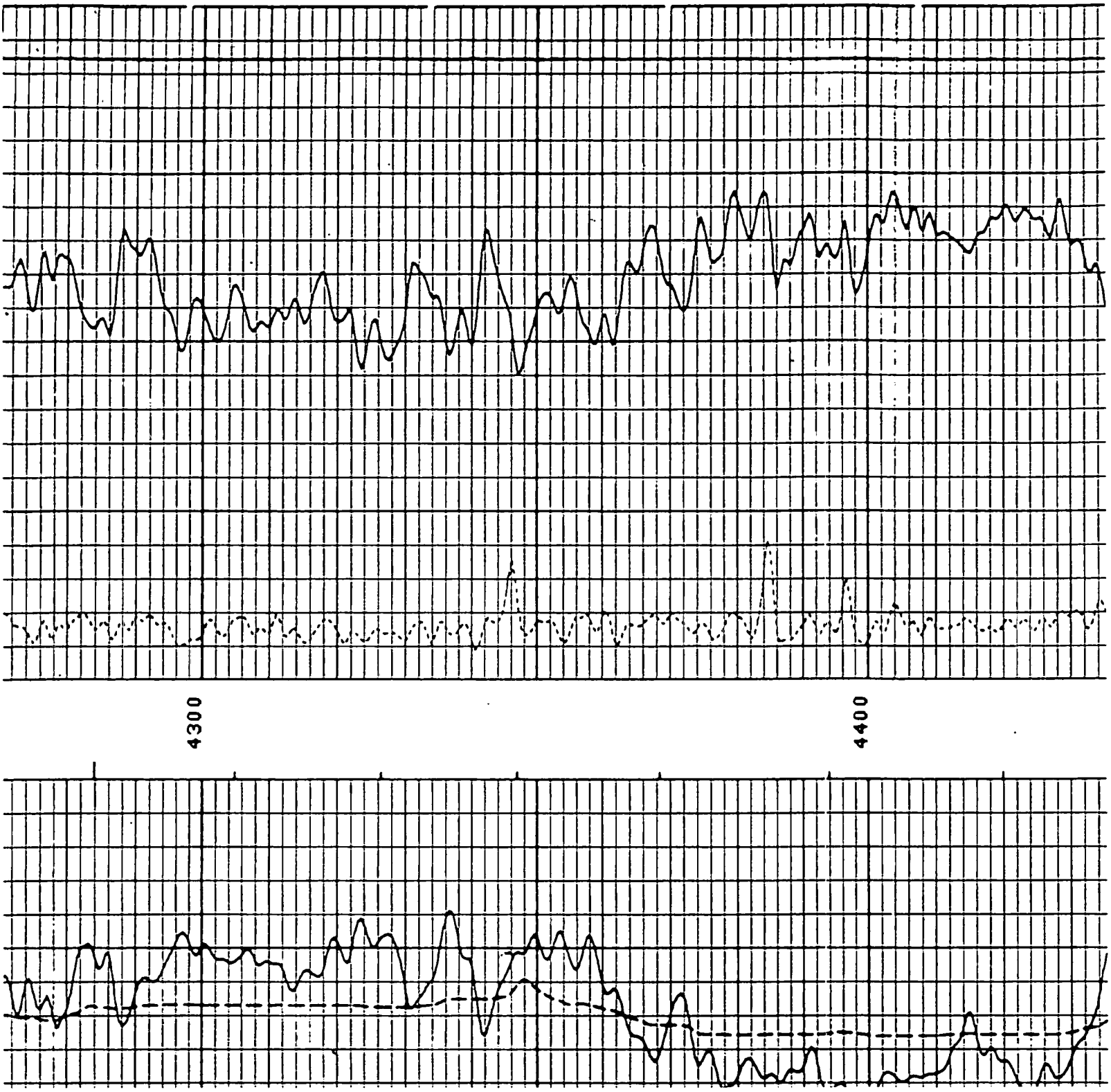
MAR02-1188



4200

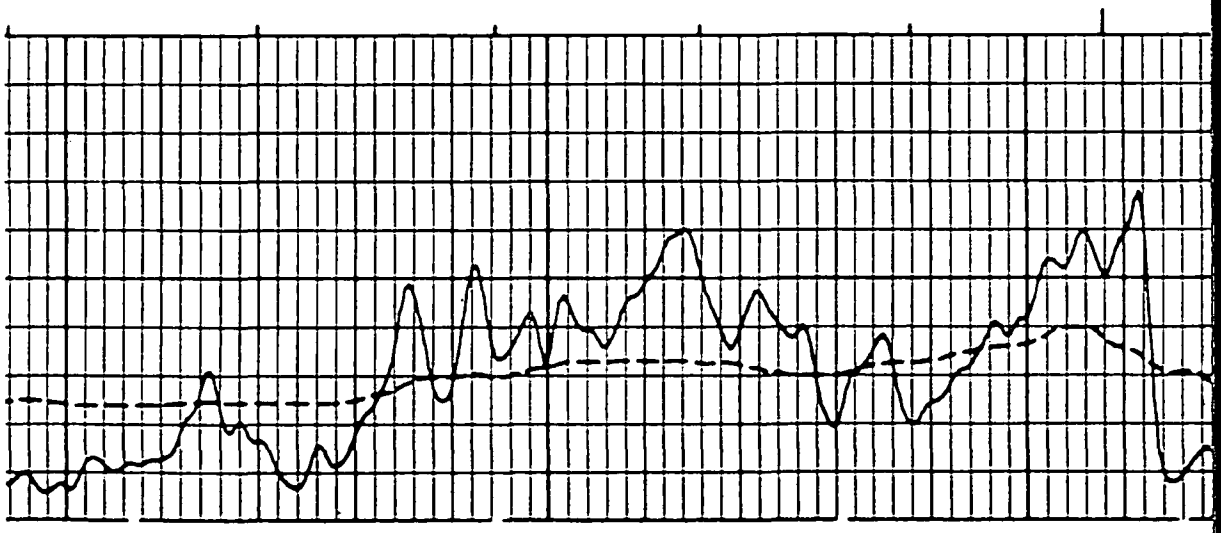


MAR02-1189

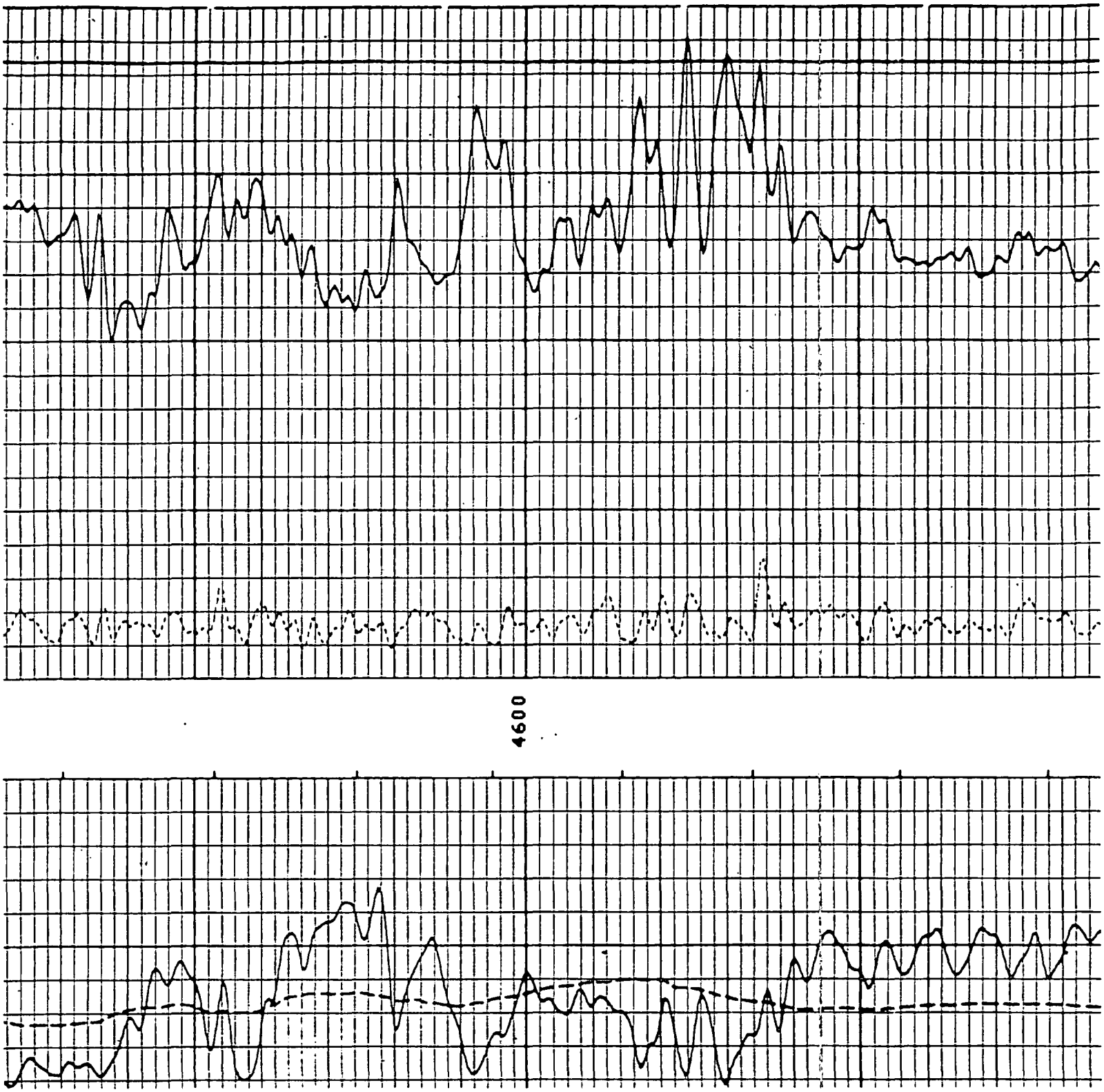


MAR02-1190

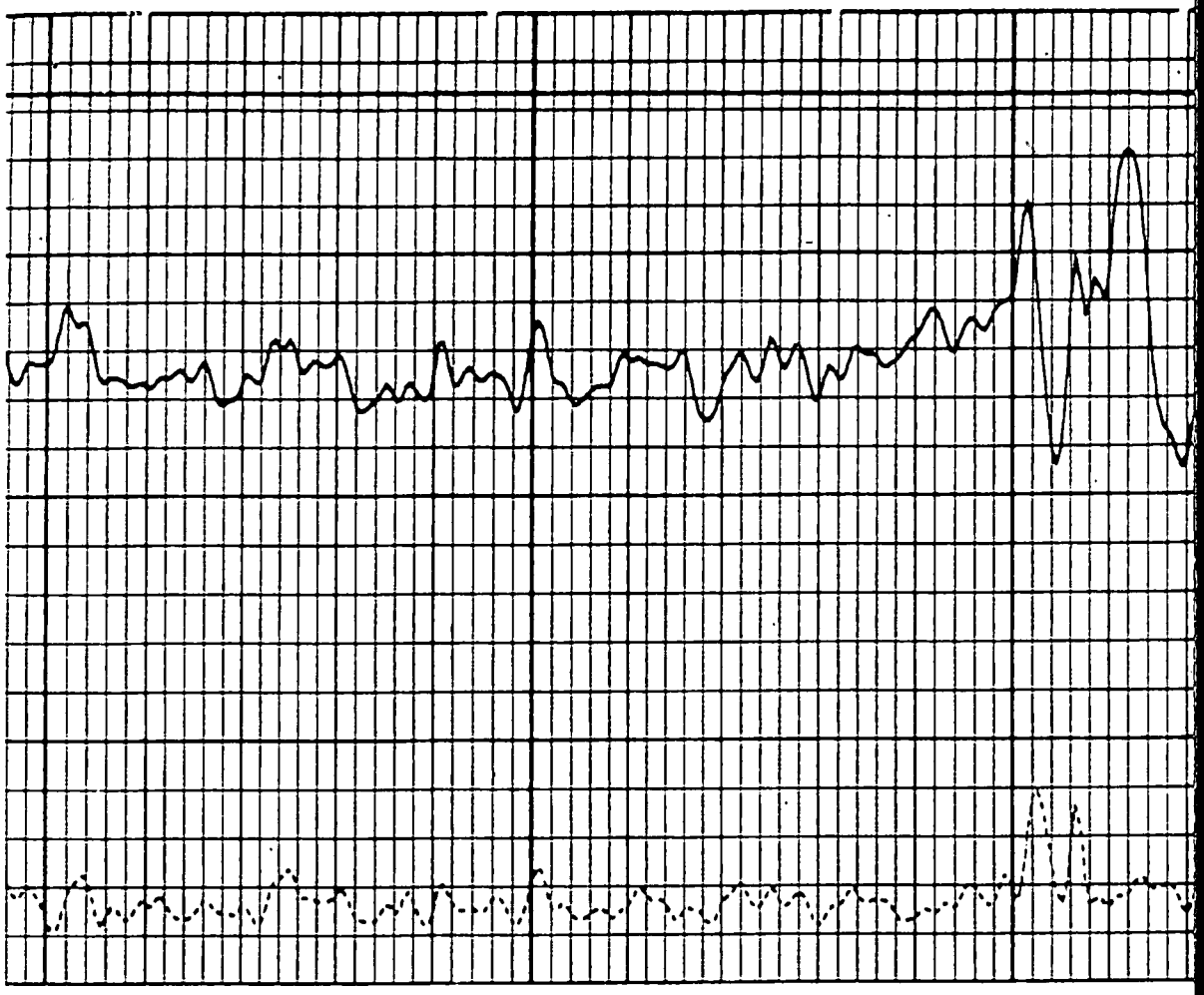
4400 4500



MAR02-1191



MAR02-1192



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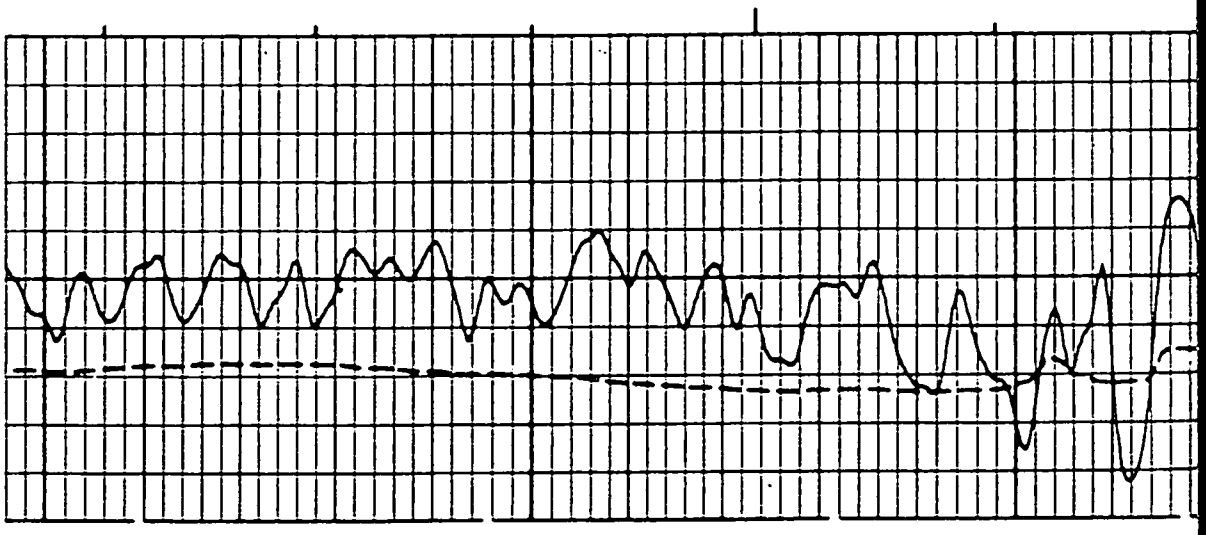
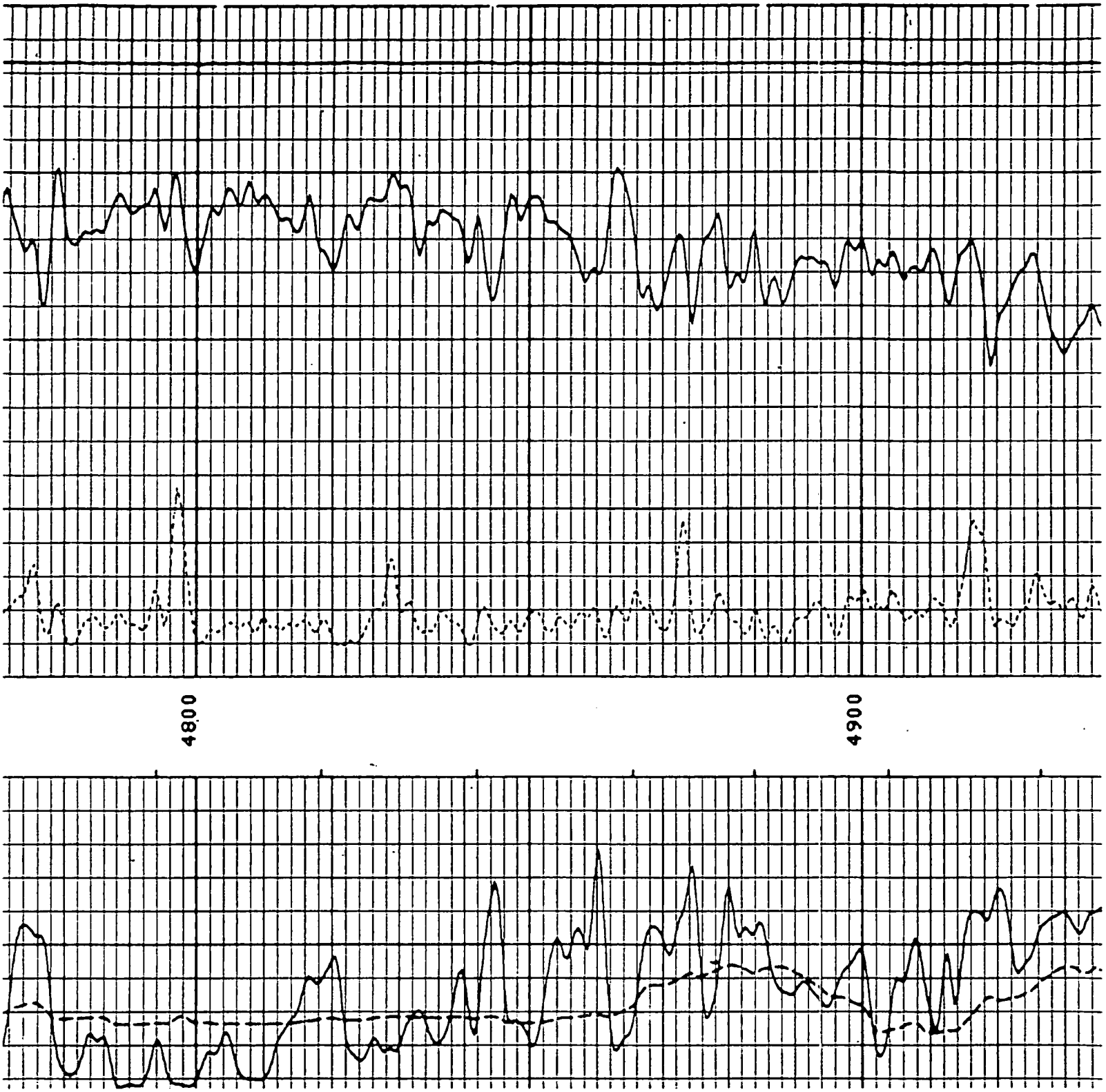
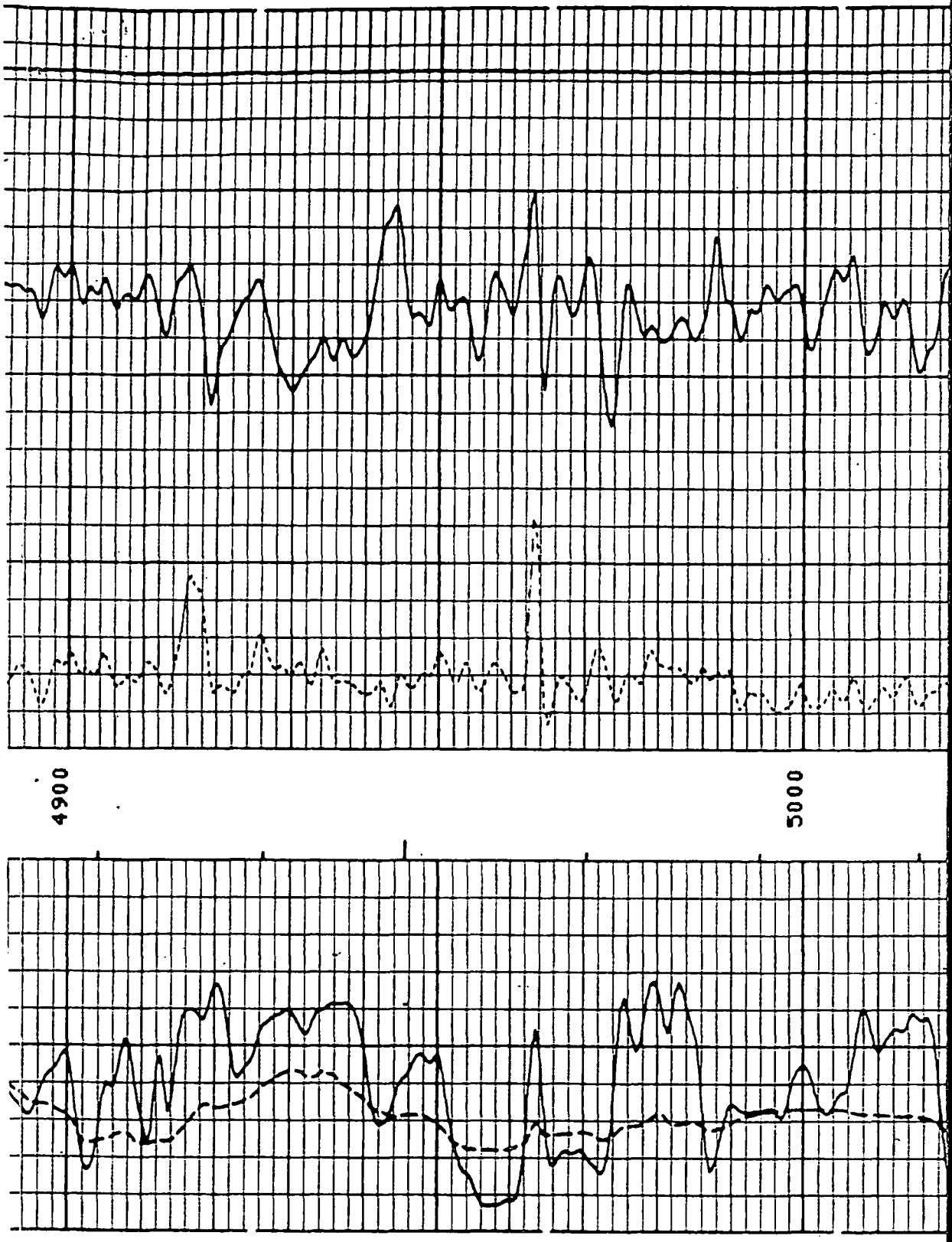


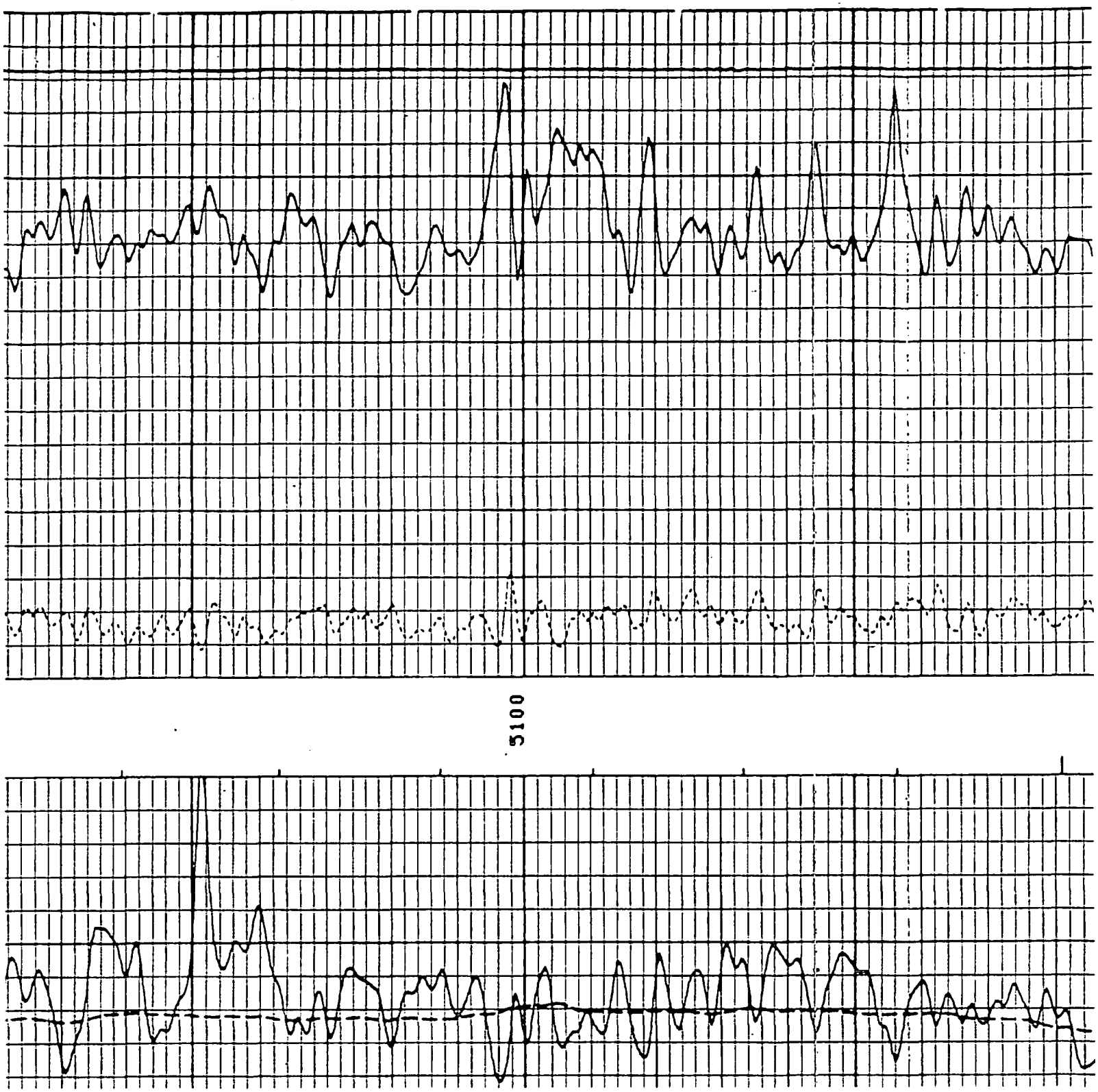
MAR02-1193



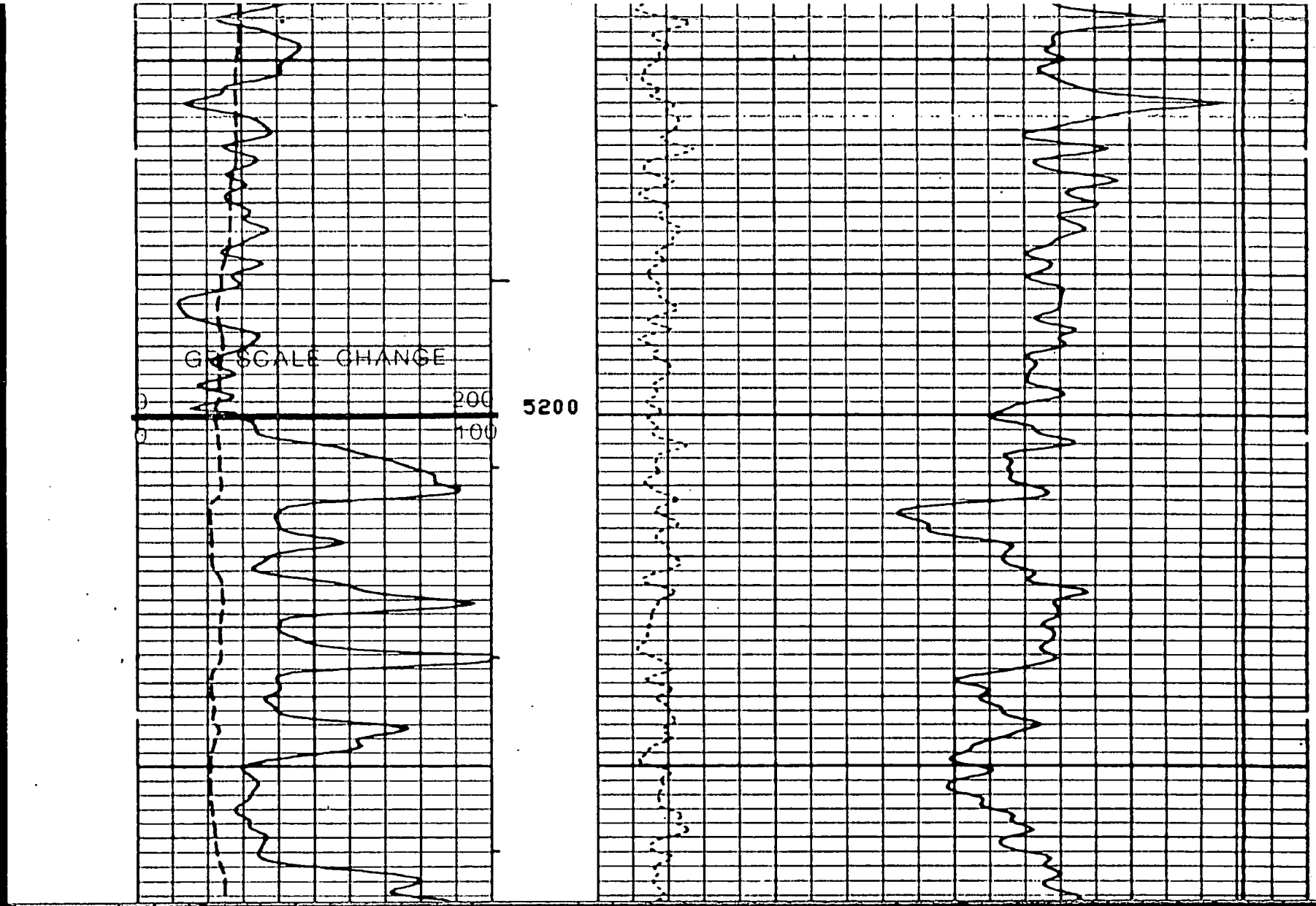
MAR02-1194



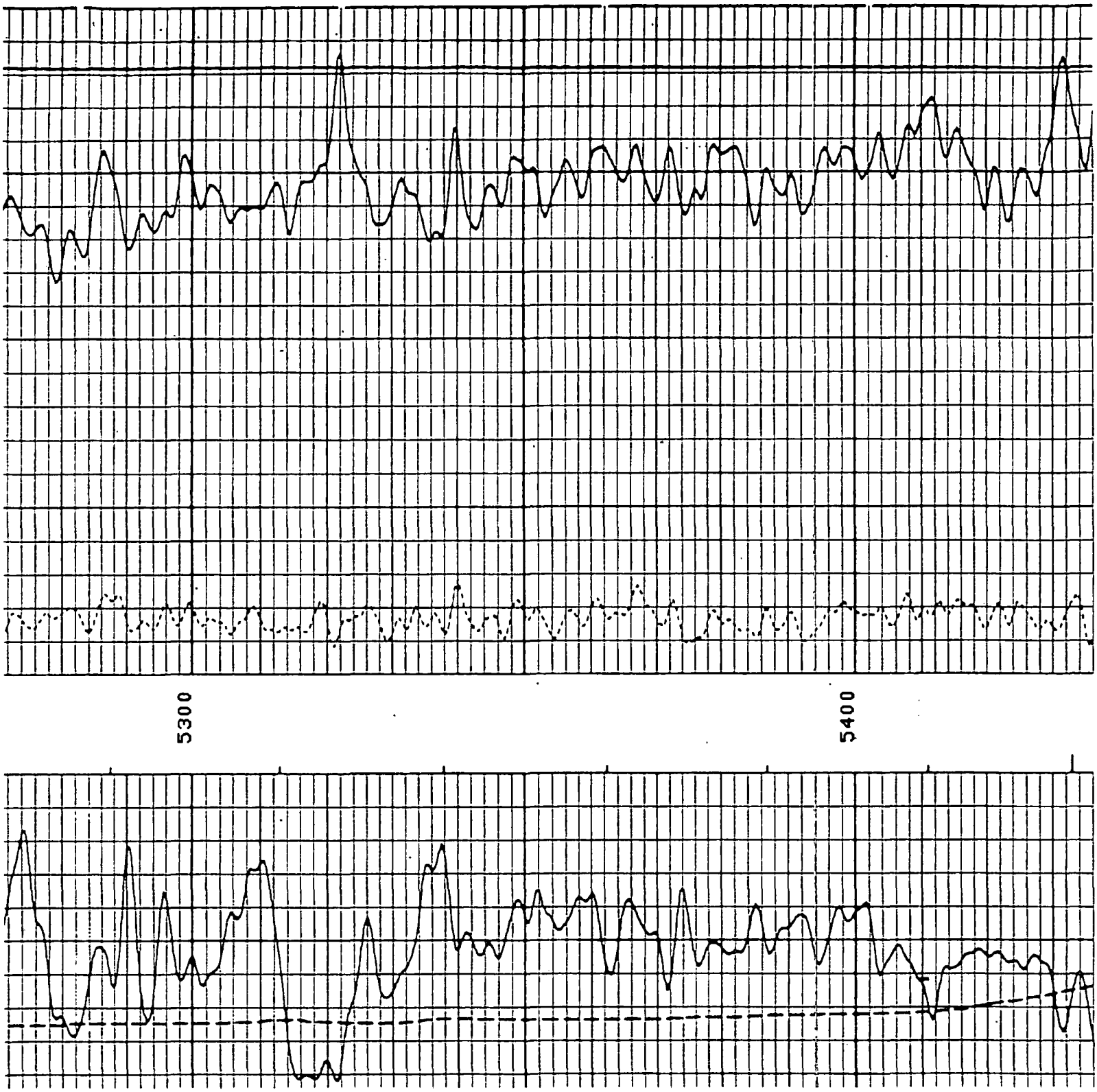
MAR02-1195



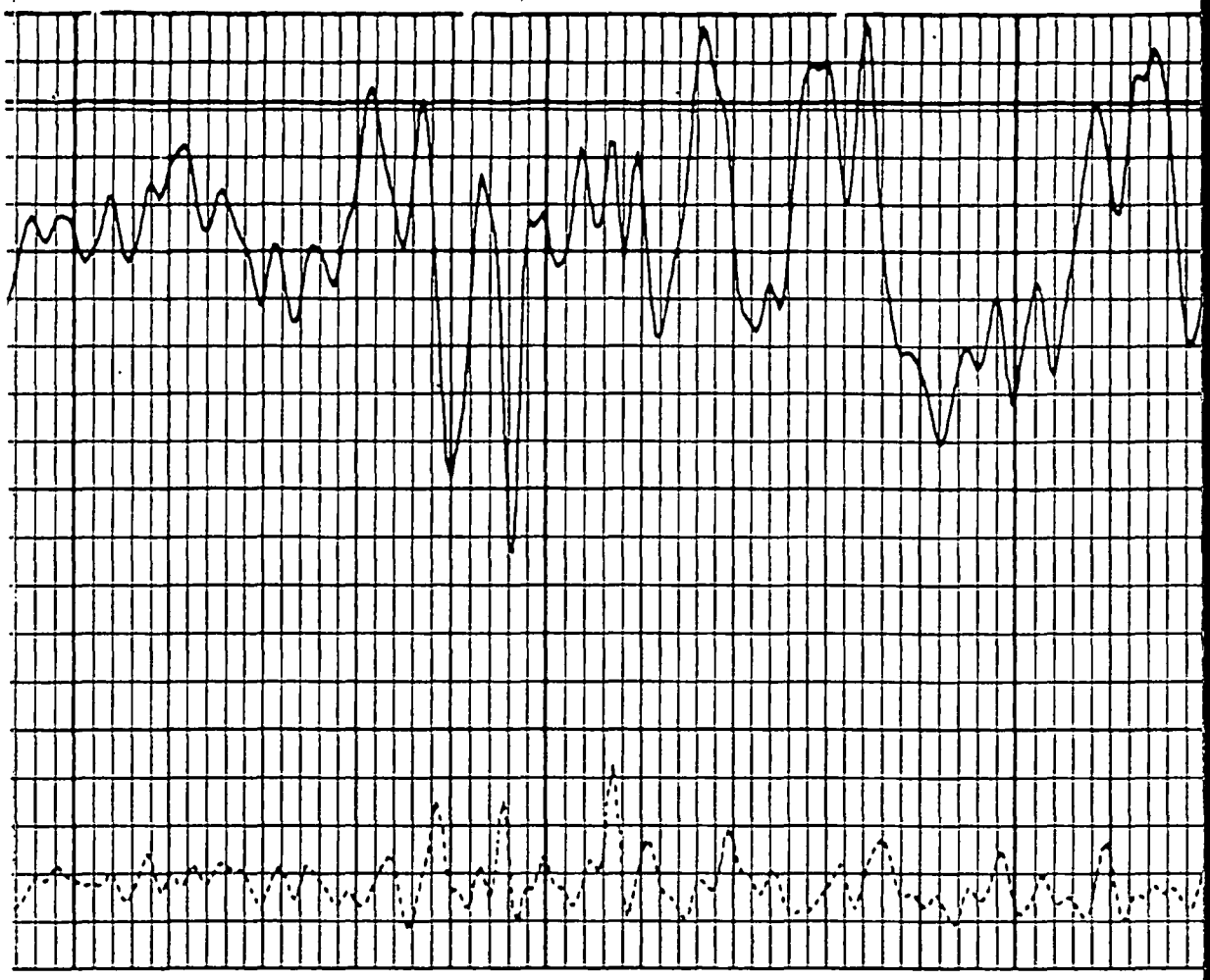
MAR02-1196



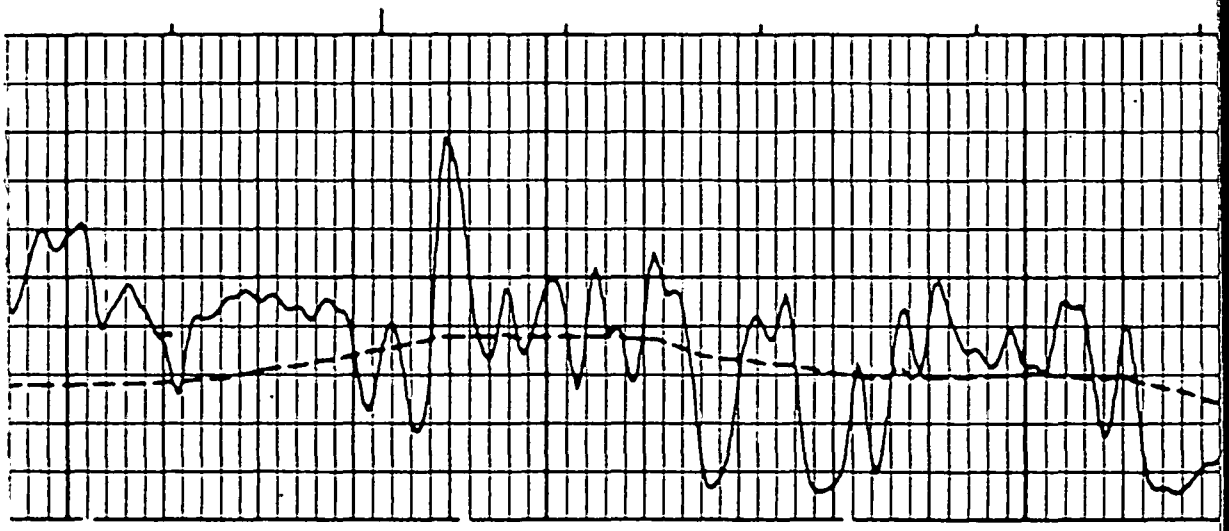
MAR02-1197



MAR02-1198



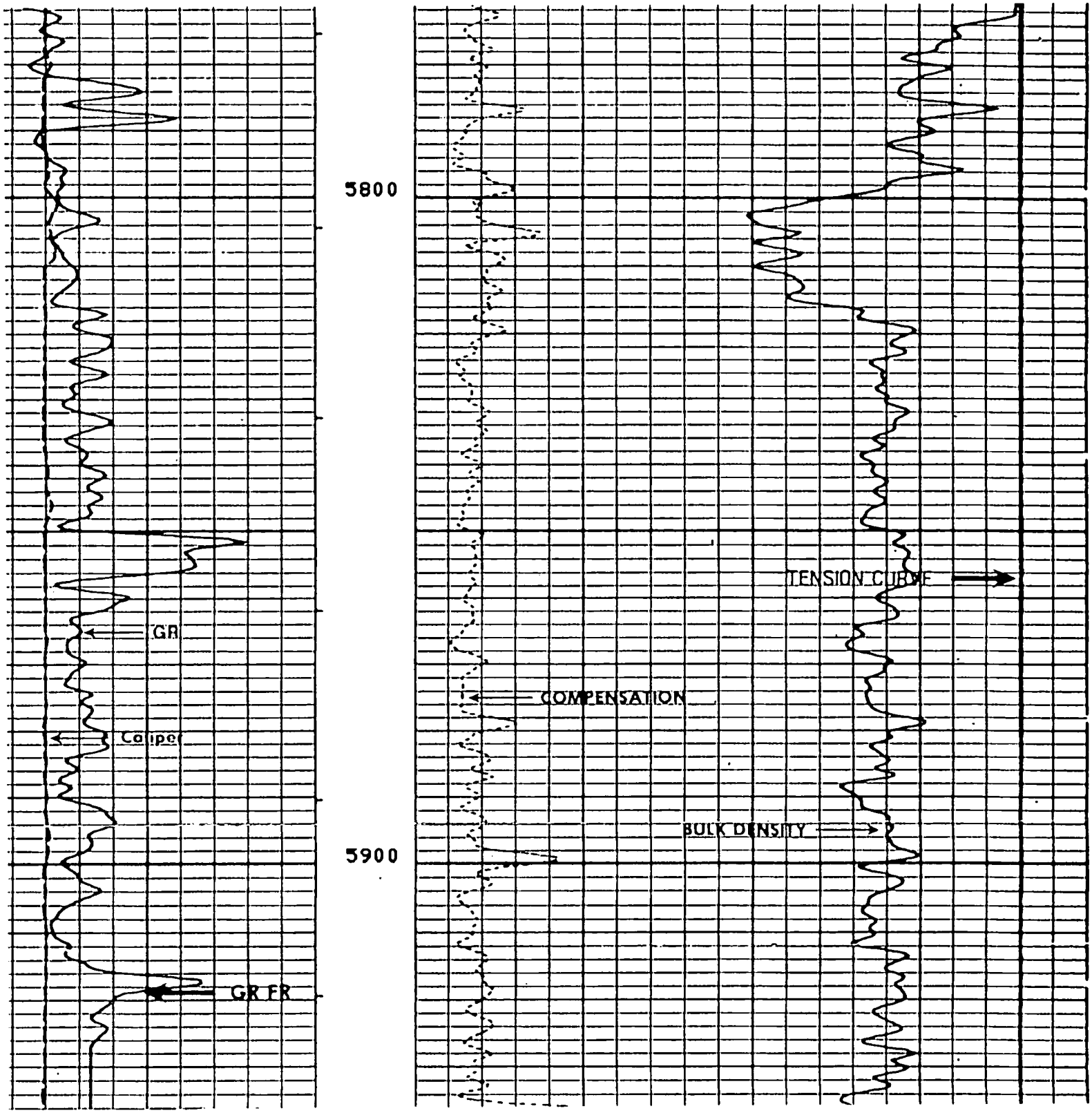
5400 5500



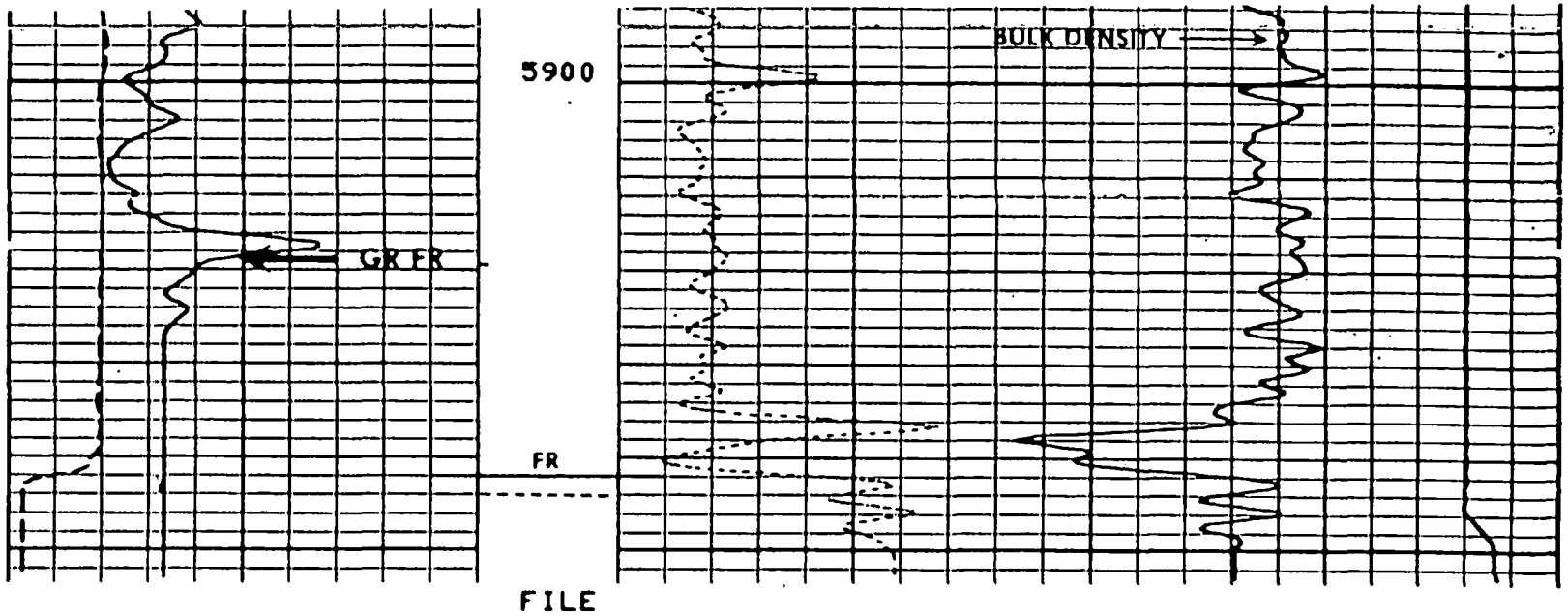
MAR02-1199

MAR02-1200

MAR02-1201


5800
5900
GR
Caliper
GR FR
TENSION CURVE
COMPENSATION
BULK DENSITY

MAR02-1202



FILE

4

CALI(IN)			
6.000 16.00			
GR (GAPI)		DRHO(G/C3)	TENS(LB)
0.0 100.0		-0.050 0.4500	10000. 0.0
CALI(IN)		RHOB(G/C3)	
16.00 26.00		2.000	3.000

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	RSMP		[illegible]	DS	[illegible]	[illegible]

MAR02-1203

MDEN	G/C3	2.710	FD	G/C3	1.100	MATR	LIME
BHF		WATE					
DO		0.0	BHS		OPEN	FPHI	PHIX

PARAMETERS

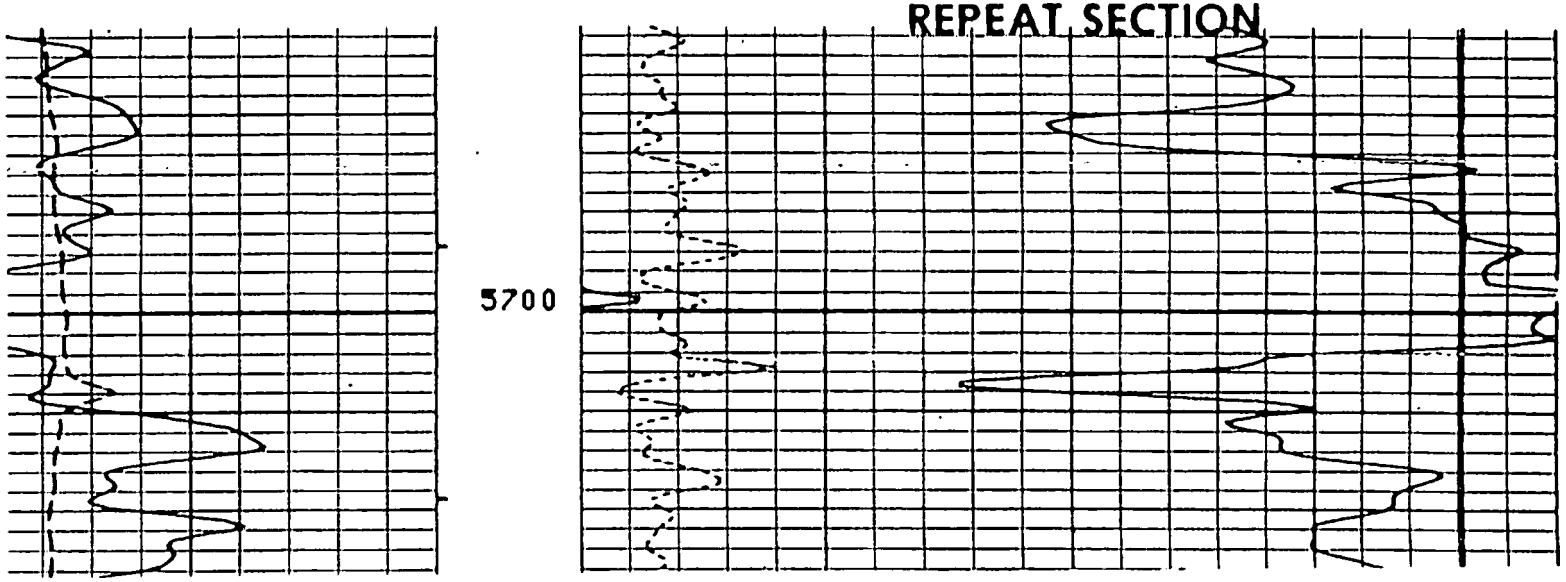
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

CALI(IN)			
000 16.00			
GR (GAPI)		DRHO(G/C3)	TENS(LB)
0 100.0		-0.050 0.4500	10000. 0.0
CALI(IN)		RHOB(G/C3)	
.00 26.00		2.000 3.000	

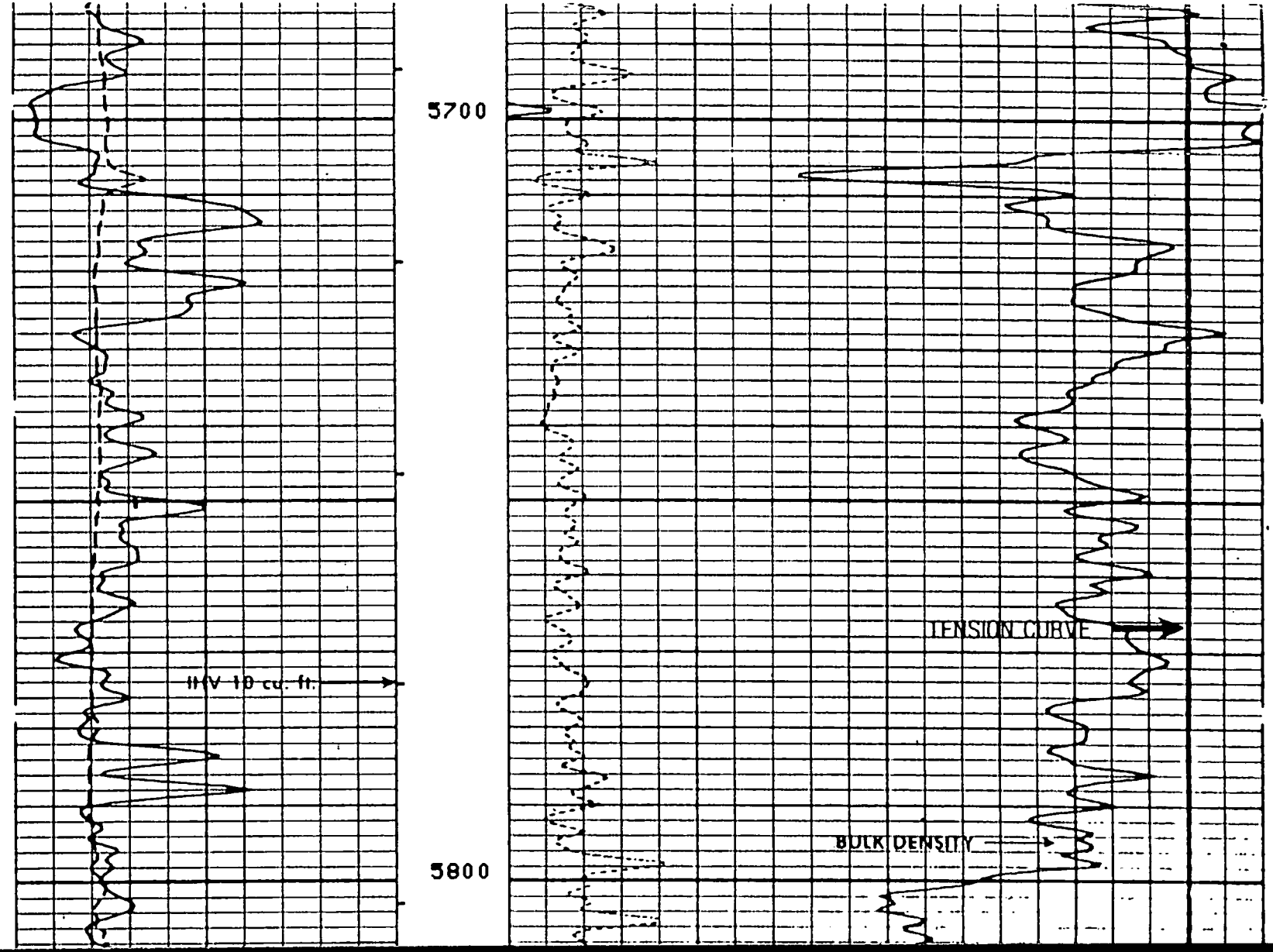
FILE

3

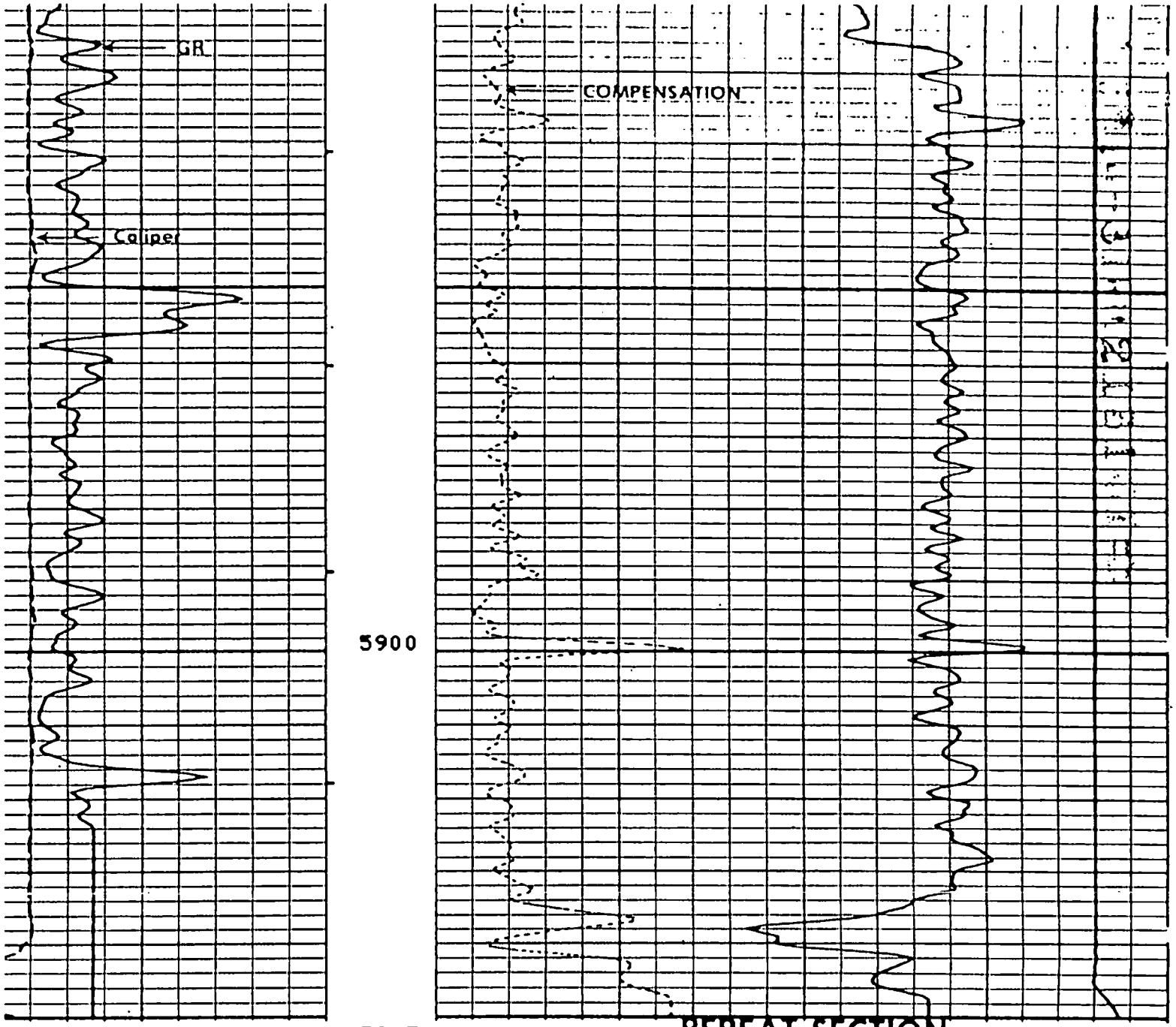
REPEAT SECTION



MAR02-1204

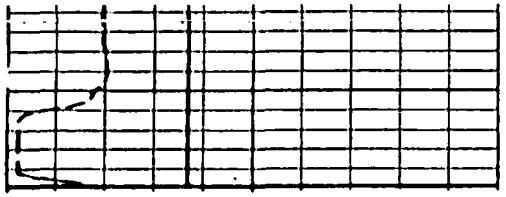


MAR02-1205



CALI(IN)			
000 16.00			
GR (GAPI)		DRHO(G/C3)	TENS(LB)

MAR02-1206



FILE

3

REPEAT SECTION

CALI(IN)		DRHO(G/C3)	TENS(LB)
6.000 16.00		-0.050 0.4500	10000. 0.0
GR (GAPI)		RHOB(G/C3)	
0.0 100.0		2.000 3.000	
CALI(IN)			
16.00 26.00			

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HC		CALI	PSNR		2.210	BS	INCH	7.875
MDEN	G/C3	2.710	FD	G/C3	1.100	MATR		LIME
BHF		WATE						
DO		0.0	BHS		OPEN	FPHI		PHIX

BEFORE SURVEY CALIBRATION SUMMARY

MAR02-1207

PROGRAM FILE: ISN (VERSION 18.2 80/08/23)

SGTE DETECTOR CALIBRATION SUMMARY

	MEASURED BKGD	MEASURED JIG	CALIBRATED	UNITS
GR	40	197	165	GAPI

CNTA DETECTOR CALIBRATION SUMMARY

	TANK INPUT	TANK CALIBRATED	JIG MEASURED	JIG CALIBRATED
NRAT	2.210	2.158	2.232	2.180

PGTE DETECTOR CALIBRATION SUMMARY

	BLOCK INPUT	BLOCK CALIBRATED	JIG MEASURED	JIG CALIBRATED	UNITS
FFDC	554	337	548	333	CPS
NFDC	769	528	754	517	CPS

PGTE CALIPER CALIBRATION SUMMARY

	MEASURED SMALL	MEASURED LARGE	CALIBRATED SMALL	CALIBRATED LARGE	UNITS
CALI	7.1	10.4	8.0	12.0	IN

FILE

2

SHOP SUMMARY

PERFORMED: 81/03/17
PROGRAM FILE: SHOP (VERSION 18.2 80/ 4/29)

CNTA DETECTOR CALIBRATION SUMMARY

	TANK MEASURED	TANK CALIBRATED	JIG MEASURED	JIG CALIBRATED
NRAT	2.210	2.158	2.203	2.151

(CNC:1339 , CNB:1634)

MAR02-1208

PERFORMED: 81/03/17
PROGRAM FILE: SHOP (VERSION 18.2 80/ 4/29)

CNTA DETECTOR CALIBRATION SUMMARY

	TANK		JIG	
	MEASURED	CALIBRATED	MEASURED	CALIBRATED
NRAT	2.210	2.158	2.203	2.151

(CNC:1339 , CNB:1634)

PGTE DETECTOR CALIBRATION SUMMARY

	BLOCK		JIG		
	MEASURED	CALIBRATED	MEASURED	CALIBRATED	UNITS
FFDC	554	337	551	335	CPS
NFDC	769	528	767	526	CPS

(PGS:C230 , PDH:E219 , GSR:5076 , SFT :1309)

COMPANY TEXAS OIL AND GAS CORP.
WELL BUCKLES NO. A-1
FIELD EAST POPLAR
COUNTY ROOSEVELT STATE MONTANA

SCHL. FR 5942
SCHL. TD 5944
DRLR TD 5938

Elev: KB 2097
DF ---
GL 2085

MAR02-1209

Schlumberger

SIMULTANEOUS

DUAL LATEROLOG MICRO-SFL

COUNTY ROOSEVELT
FIELD EAST POPLAR
LOCATION SEC. 22-28N-51E
WELL BUCKLES NO. A-1
COMPANY TEXAS OIL & GAS

COMPANY TEXAS OIL AND GAS CORP.
PRODUCTION DEPT.
WELL BUCKLES NO. A-1
FIELD EAST POPLAR
COUNTY ROOSEVELT STATE MONTANA

LOCATION 1980'FNL - 1980'FWL

API SERIAL NO.	SEC.	TWP	RANGE
	22	28N	51E

Other Services:
FDC/CNL/GR
INT/BHC/GR

Permanent Datum: GL ; Elev.: 2085
Log Measured From KB 12 Ft. Above Perm. Datum
Drilling Measured From KB

Elev.: K.B. 2097
D.F. ---
G.L. 2085

Date	4-16-81			
Run No.	ONE			
Depth—Driller	5938			
Depth—Logger (Schl.)	5944			
Btm. Log Interval	5943			
Top Log Interval	1220			
Casing—Driller	8-5/8 @ 1214	@	@	@
Casing—Logger	1220			
Bit Size	7-7/8			
Type Fluid in Hole	SALT-LOW SOLIDS			
Dens. / Visc.	11.3 / 41			
pH / Fluid Loss	6.4 / 6 ml	ml	ml	ml
Source of Sample	MUD TANK			
Rm @ Meas. Temp.	.056 @ 68 °F	@ °F	@ °F	@ °F
Rmf @ Meas. Temp.	.049 @ 68 °F	@ °F	@ °F	@ °F
Rmc @ Meas. Temp.	.084 @ 68 °F	@ °F	@ °F	@ °F
Source: Rmf / Rmc	M / C			
Rm @ BHT	.022 @ 188°F	@ °F	@ °F	@ °F
TIME: Circulation Stopped	4-16-0600			
TIME: Logger on Bottom	4-16-0920			
Max. Rec. Temp.	188 °F	°F	°F	°F
Equip. / Location	8135 / WLSTN-4109			
Recorded By	SACHAU			
Witnessed By	WALEN - PERIUS			

MAR-839

The well name, location and borehole reference data were furnished by the customer.

MAR02-1210

Schlumberger

SIMULTANEOUS
DUAL LATEROLOG MICRO-SFL

COMPANY TEXAS OIL AND GAS CORP.

PRODUCTION DEPT.

WELL BUCKLES NO. A-1

FIELD EAST POPLAR

COUNTY ROOSEVELT STATE MONTANA

COUNTY ROOSEVELT
FIELD EAST POPLAR
LOCATION SEC. 22-28N-51E
WELL BUCKLES NO. A-1
COMPANY TEXAS OIL & GAS

LOCATION 1980'FNL - 1980'FWL

API SERIAL NO.	SEC.	TWP	RANGE
	22	28N	51E

Other Services: FDC/CNL/GR INT/BHC/GR

Permanent Datum: GL ; Elev.: 2085
Log Measured From KB 12 Ft. Above Perm. Datum
Drilling Measured From KB

Elev.: K.B. 2097
D.F. ---
G.L. 2085

Date	4-16-81			
Run No.	ONE			
Depth—Driller	5938			
Depth—Logger (Schl.)	5944			
Btm. Log Interval	5943			
Top Log Interval	1220			
Casing—Driller	8-5/8@ 1214	@	@	@
Casing—Logger	1220			
Bit Size	7-7/8			
Type Fluid in Hole	SALT-LOW SOLIDS			
Dens. / Visc.	11.3 / 41			
pH / Fluid Loss	6.4 / 6 ml	ml	ml	ml
Source of Sample	MUD TANK			
Rm @ Meas. Temp.	.056 @ 68 °F	@ °F	@ °F	@ °F
Rmf @ Meas. Temp.	.049 @ 68 °F	@ °F	@ °F	@ °F
Rmc @ Meas. Temp.	.084 @ 68 °F	@ °F	@ °F	@ °F
Source: Rmf / Rmc	M / C			
Rm @ BHT	.022 @ 188F	@ °F	@ °F	@ °F
Circulation Stopped	4-16-0600			

The well name, location and borehole reference data were furnished by the customer.

SCALE CHANGES

Type Log	Depth	Scale Up Hole	Scale Down Hole
GR	5200	0-200	0-100

REMARKS:

MSFL ON 5" ONLY

No.	ONE					
	213161					
	FULL					
CL.	130000					
T DATA						
	DLM-B-867					
	MRM-AB-872					
C)	DLC-BB-869					
E)	SRE-B-1781					
	DLS-BB-799					
	SRS-A-1767					
de (DLE)	---					
nel	CPU-CAA-535					
r (TTR)	MTU-D-2745					
r (DRE)	OMU-CAA-362					
el (CPW)	CMD-BAB-195					
Type	CME-Z	CALIPER				
No.	1	1				
S. O. Inches	---	---				
ON DATA						
BKG. API	33					
Source API	208					
DATA						
Sensitivity	100/200					
Scale-100 Div.	0-100/0-200					
D.C.F.T.	1					
	60					
HOLE TEMPERATURE						
g Hole	0900					
Reached	0920					
f Bottom	0930					
Hole	1100					
lo Therm.	36'	°F	°F	°F	°F	°F
er #1	188	°F	°F	°F	°F	°F
er #2	---	°F	°F	°F	°F	°F

MAR02-1211

r @ 100 °F	---	ΩM	ΩM	ΩM	ΩM
@ 100 °F	---	ΩM	ΩM	ΩM	ΩM

rpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any inter-ons, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or d by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our General Terms and ons as set out in our current Price Schedule

AFTER SURVEY TOOL CHECK SUMMARY

PERFORMED: 81/04/16
PROGRAM FILE: MILL (VERSION 18.2 80/08/29)

DSTB TOOL CHECK

PLUS

	BEFORE	AFTER	UNITS
LLS	31.60	31.69	OHM
LLD	31.60	31.75	OHM

DST TOOL CHECK

	ZERO		PLUS		
	BEFORE	AFTER	BEFORE	AFTER	UNITS
CMSF	0.0	-0.0	999.9	999.4	MM/M
I1	0.0	-1.2	199.9	210.8	MM/M

FILE

8

PARAMETERS

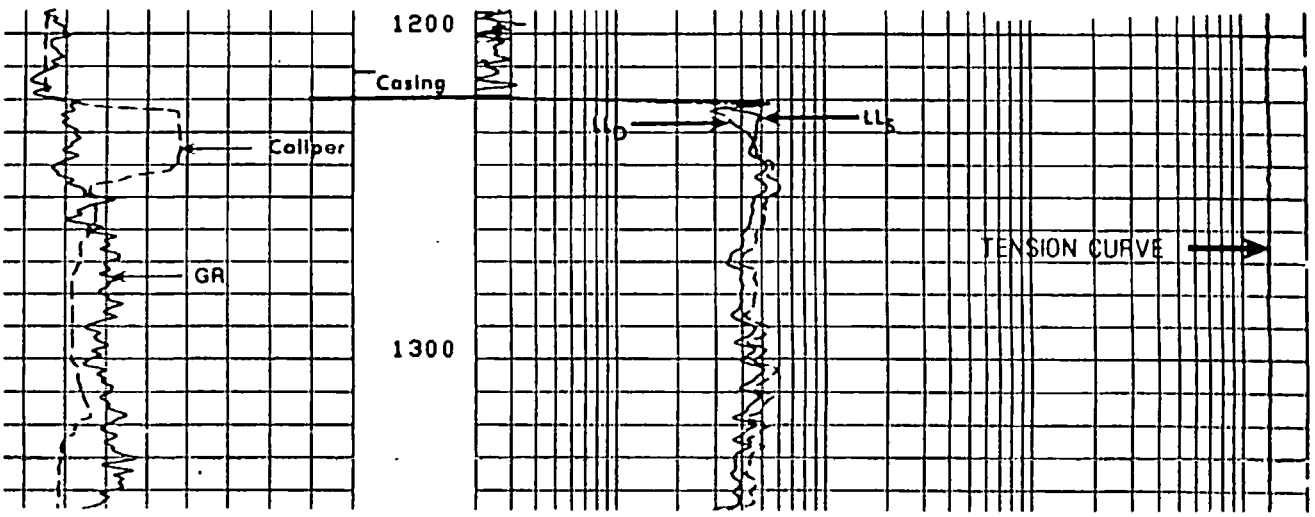
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
FPHI		PHIX	SPT		STAN	BS	INCH	7.875
DO		0.0	BHS		OPEN			

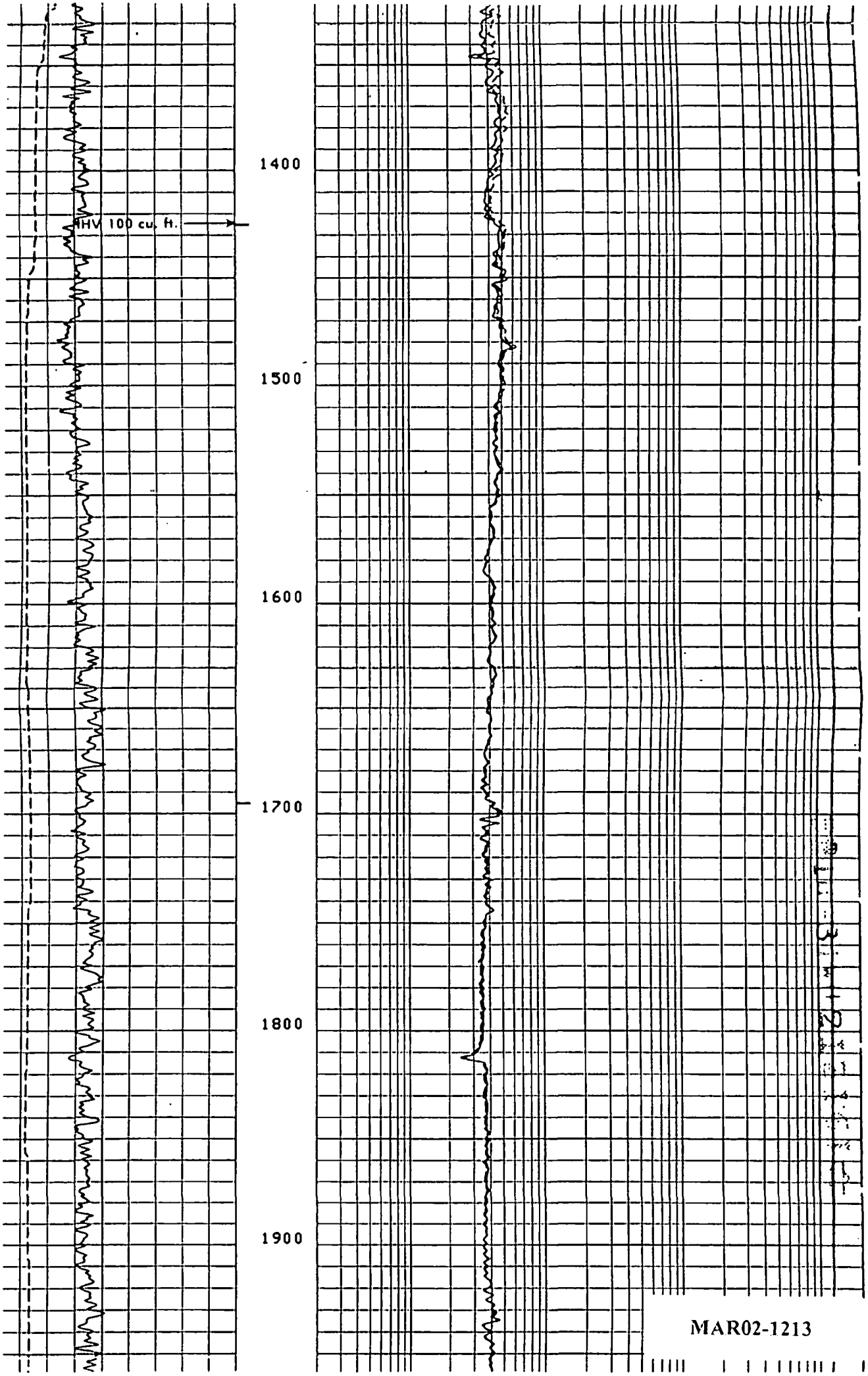
CALI(IN) .00 26.00	LLD (OHMM) 2000. 200000	TENS(LB) 10000. 0.0
CALI(IN))00 16.00	LLS (OHMM) 0.2000 2000.	
GR (GAPI) 200.0	LLD (OHMM) 0.2000 2000.	

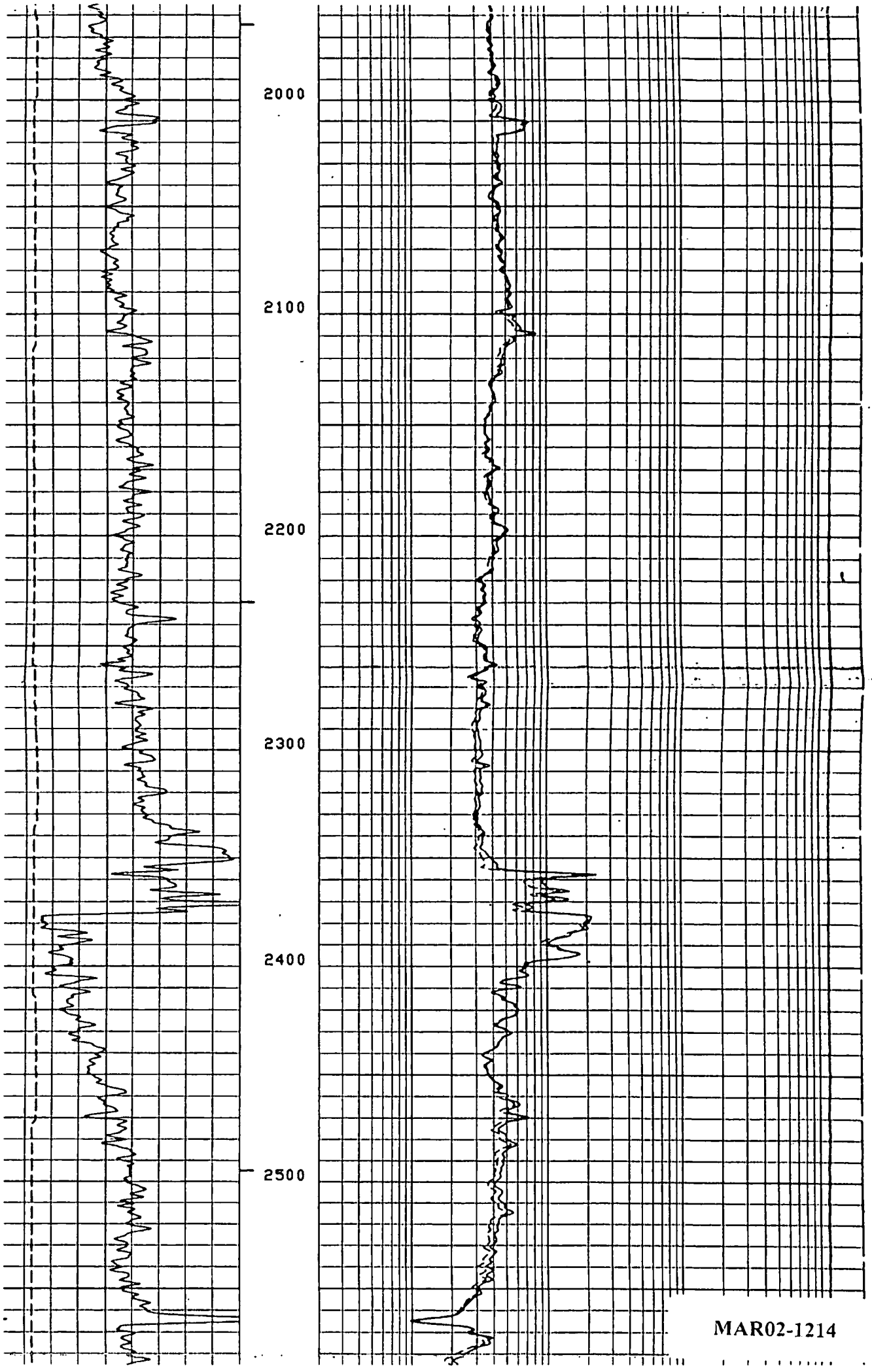
FILE

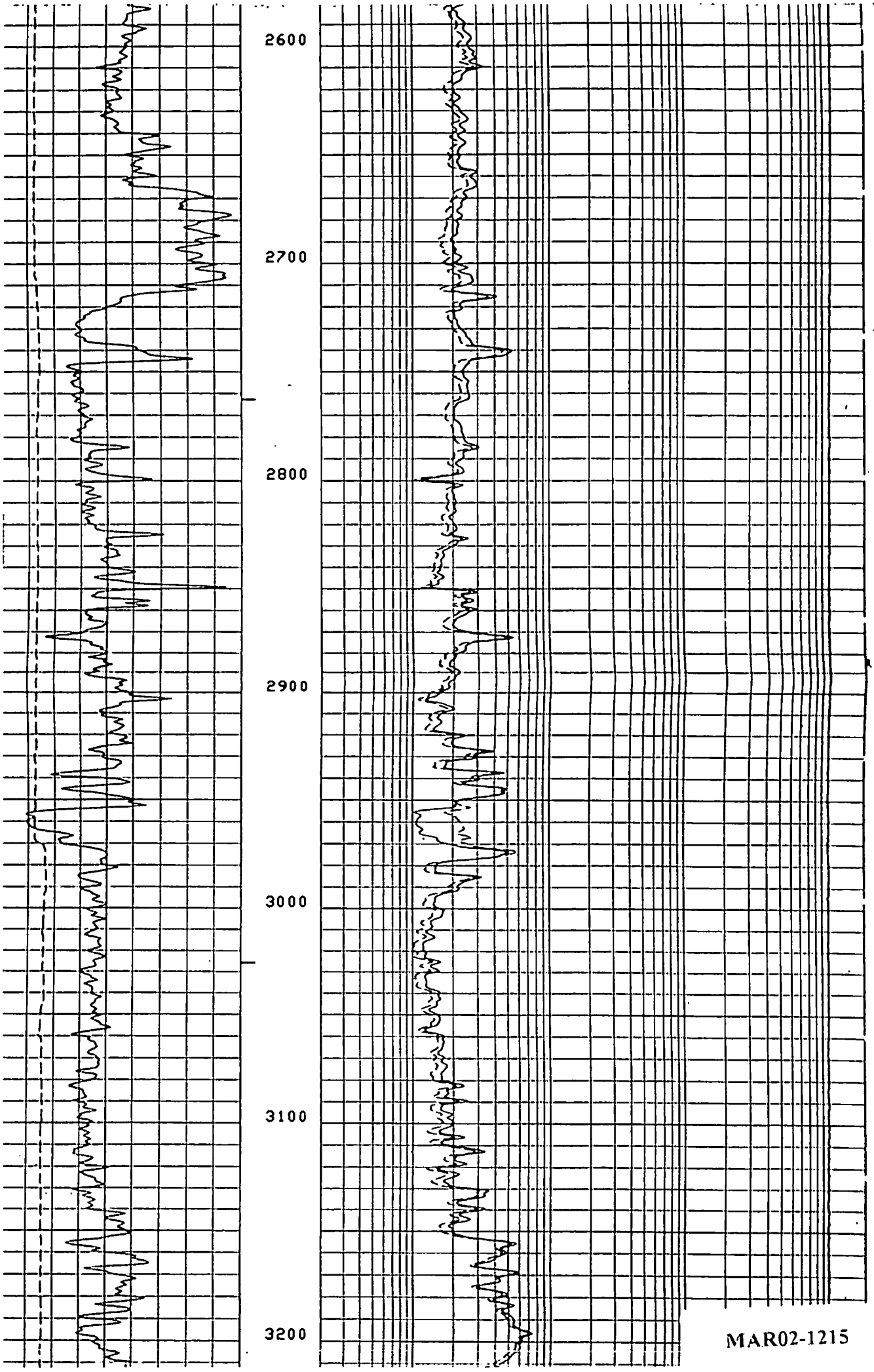
6

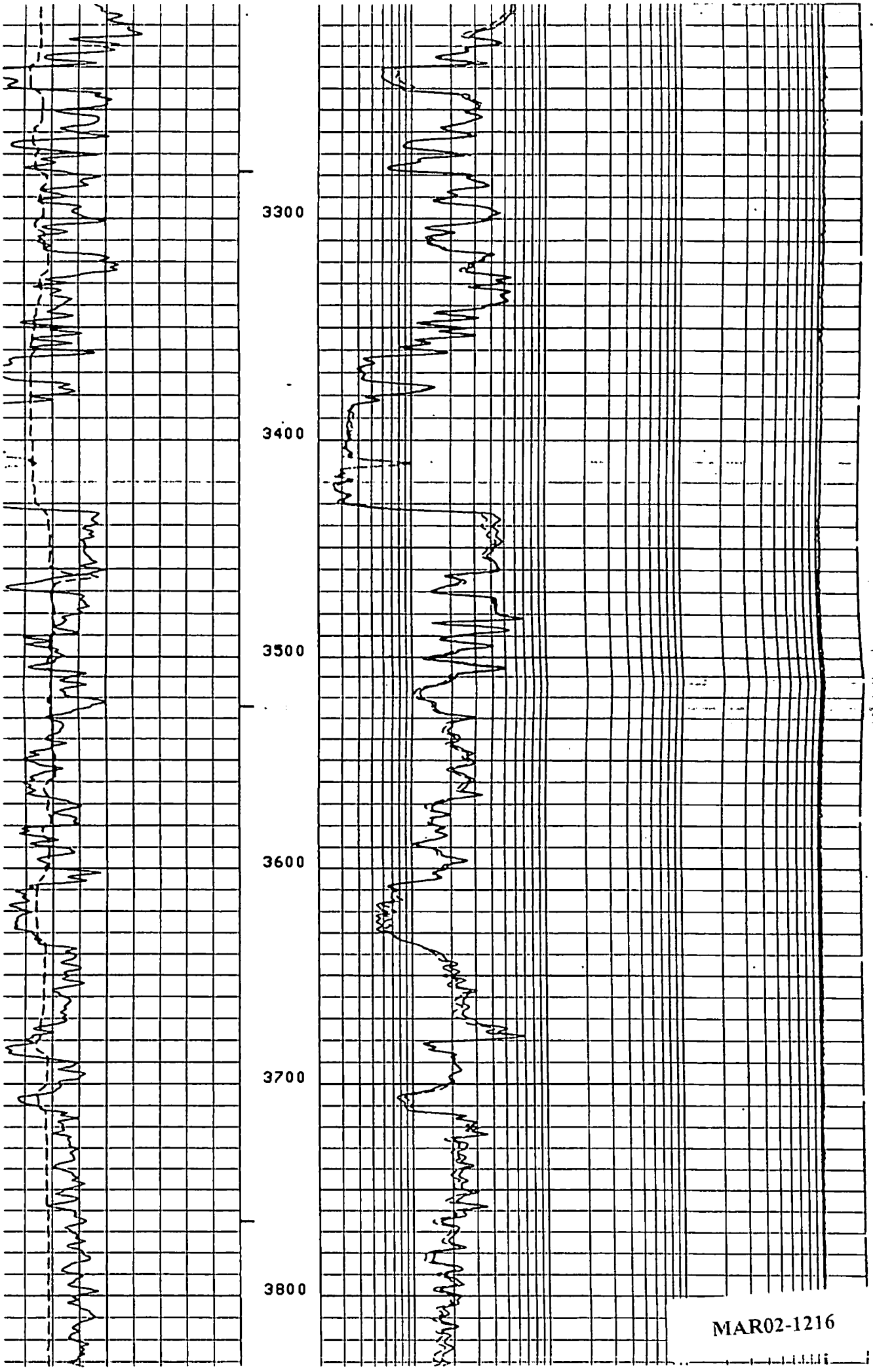
MAR02-1212

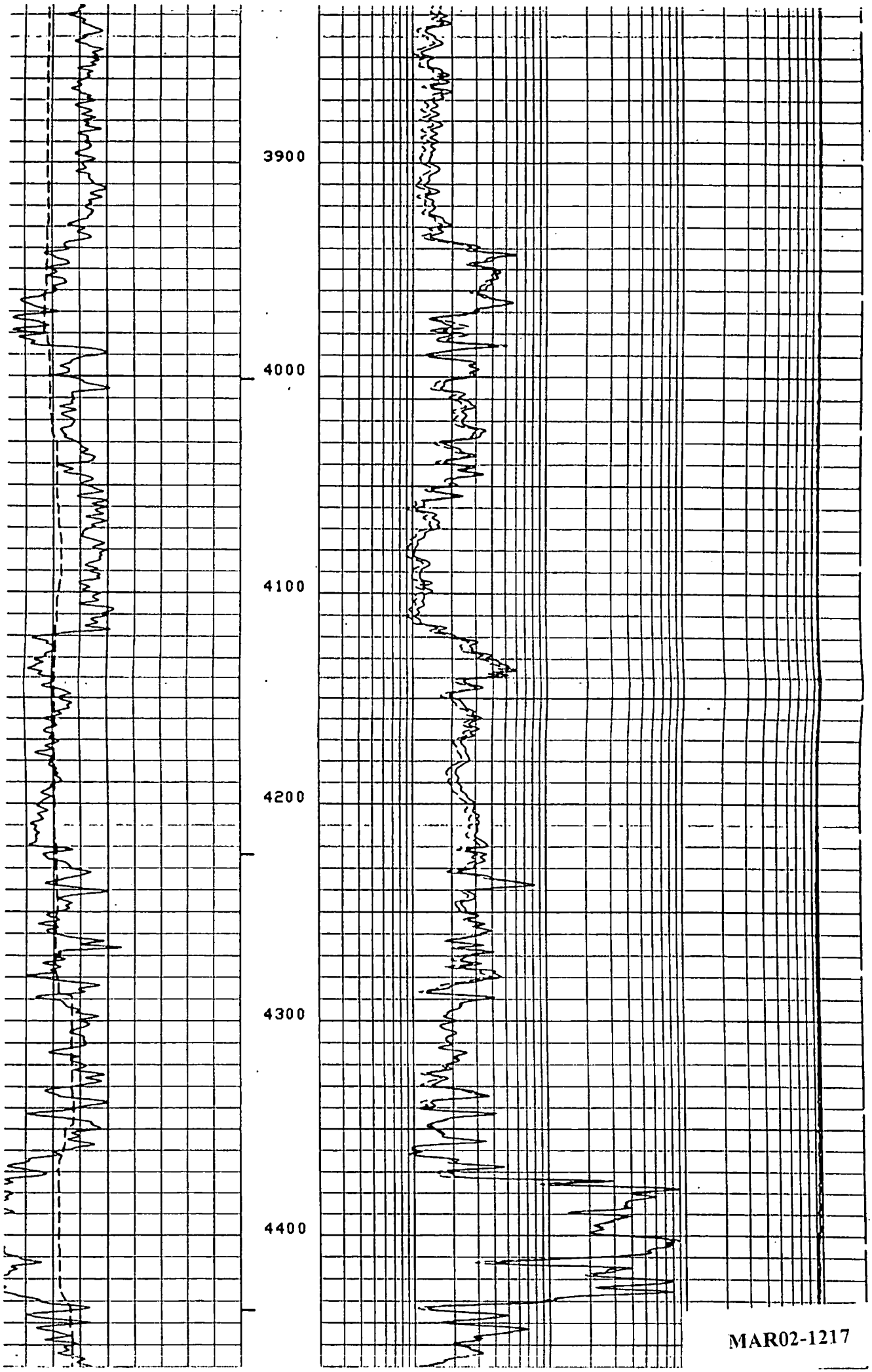


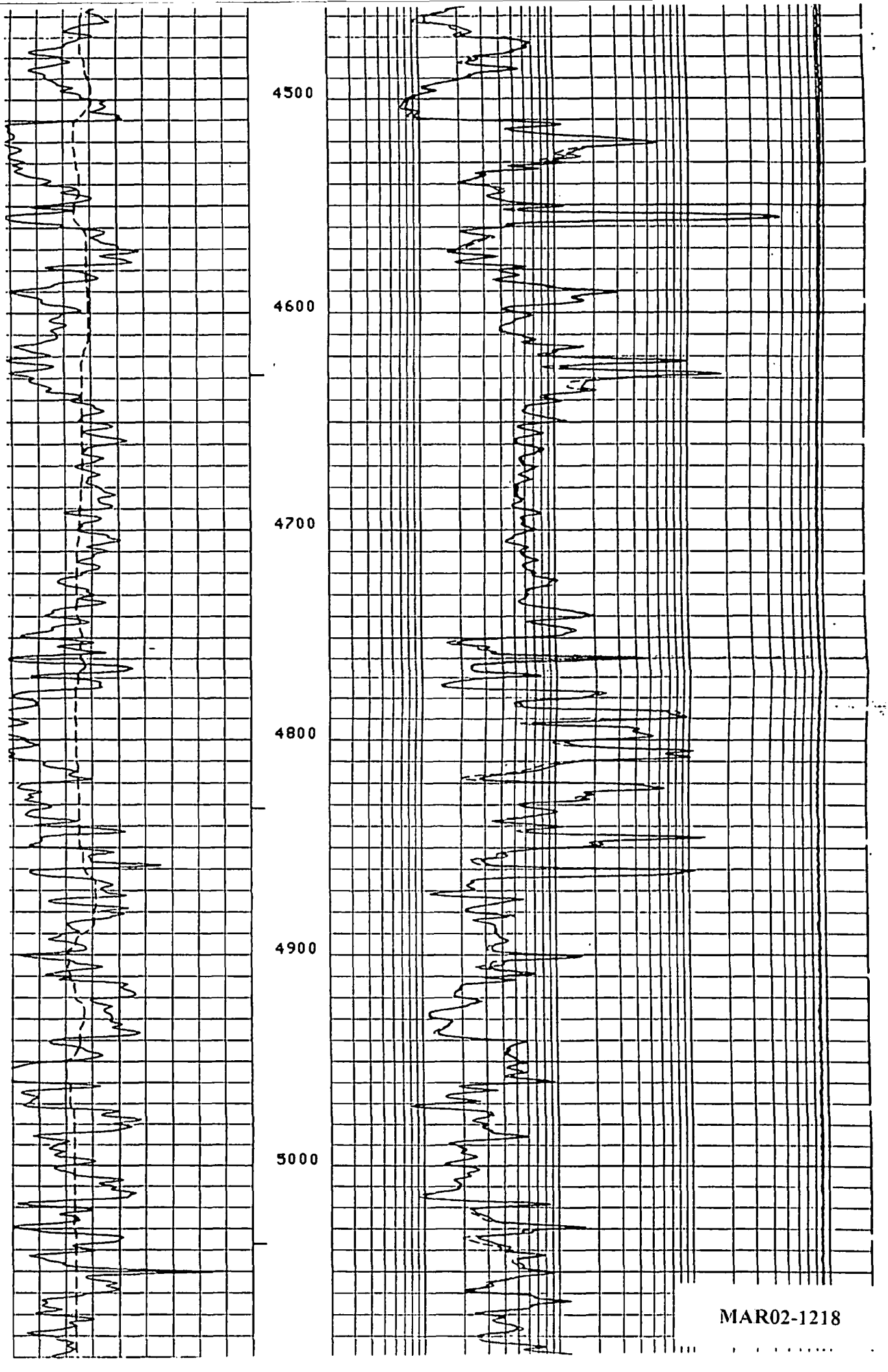

1400
HV 100 cu. ft.
1500
1600
1700
1800
1900
MAR02-1213

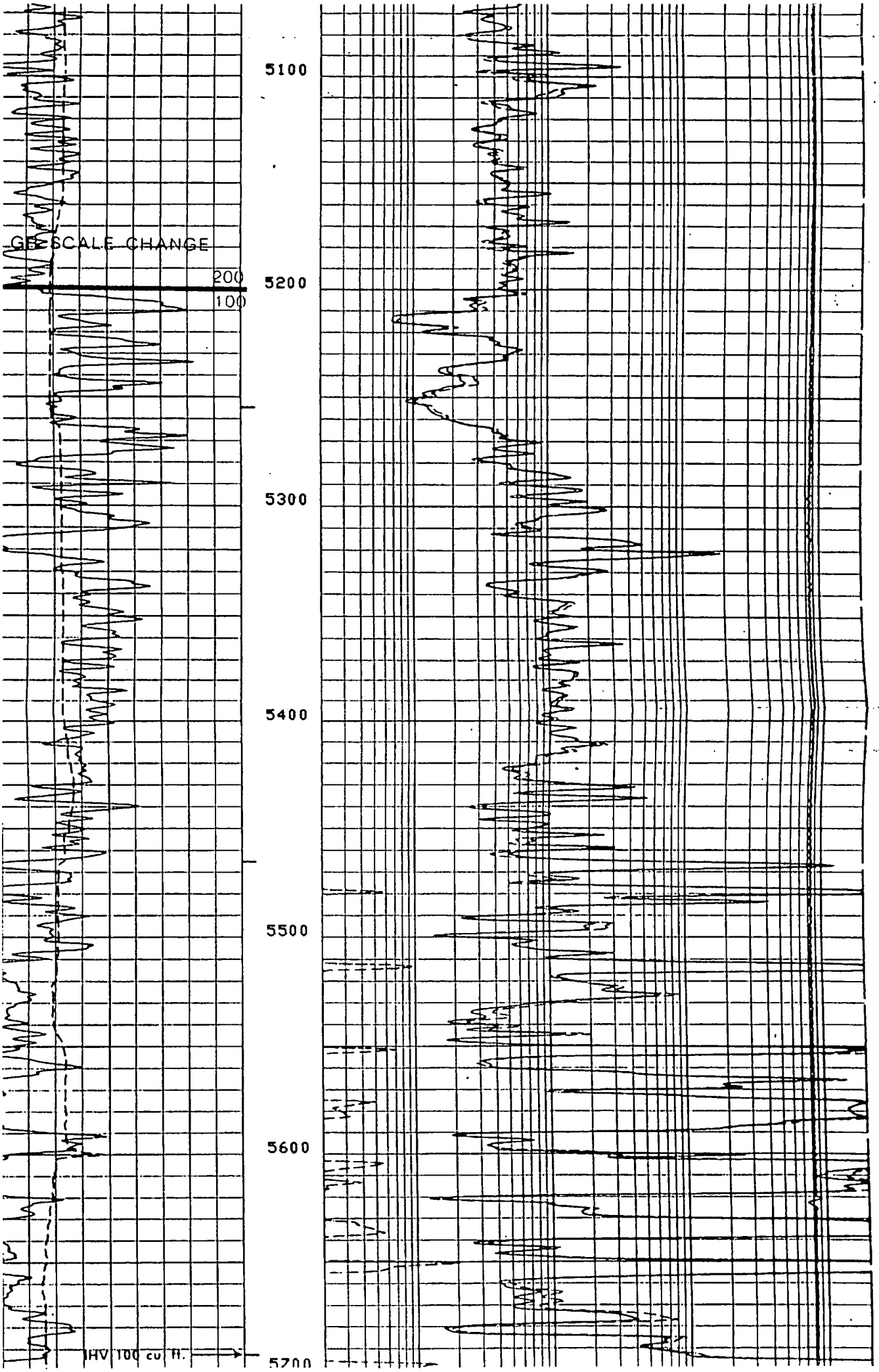

2000
2100
2200
2300
2400
2500
MAR02-1214


2600
2700
2800
2900
3000
3100
3200
MAR02-1215

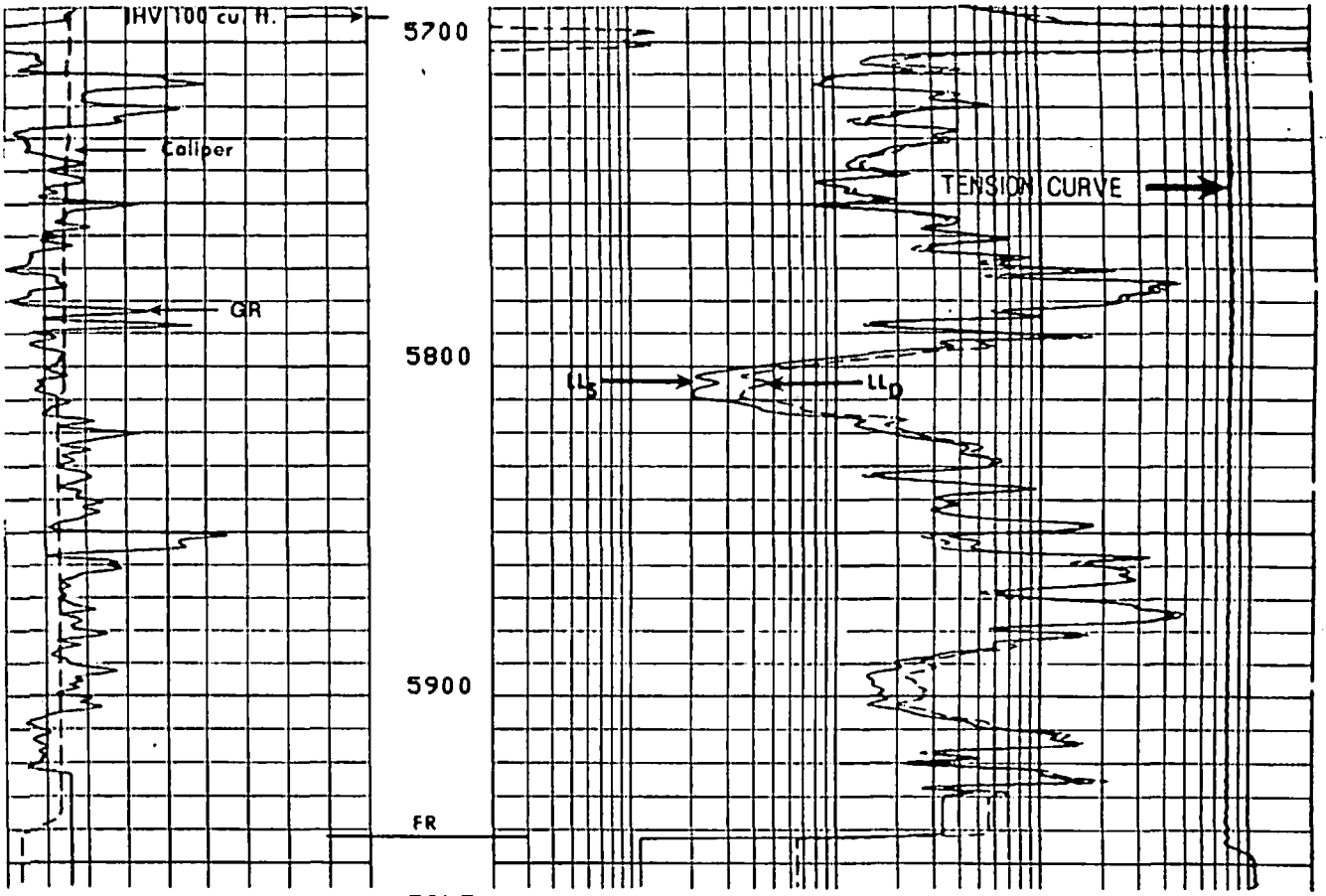

3300
3400
3500
3600
3700
3800
MAR02-1216


3900
4000
4100
4200
4300
4400
MAR02-1217


4500
4600
4700
4800
4900
5000
MAR02-1218


GR SCALE CHANGE
200
100
5100
5200
5300
5400
5500
5600
5700
HV 100 cu ft.

MAR02-1219



FILE

6

CALI(IN)		LLD (OHMM)		TENS(LB)	
5.00	26.00	2000.	200000	10000.	0.0
CALI(IN)		LLS (OHMM)			
.000	16.00	0.2000			2000.
GR (GAPI)		LLD (OHMM)			
.0	100.0	0.2000			2000.

PARAMETERS

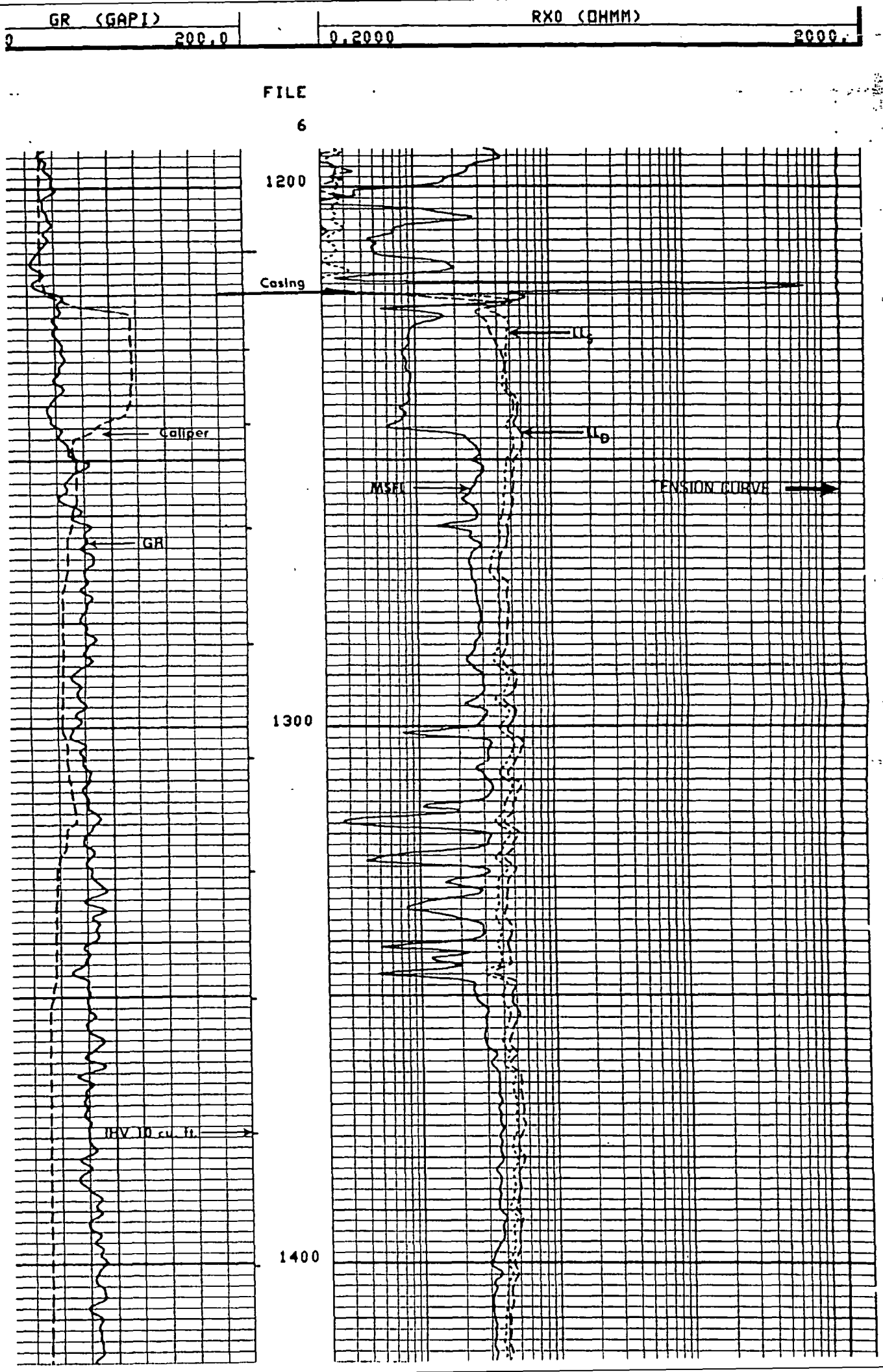
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
FPHI		PHIX	SPT		STAN	BS	INCH	7.875
DO		0.0	BHS		OPEN			

PARAMETERS

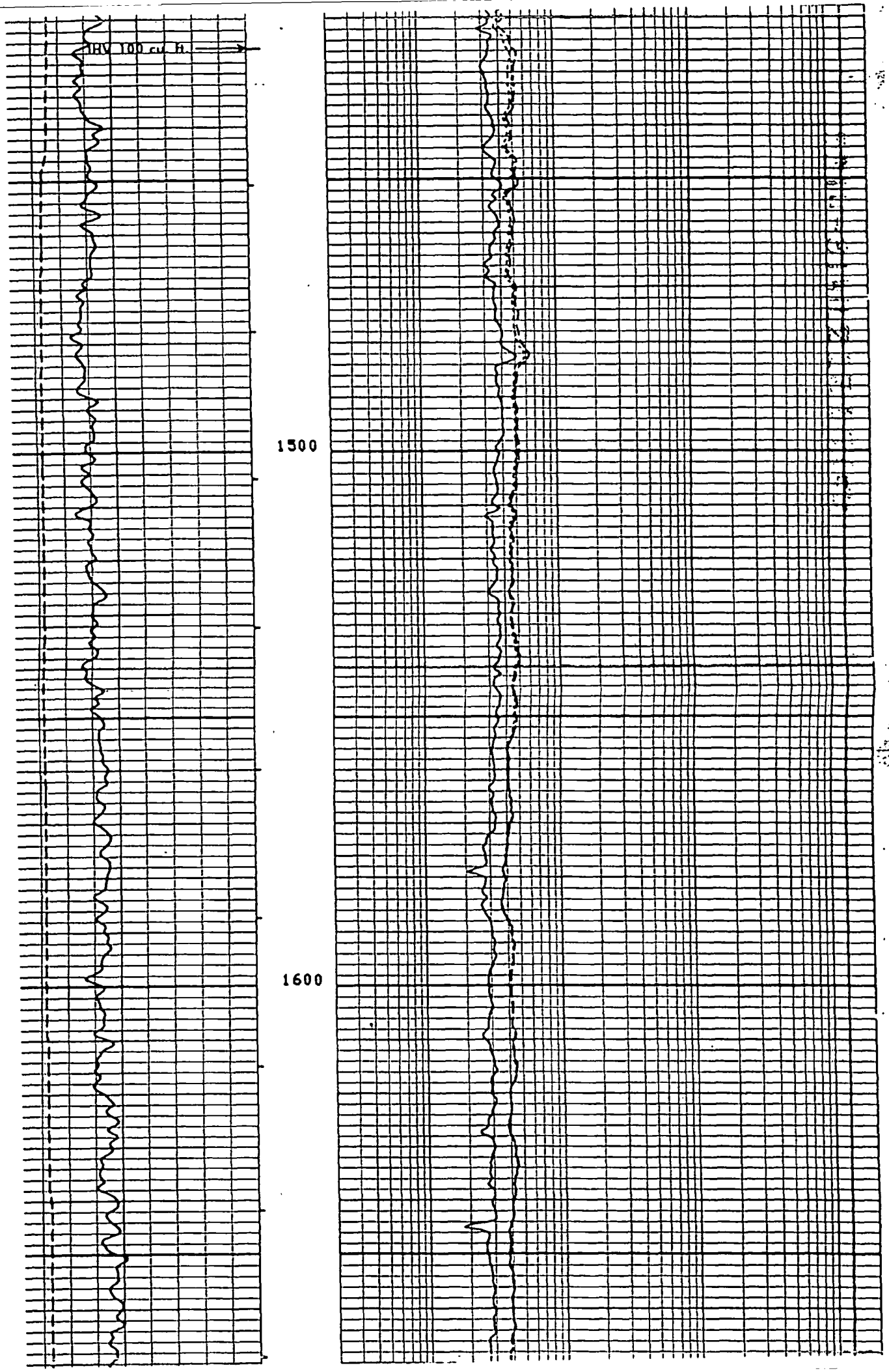
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
FPHI		PHIX	SPT		STAN	BS	INCH	7.875
DO		0.0	BHS		OPEN			

		LLD (OHMM)		TENS(LB)	
		2000.	200000	10000.	0.0
CALI(IN)		LLS (OHMM)			
.00	26.00	0.2000			2000.
CALI(IN)		LLD (OHMM)			
)00	16.00	0.2000			2000.

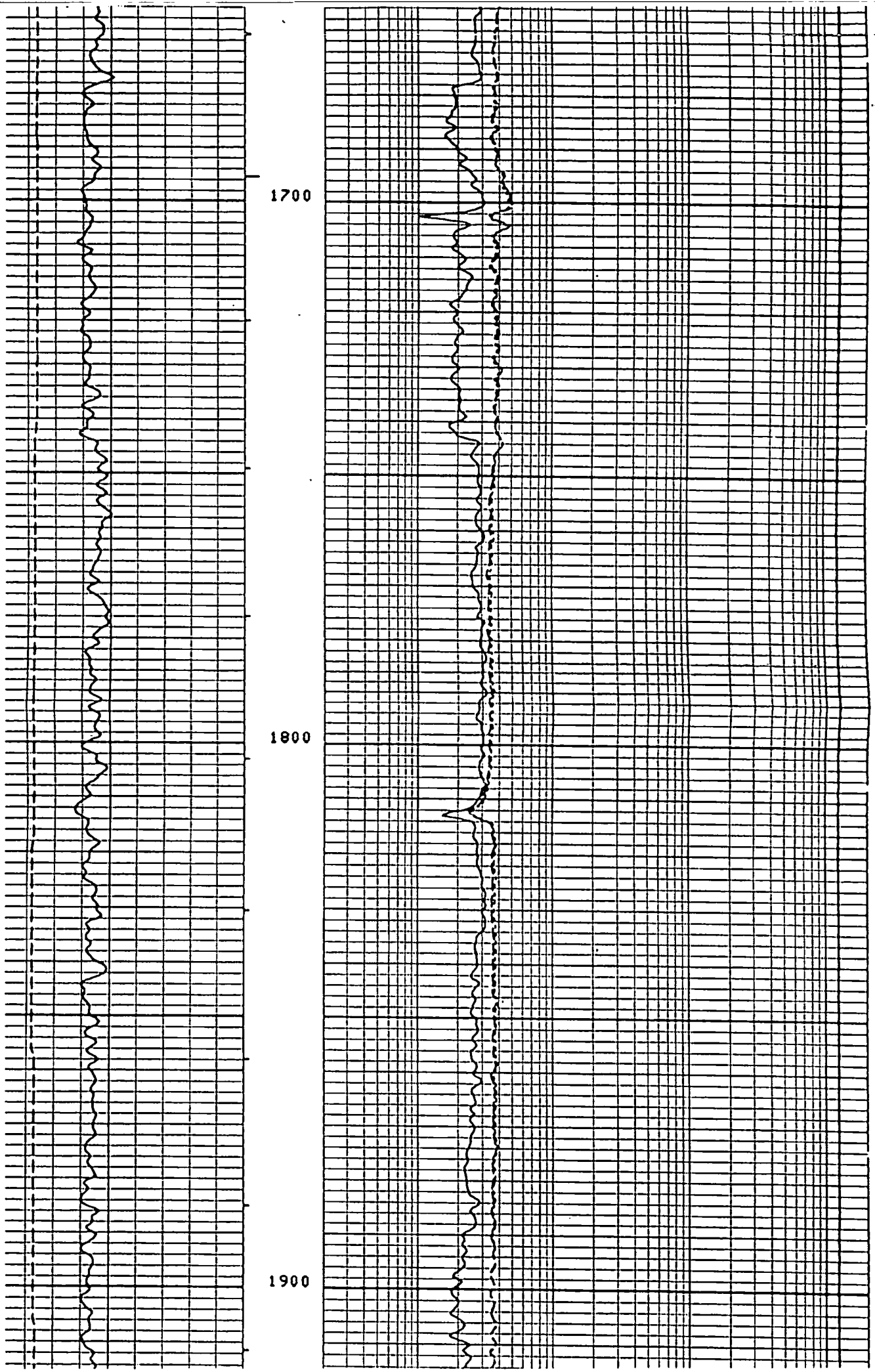
MAR02-1220


GR (GAPI)
0
200.0
RXO (OHMM)
0.2000
2000.
FILE
6
1200
Casing
LL$_S$
Caliper
LL$_D$
MSFL
TENSION CURVE
GR
1300
IHV 10 cu. ft.
1400

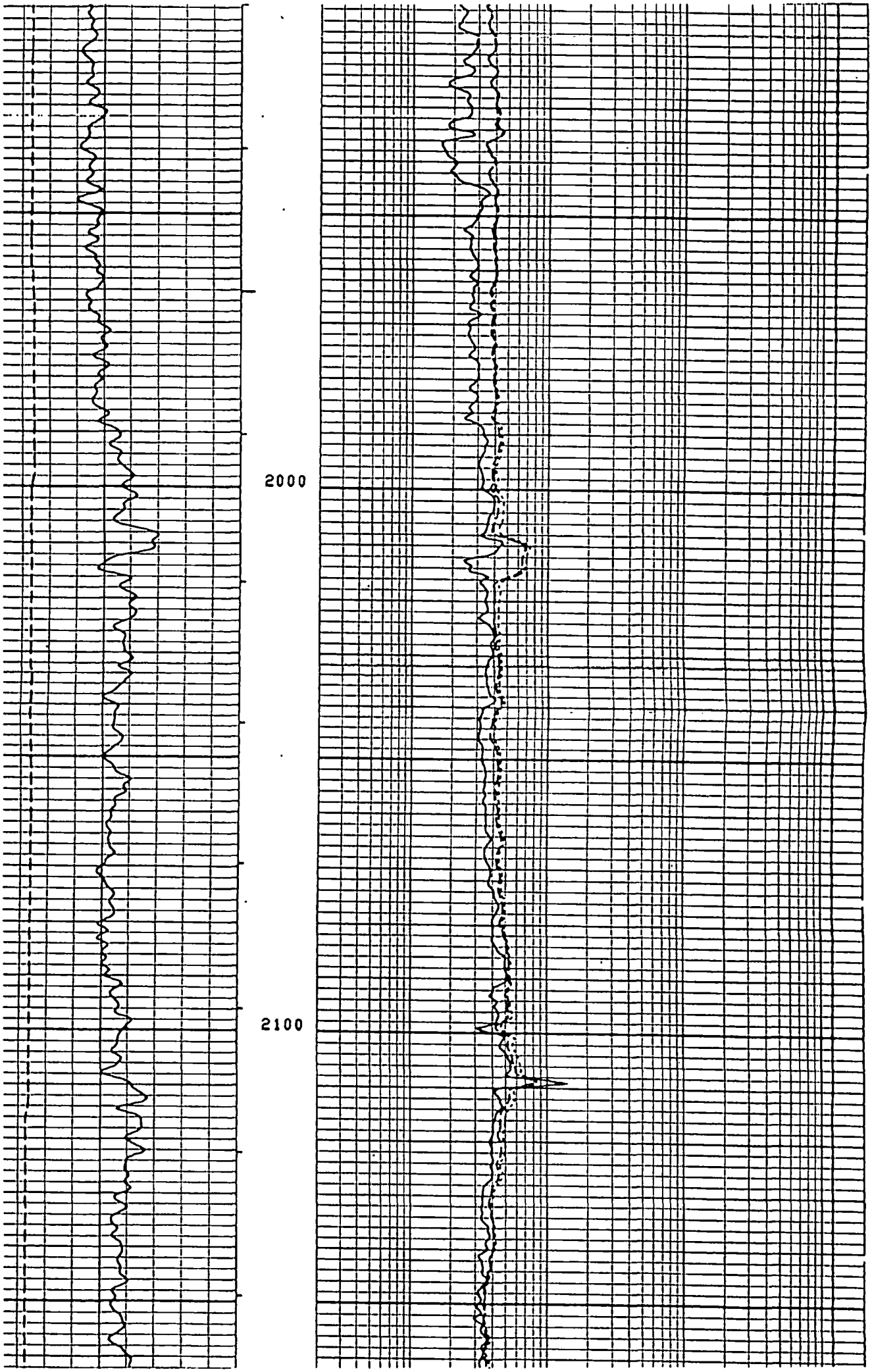
MAR02-1221



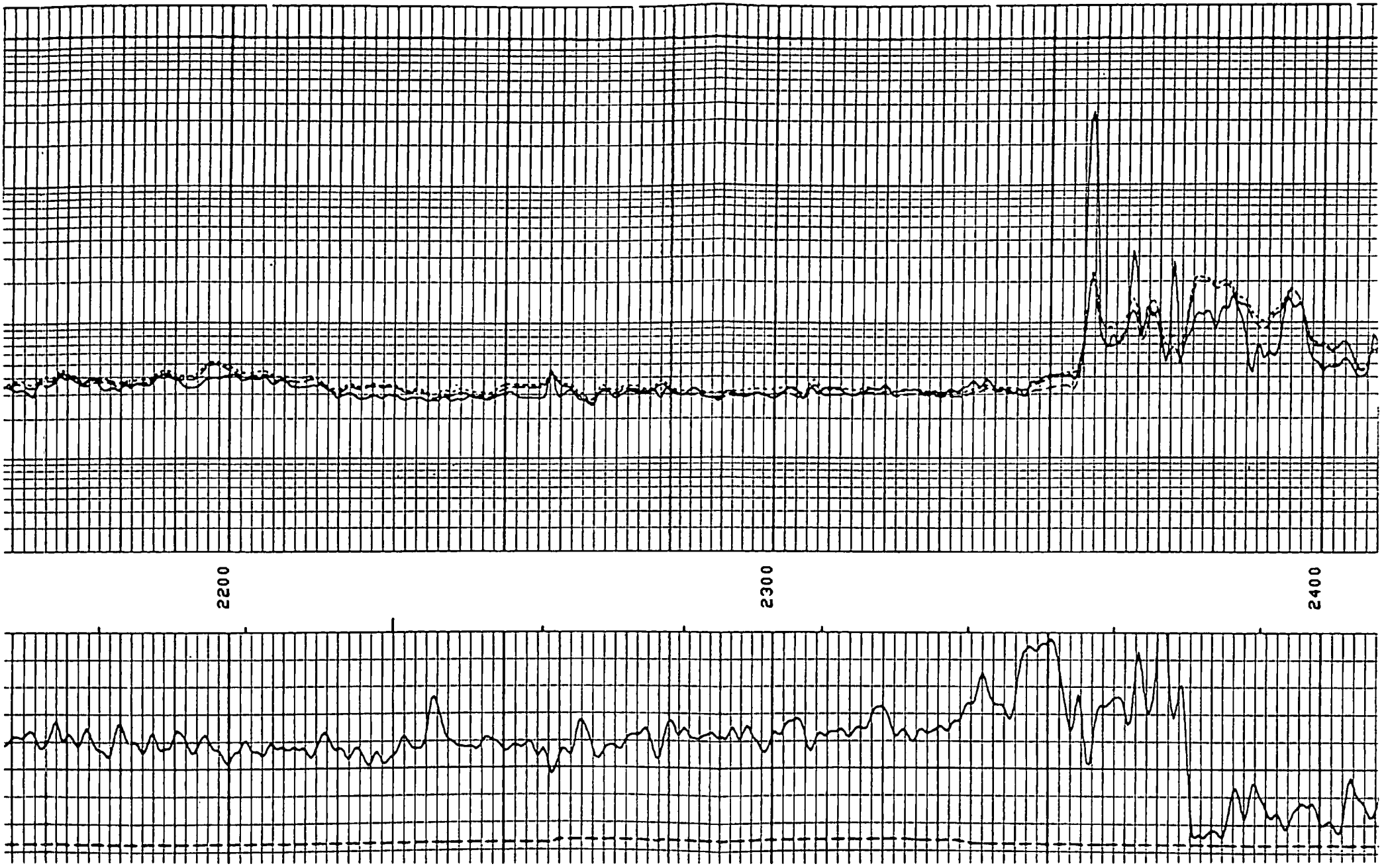
MAR02-1222



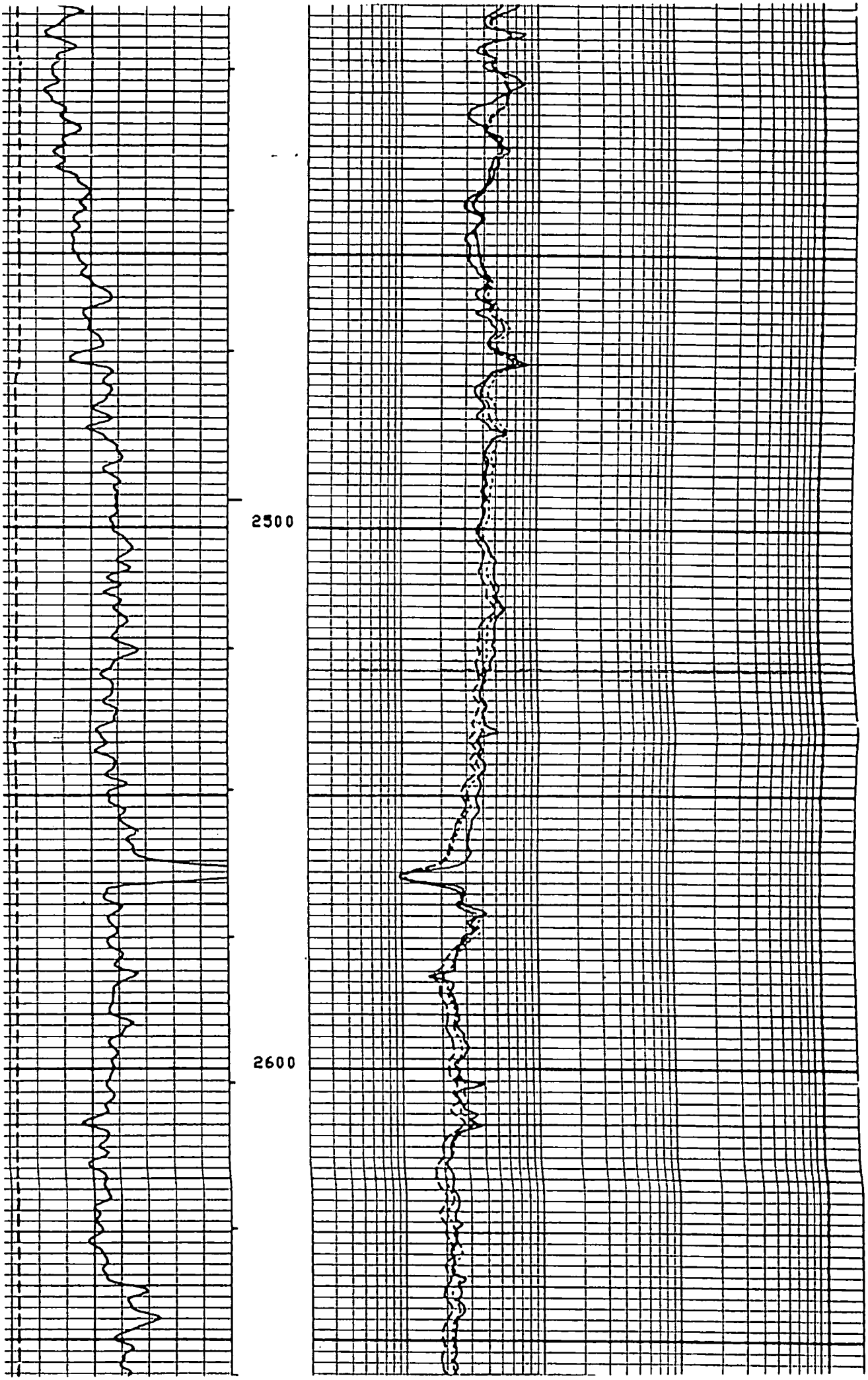
MAR02-1223



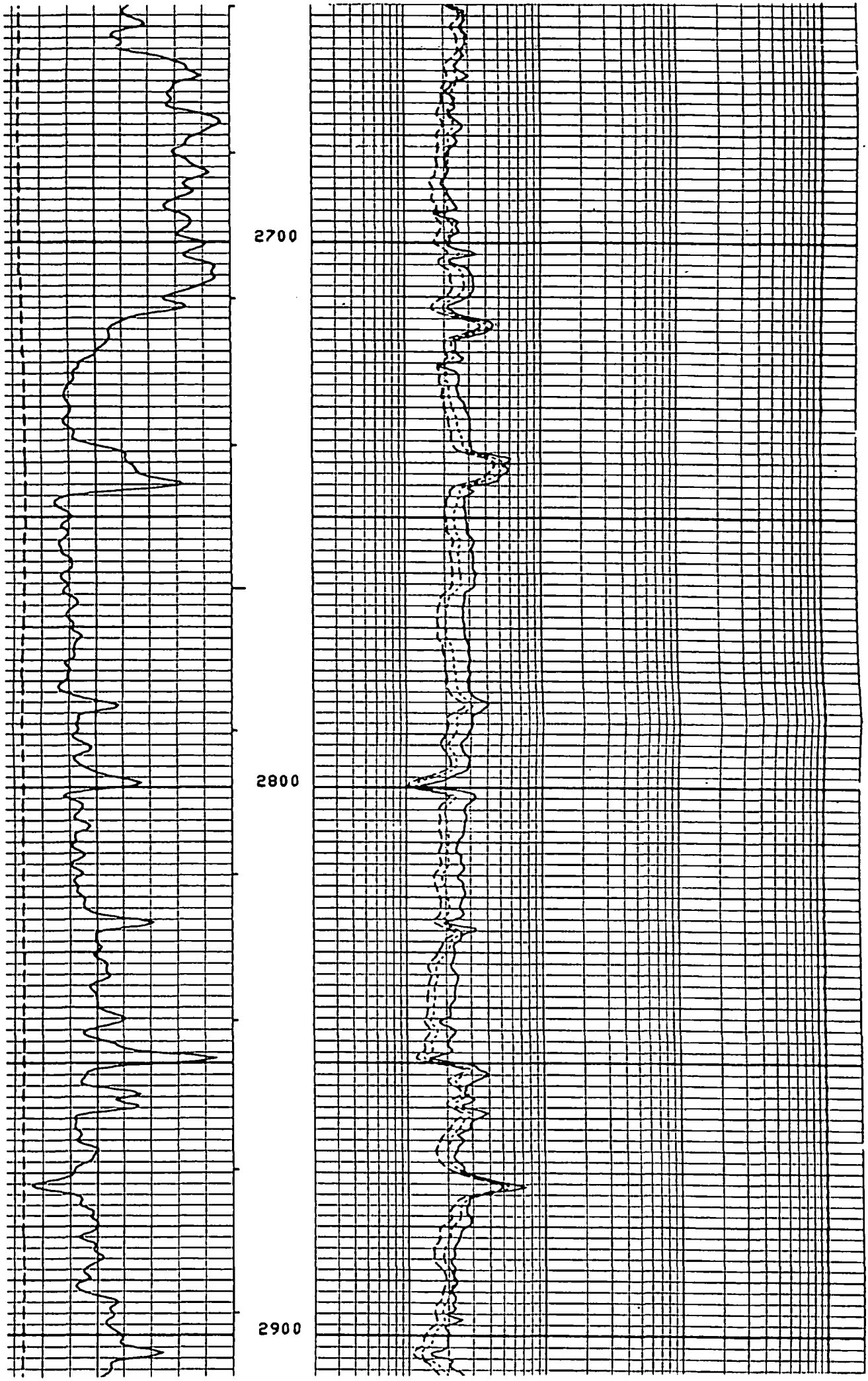
MAR02-1224



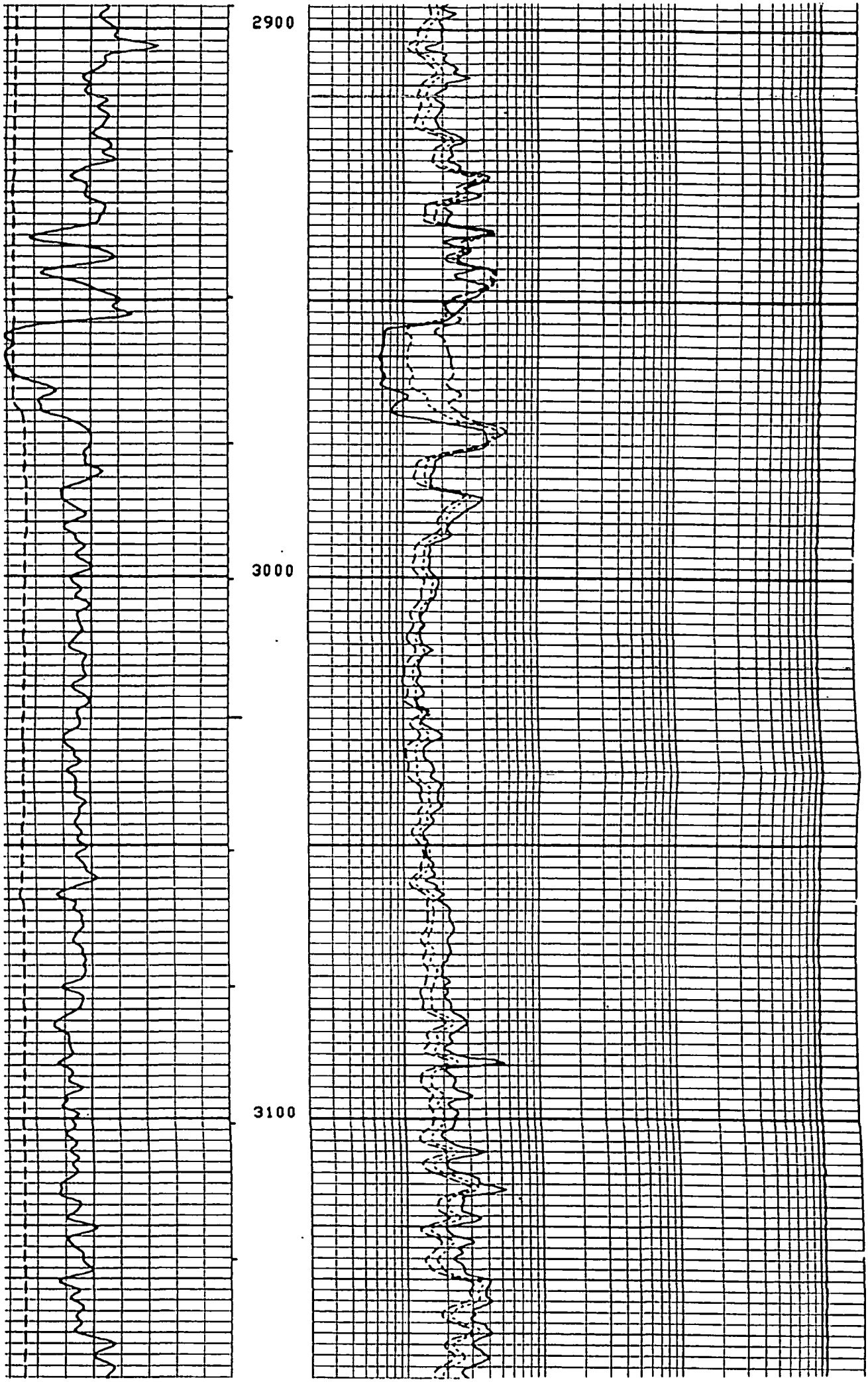
MAR02-1225



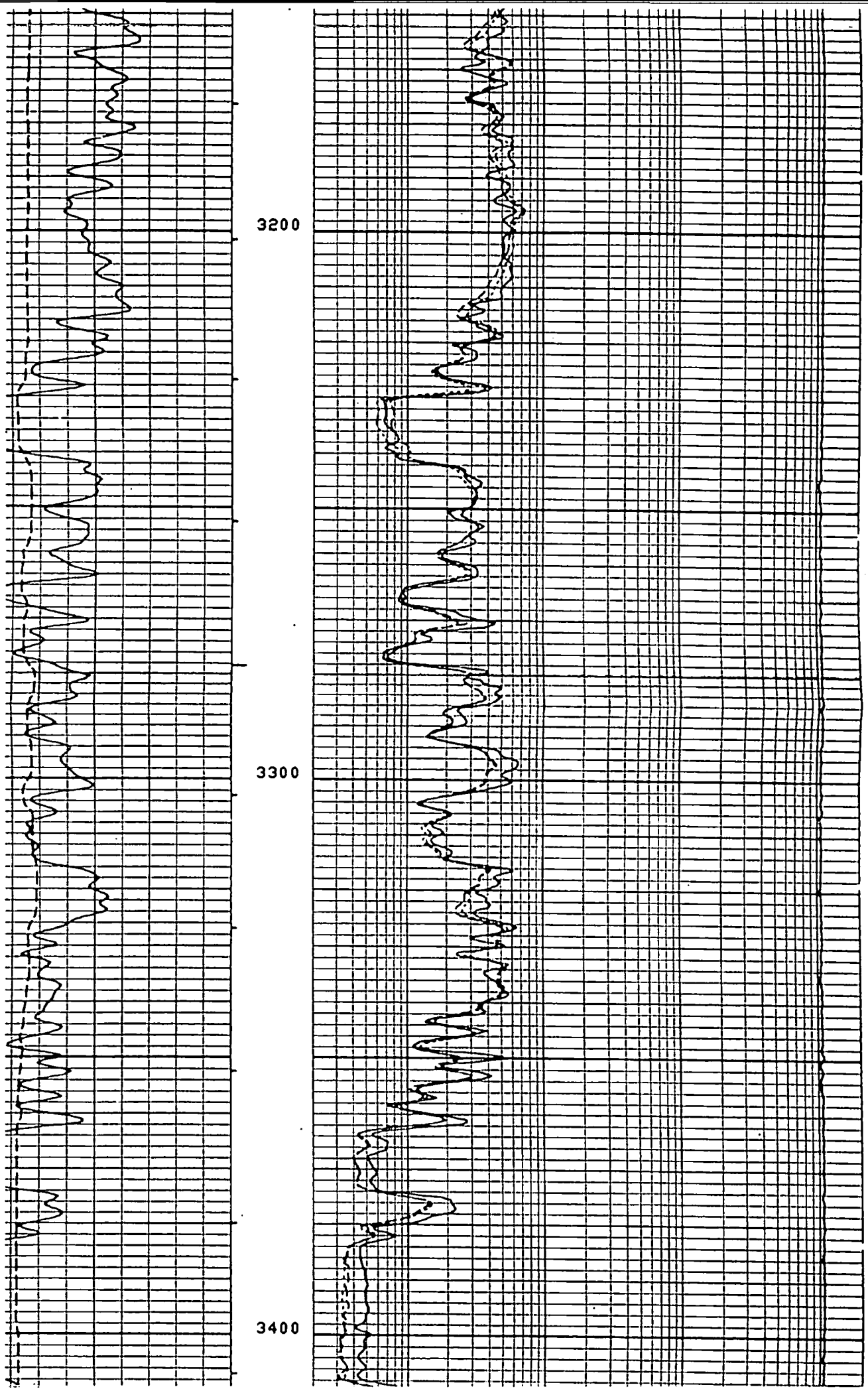
MAR02-1226



MAR02-1227

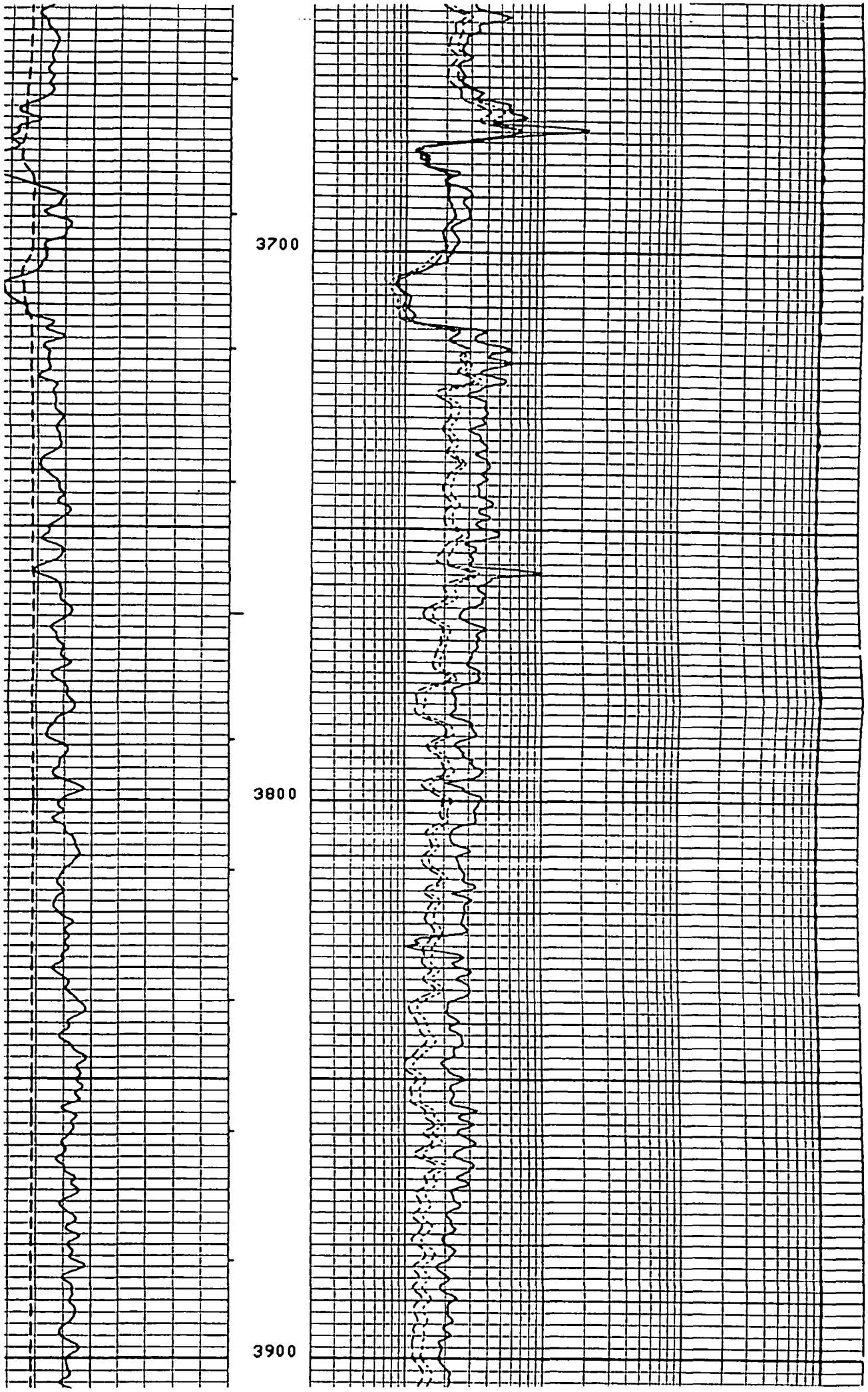


MAR02-1228

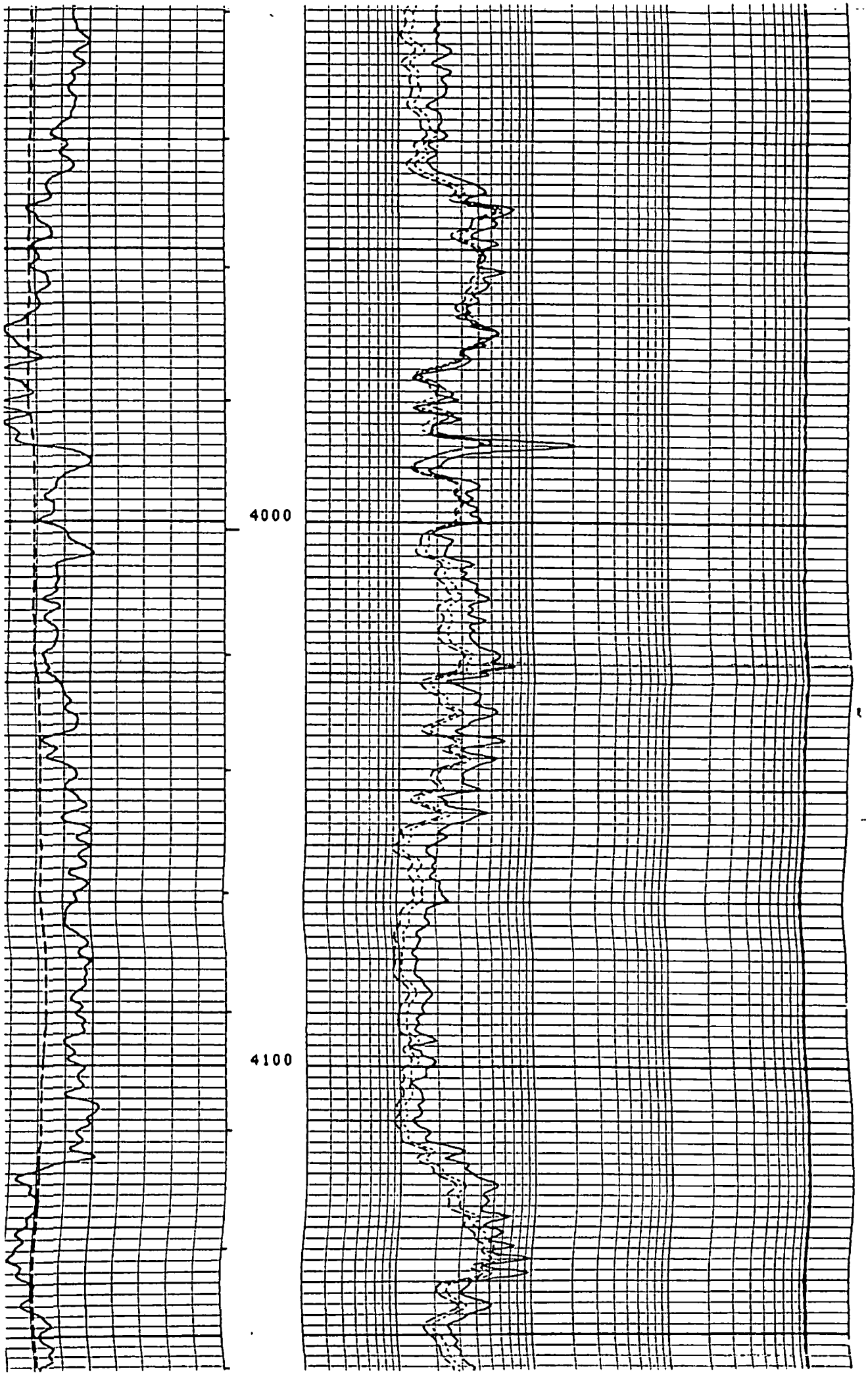


MAR02-1229

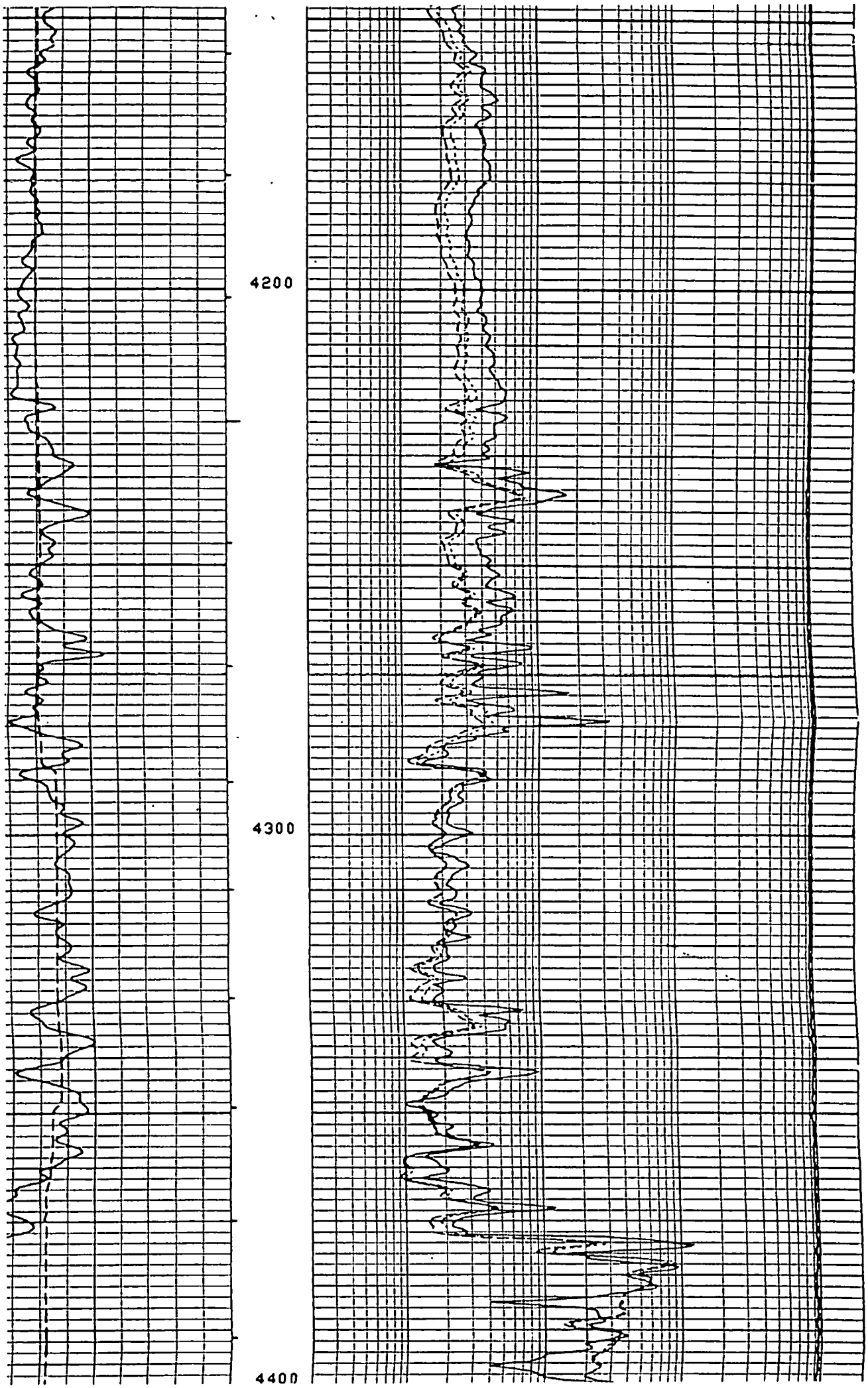
MAR02-1230



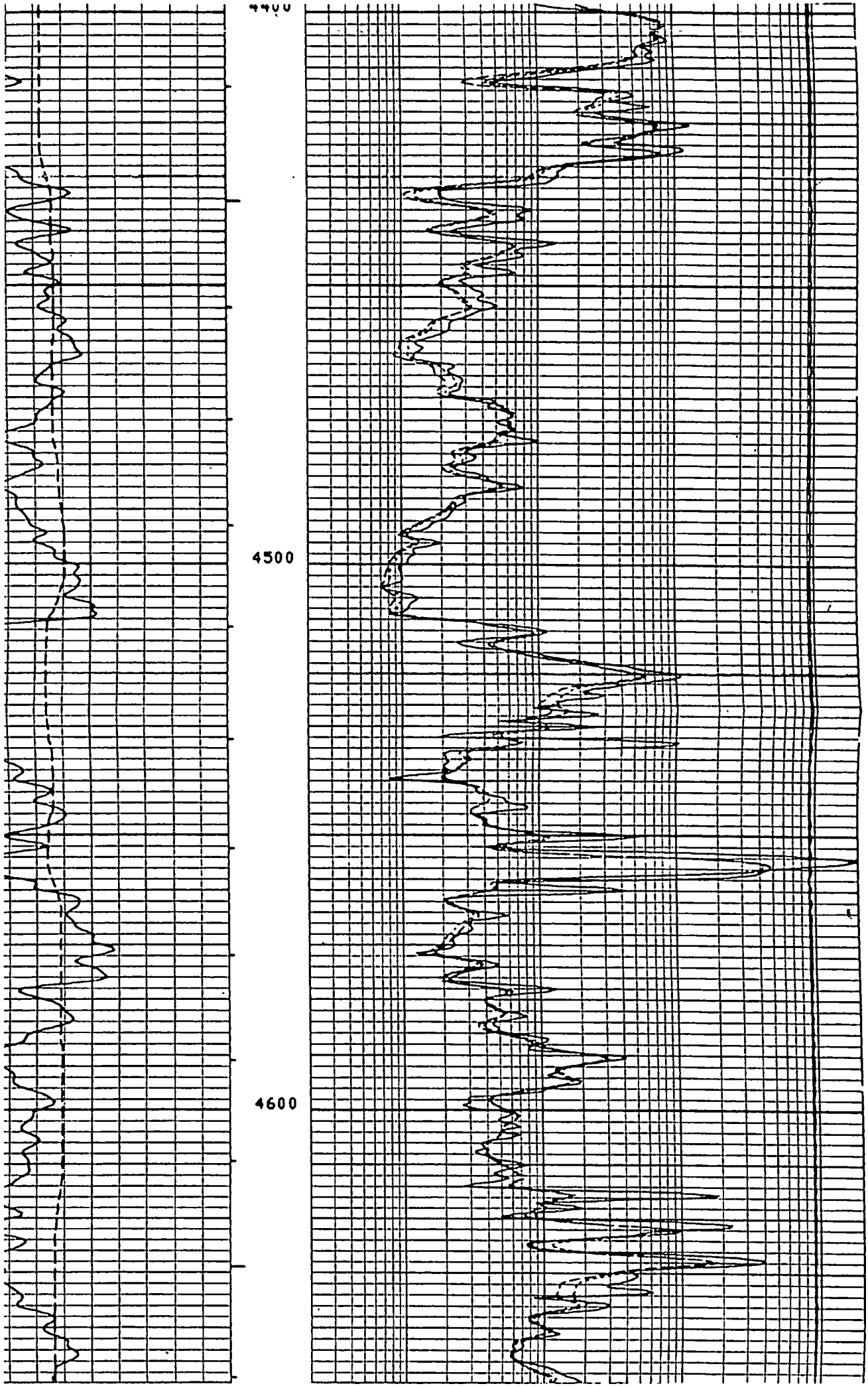
MAR02-1231



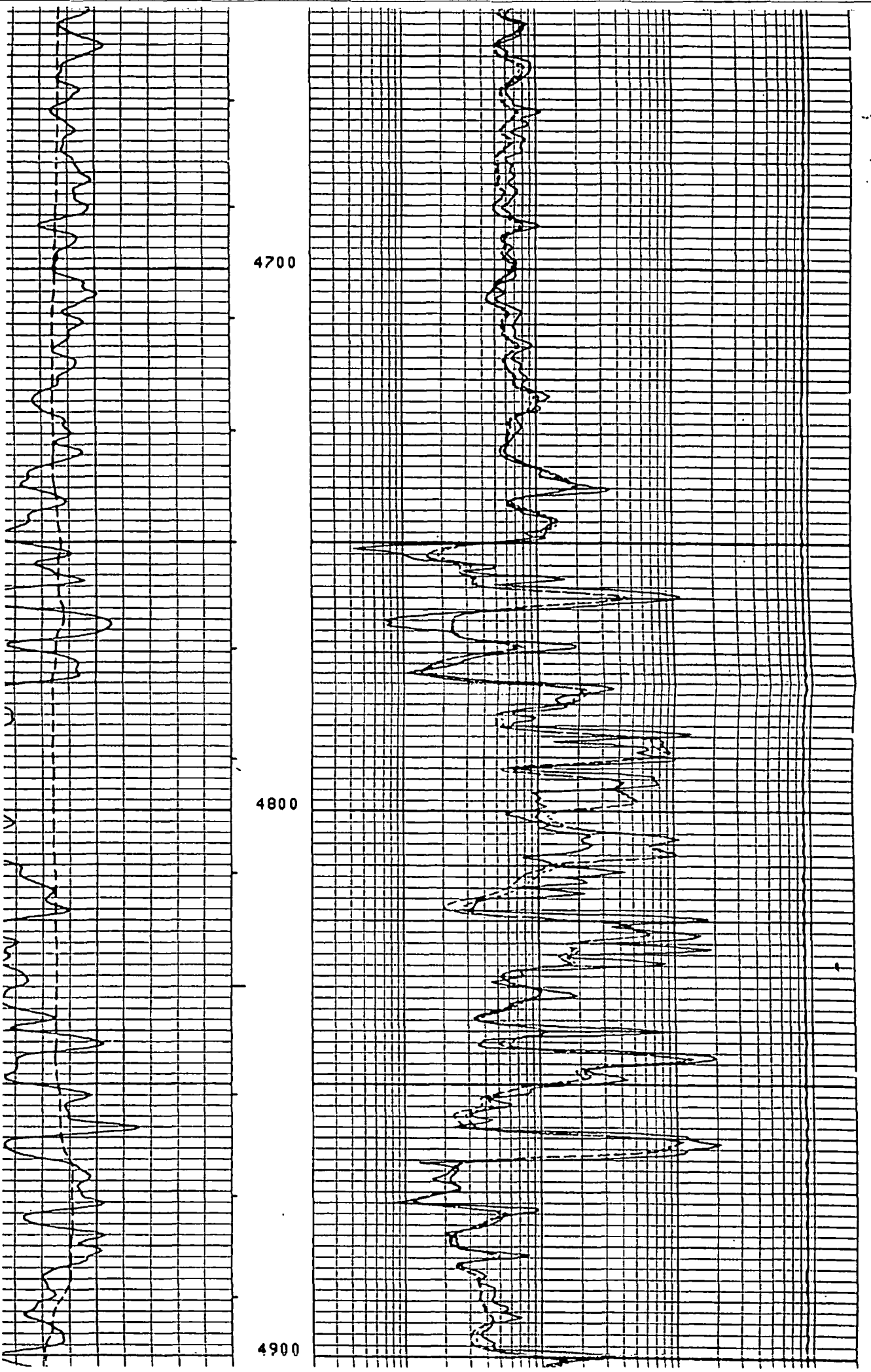
MAR02-1232



MAR02-1233



MAR02-1234



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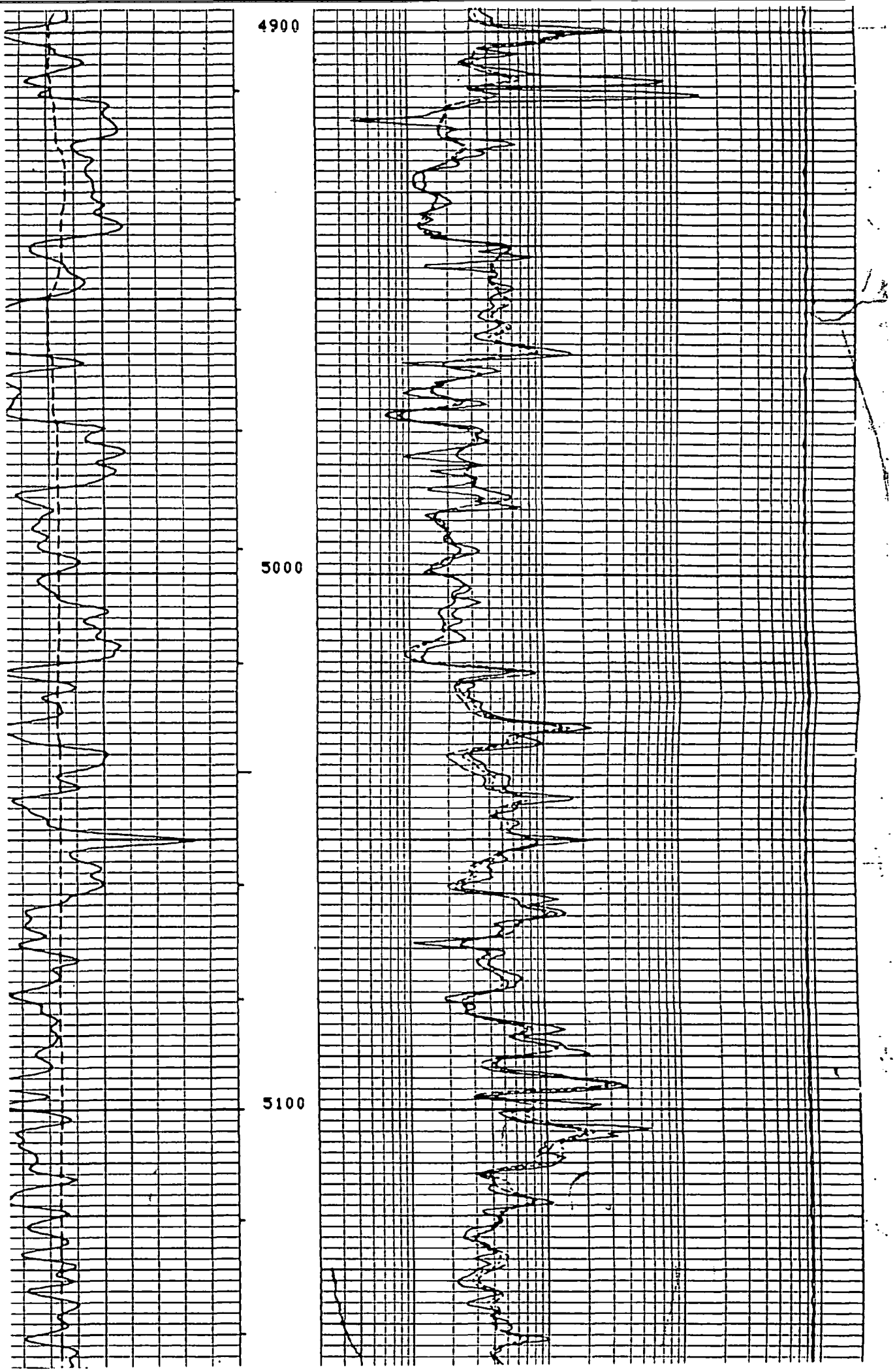
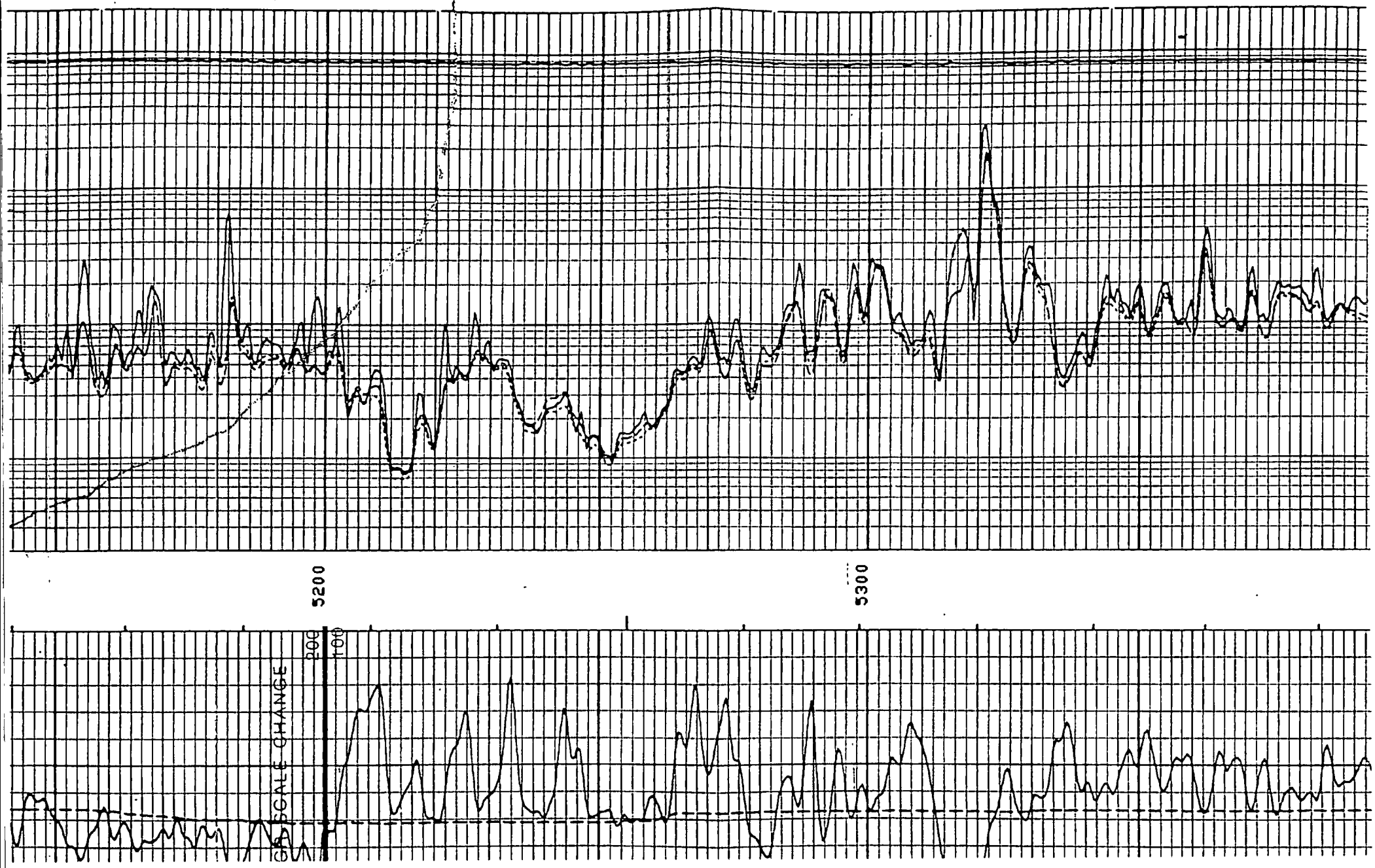
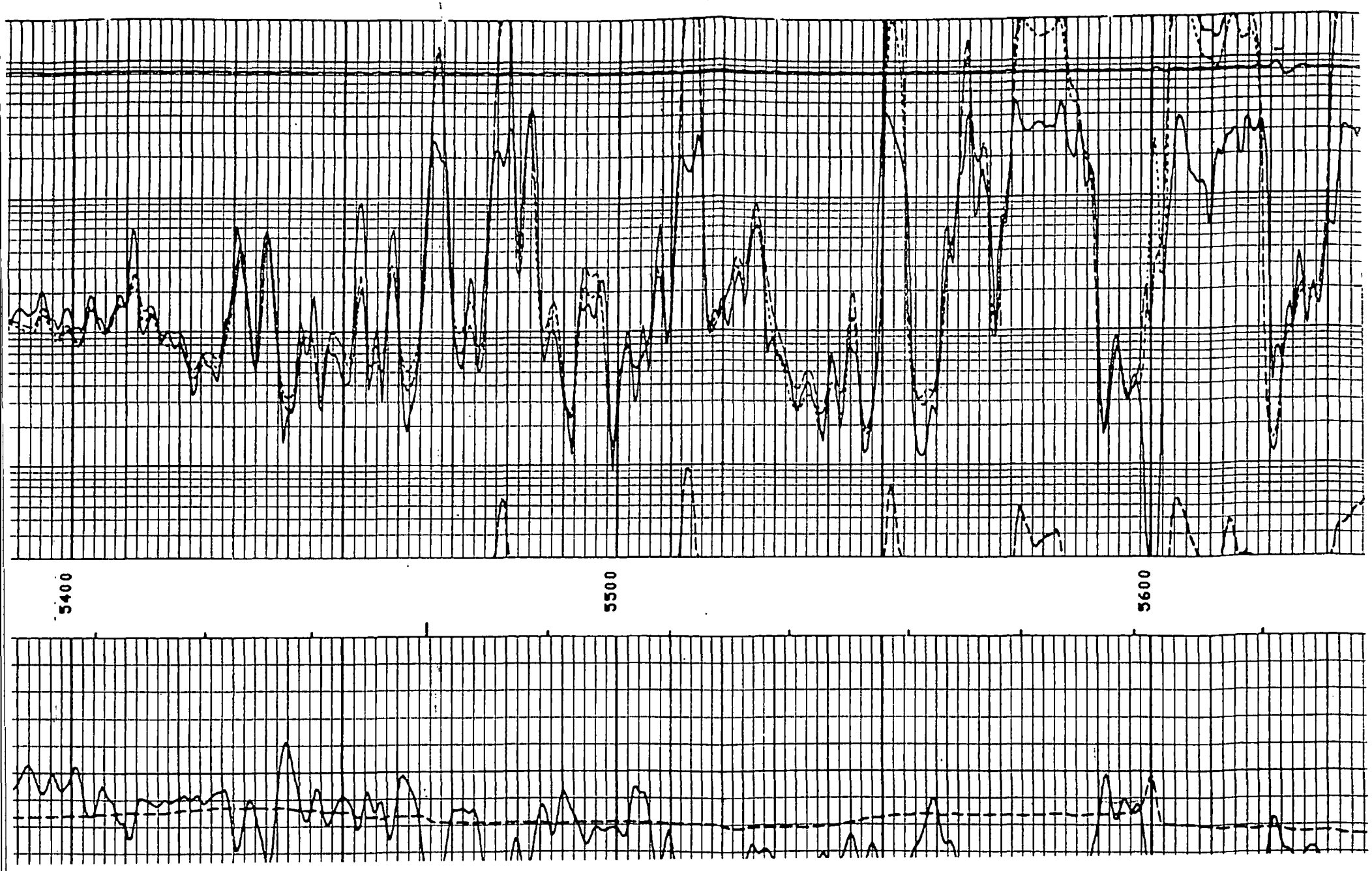


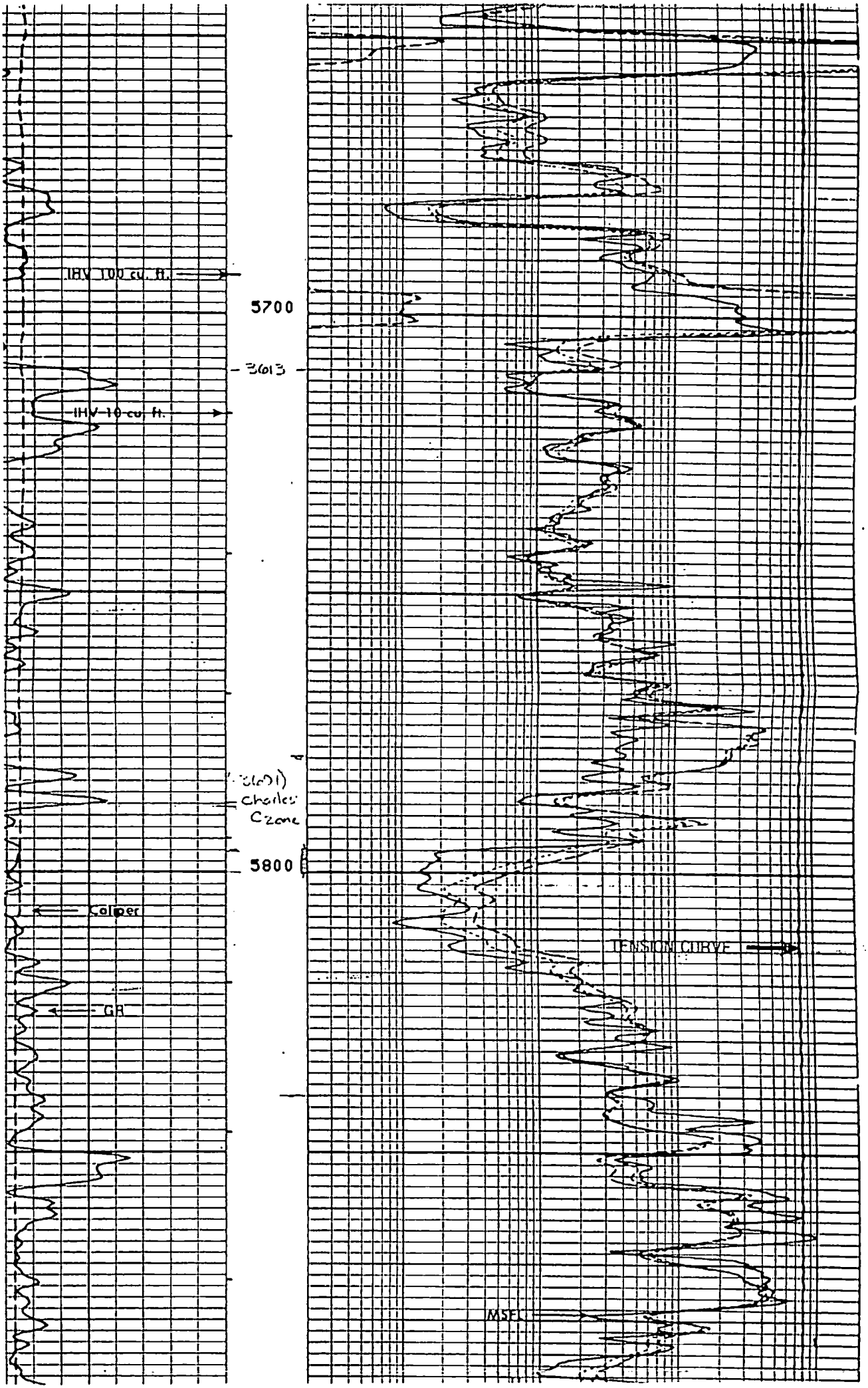
MAR02-1236



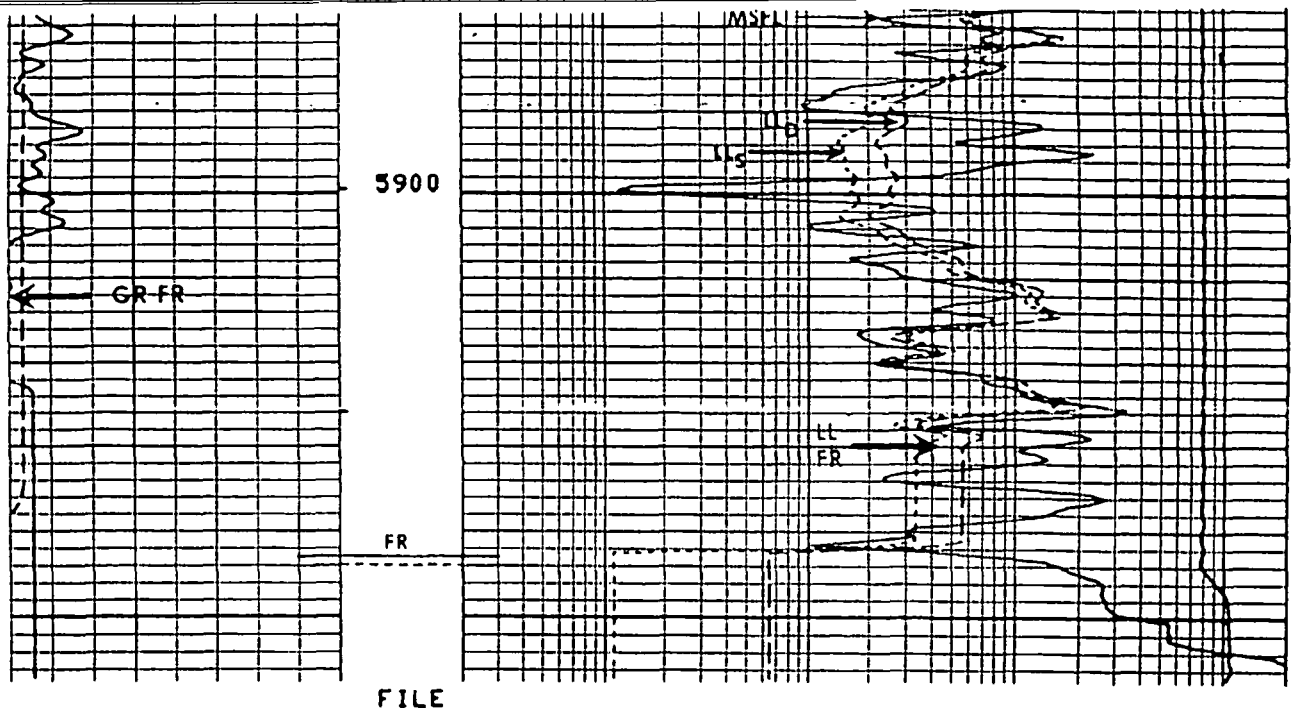
MAR02-1237



MAR02-1238


IHV 100 cu. ft.
5700
3613
IHV 10 cu. ft.
3691
Charles
C zone
5800
Caliper
GR
TENSION CURVE
MSFL

MAR02-1239



FILE

6

		LLD (OHMM)	TENS(LB)
		2000. 200000	10000. 0.0
CALI(IN)		LLS (OHMM)	
0 26.00		0.2000	2000.
CALI(IN)		LLD (OHMM)	
0 16.00		0.2000	2000.
GR (GAPI)		RXO (OHMM)	
100.0		0.2000	2000.

PARAMETERS

NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
PHI		PHIX	SPT		STAN	BS	INCH	7.875
D		0.0	BHS		OPEN			

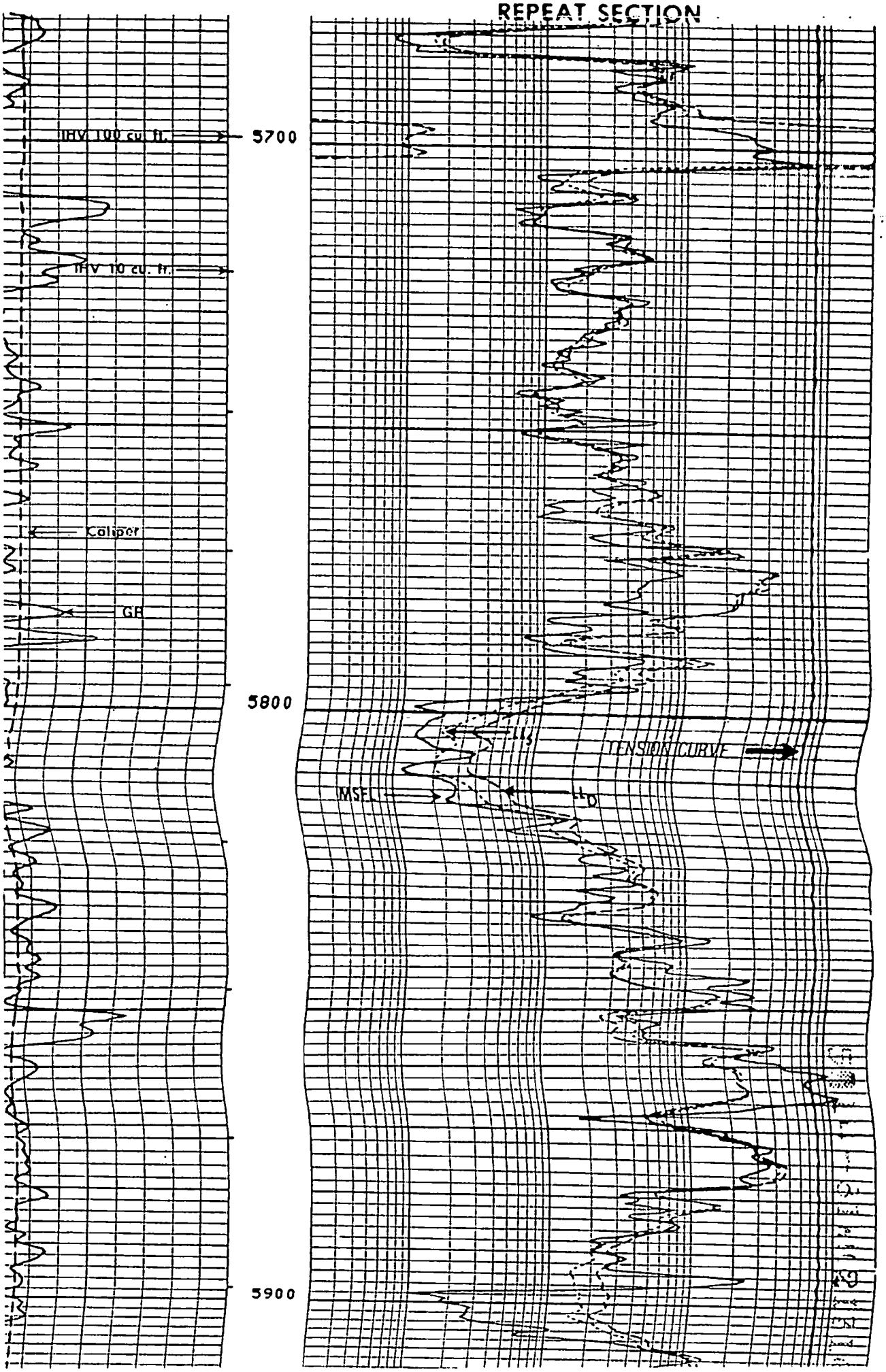
PARAMETERS

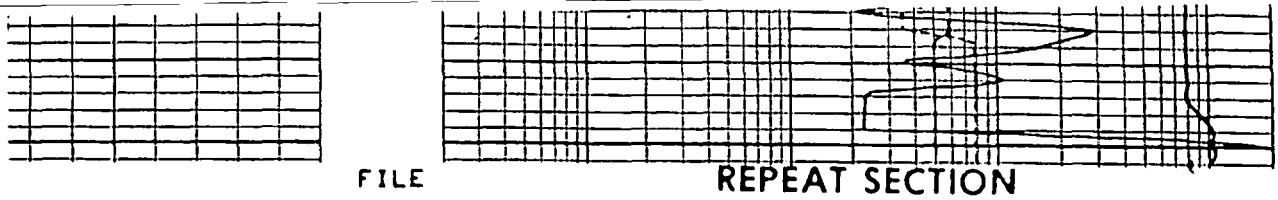
NAME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
PHI		PHIX	SPT		STAN	BS	INCH	7.875
D		0.0	BHS		OPEN			

		LLD (OHMM)	TENS(LB)
		2000. 200000	10000. 0.0
CALI(IN)		LLS (OHMM)	
0 26.00		0.2000	2000.
CALI(IN)		LLD (OHMM)	
0 16.00		0.2000	2000.
GR (GAPI)		RXO (OHMM)	
100.0		0.2000	2000.

FILE

MAR02-1240


REPEAT SECTION
IHV 100 cu. ft.
IHV 10 cu. ft.
Caliper
GR
5700
5800
5900
TENSION CURVE
MSEL



FILE

5

REPEAT SECTION

		LLD (OHMM)	TENS(LB)
		2000. 200000	10000. 0.0
CALI(IN)		LLS (OHMM)	
26.00		0.2000	2000.
CALI(IN)		LLD (OHMM)	
16.00		0.2000	2000.
GR (GAPI)		RXO (OHMM)	
100.0		0.2000	2000.

PARAMETERS

ME	UNIT	VALUE	NAME	UNIT	VALUE	NAME	UNIT	VALUE
HI		PHIX	SPT		STAN	BS	INCH	7.875
		0.0	BHS		OPEN			

BEFORE SURVEY CALIBRATION SUMMARY

PERFORMED: 81/04/16
PROGRAM FILE: MILL (VERSION 18.2 80/08/29)

TB ELECTRONICS CALIBRATION SUMMARY

	MEASURED	CALIBRATED	UNITS
LLS	33.31	31.60	OHM
LLD	33.40	31.60	OHM

ST ELECTRONICS CALIBRATION SUMMARY

	MEASURED		CALIBRATED		
	ZERO	PLUS	ZERO	PLUS	UNITS
MSF	0.2	1008.	0.0	999.9	MM/M
I1	-0.4	151.0	0.0	199.9	MM/M

E DETECTOR CALIBRATION SUMMARY

	MEASURED			
	BKGD	JIG	CALIBRATED	UNITS
GR	33	208	165	GAPI

ST CALIPER CALIBRATION SUMMARY

	MEASURED		CALIBRATED		
	SMALL	LARGE	SMALL	LARGE	UNITS
ALI	6.2	9.9	8.0	12.0	IN

FILE

4

NY TEXAS OIL AND GAS CORP.

SCHL. FR 5943
SCHL. TD 5944

MAR02-1242

	MEASURED SMALL	MEASURED LARGE	CALIBRATED SMALL	CALIBRATED LARGE	UNITS
CALI	6.2	9.9	8.0	12.0	IN

FILE

4

COMPANY TEXAS OIL AND GAS CORP.

WELL BUCKLES NO. A-1

FIELD EAST POPLAR

COUNTY ROOSEVELT STATE MONTANA

SCHL. FR 5943
SCHL. TD 5944
DRLR TD 5938

Elev: KB 2097
DF ---
GL 2085

MAR02-1243

BEFORE THE OIL AND GAS CONSERVATION COMMISSION

OF THE STATE OF MONTANA

IN THE MATTER OF THE APPLICATION OF MESA PETROLEUM COMPANY FOR PERMIT TO INJECT WATER INTO THE JUDITH RIVER FORMATION, POPLAR FIELD, ROOSEVELT COUNTY, MONTANA.

A P P L I C A T I O N

COMES NOW the applicant, MESA PETROLEUM COMPANY, and in support of its application as above entitled, respectfully shows to the Oil and Gas Conservation Commission of Montana, that:

1. Mesa Petroleum Company has submitted to the Montana Oil and Gas Conservation Commission a Notice of Intent to drill a water injection well at the following location:

   1750' FSL and 140' FWL Sec. 22 T28N-R51E
   Roosevelt County, Montana.

2. Mesa Petroleum Company has completed a producing oil well known as the Biere No. 1-22, NW SW Section 22-Township 28 North, Range 51 East, Poplar Field, Roosevelt County, which will be served by the proposed water injection well.

3. The Biere No. 1-22 is completed in the Charles 'C' Formation with a notch in casing at 5790' and is presently shut-in pending installation of surface production equipment and salt water disposal facilities.

4. The proposed injection formation is the Judith River zone located at a depth of approximately 698' - 878' in the Mesa Petroleum Company Biere No. 1-22 and is described as a fine to medium grained sandstone.

5. The top of the Judith River Formation is found at +1388 feet above sea level in the Mesa Petroleum Company Biere No. 1-22.

6. Attached as Exhibit 'A' is a portion of the Laterolog-Gamma Ray Log of the Mesa Petroleum Company Biere No.

1-22 marked to show the approximate top and base of the Judith River Formation.

7. The proposed injection well will be drilled to a depth of approximately 1000', cased with 8-5/8" pipe and cemented to the surface. The lower portion of the Judith River Formation will be perforated and stimulated as necessary to obtain adequate injection rates.

8. It is anticipated that approximately 1000 barrels per day of produced water from the Charles 'C' formation in the Mesa Petroleum Company Biere No. 1-22 will be injected into the proposed input well.

9. Mesa Petroleum Company with Post Office address, Box 2009, Amarillo, Texas, is the operator of the Biere No. 1-22 producing well and will operate the proposed salt water disposal well and injection system.

10. Attached as Exhibit 'B' is a plat showing the proposed injection well location and the Mesa Petroleum Company Biere No. 1-22. There are no drilling or producing wells or wells which have produced, other than the Mesa Petroleum Company Biere No. 1-22, NW SW Section 22 - Township 28 North, Range 51 East, within the one-half mile radius of the proposed salt water disposal well.

WHEREFORE, Mesa Petroleum Company requests that it be permitted to drill a water disposal well and inject produced salt water from the Charles 'C' zone into the Judith River Formation in said disposal well as heretofore set forth.

Respectfully submitted:

THE PETROLEUM ENGINEERING & MANAGEMENT CORPORATION

RONALD D. RAGLAND
Petroleum Engineer
Consultant for Applicant
250 Securities Building
Billings, Montana 59101

MAR02-1267

SCHLUMBERGER

WITH GAMMA RAY

MAR02-1268

COUN. FIELD or LOCATION WELL COMPANY

COMPANY MESA PETROLEUM CO.

WELL BIERE # 1-22

FIELD WILDCAT

COUNTY ROOSEVELT STATE MONTANA

LOCATION NW SW

Sec. 22 Twp. 28 N Rge. 51E

Other Services: SNP MLL MDP

Permanent Datum: GL. Elev. 2074

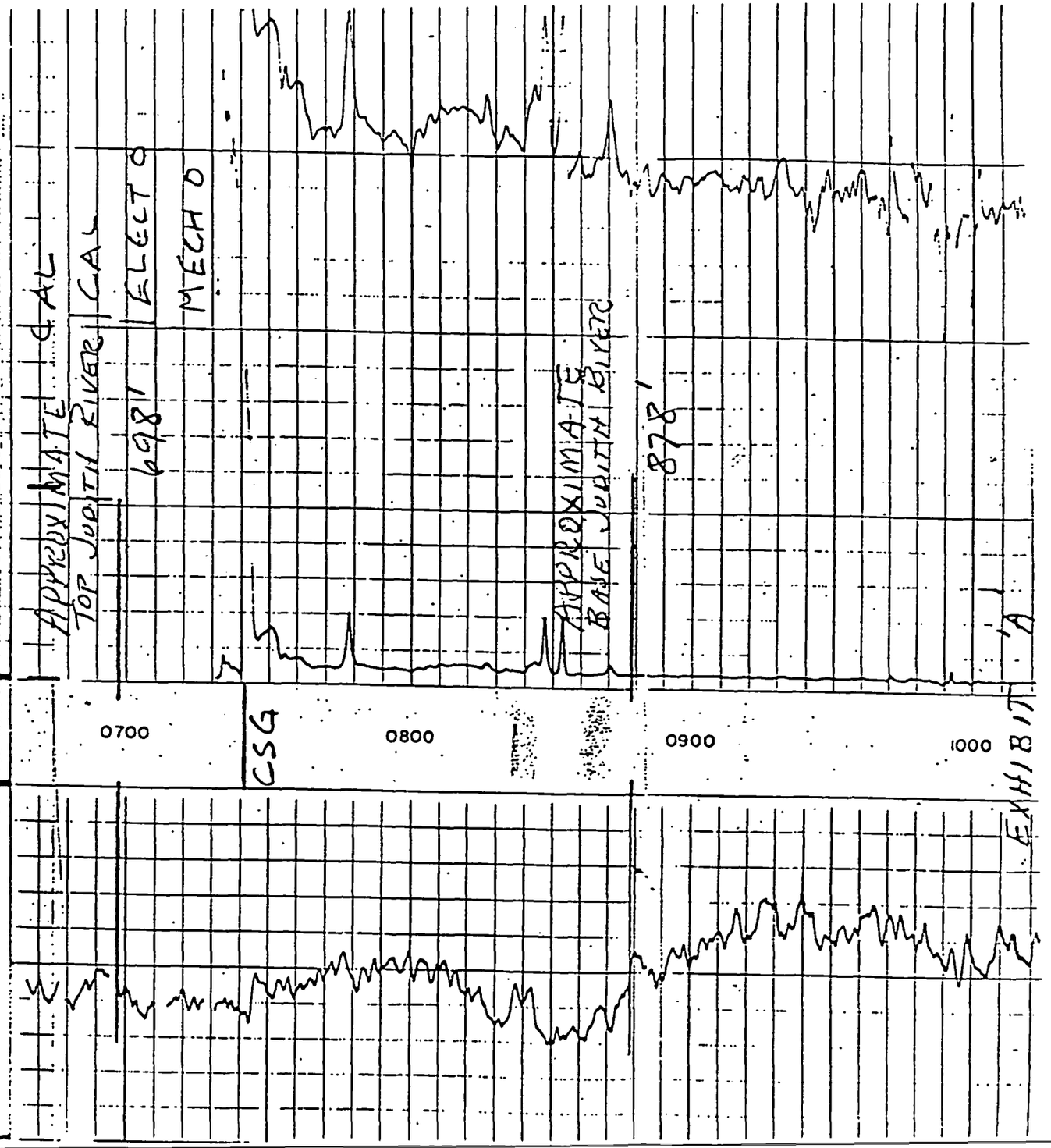
Log Measured From KB 12 Ft. Above Perm. Datum

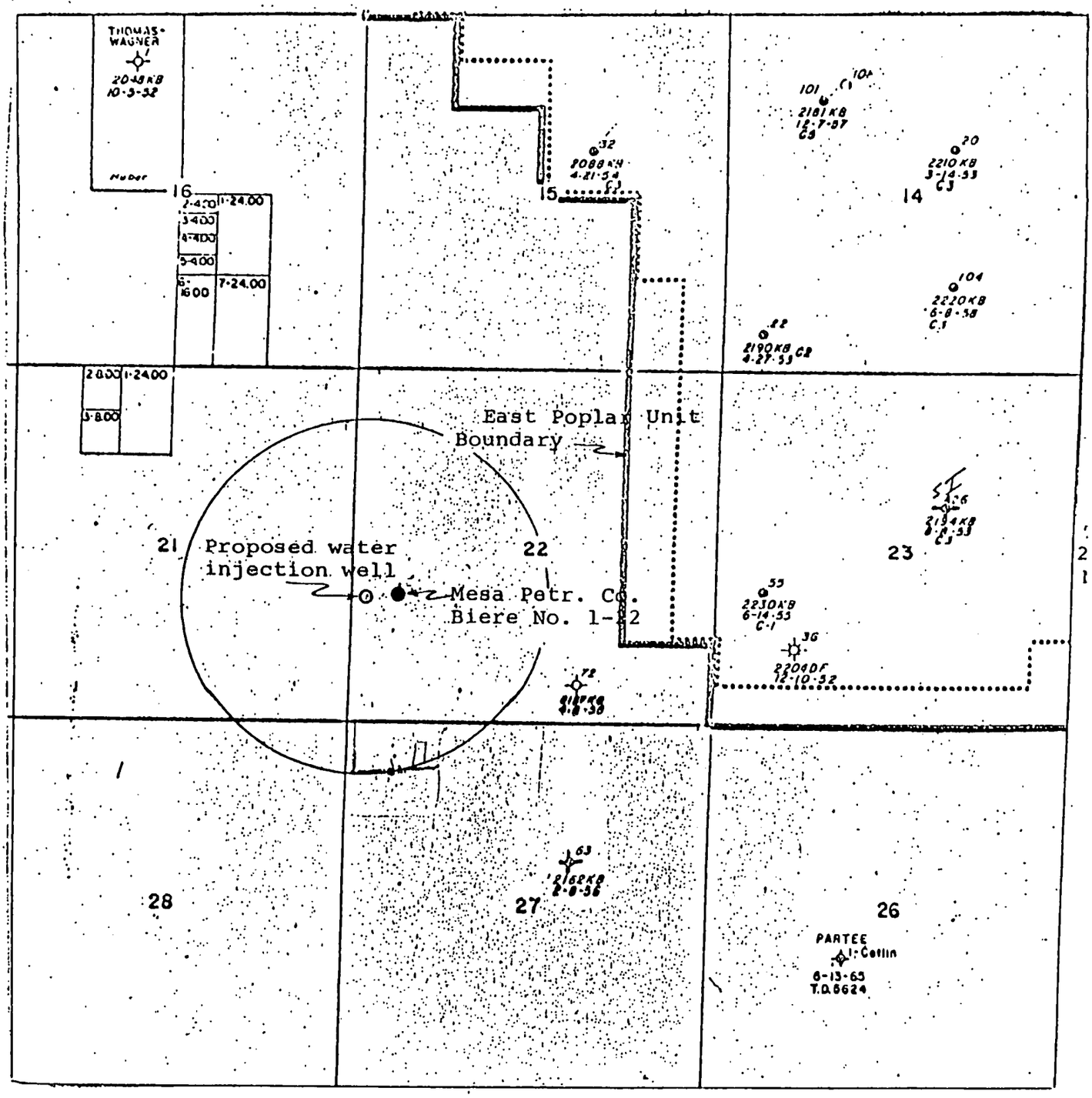
Drilling Measured From KB

Elev.: K.B. 2086 D.F. G.L. 2074

Date	5-25			
Run No.	ONE			
Depth—Driller	5845			
Depth—Logger	5845			
Btm. Log Interval	5840			
Top Log Interval	741			
Casing—Driller	8 5/8 @ 741	@	@	@
Casing—Logger	741			
Bit Size	7 7/8			
Type Fluid in Hole	SBM			
Dens. / Visc.	10.9 / 58			
pH / Fluid Loss	9 / 6.0 ml	ml	ml	ml
Source of Sample	FLOW LINE			
R_m @ Meas. Temp.	.116 @ 167 °F	@ °F	@ °F	@ °F
R_{mf} @ Meas. Temp.	.103 @ 167 °F	.035 @ 195 °F	@ °F	@ °F
R_{mc} @ Meas. Temp.	— @ — °F	@ °F	@ °F	@ °F
Source: R_{mf} / R_{mc}	M / —			
R_m @ BHT	.055 @ 195 °F	@ °F	@ °F	@ °F
Time Since Circ.	4 HRS			
Max. Rec. Temp.	195 °F	°F	°F	°F
Equip. / Location	5642 / WLSTN			
Recorded By	ERICKSON			
Witnessed By	MR. [illegible]			

The well name, location and borehole reference data were furnished by the customer.





MESA PETROLEUM CO.
PROPOSED WATER INJECTION SYSTEM

POPLAR FIELD

ROOSEVELT COUNTY, MONTANA

EXHIBIT 'B'

Ronald D. Ragland

6/16/70

MAR02-1269

sent a note to J.O. to check if well could be released from bond as we receive a SRA.

J.O. had contacted owner to clean up [illegible]

Well will be released from Bond when we receive a SRA.

otary tools were used from 0 to 998

able tools were used from to

otal depth 998 ft.; Plugged back to 950 T.D.; Open hole from to

PERFORATIONS			ACIDIZED, SHOT, SAND FRACED, CEMENTED			
Interval		Number and Size and Type	Interval		Amount of Material Used	Pressure
From	To		From	To		
796	800	9-3/8 Jet	796	800	500 Gal. 15% HCl	400#
804	808	9-3/8 Jet				
812	820	17-3/8 Jet				
825	834	19-3/8 Jet				

(If P&A show plugs above)

INITIAL ~~PRODUCTION~~ S.W.D.

Well is ~~producing from~~ injecting in Judith River (pool) formation. Initial injection 966 B.W.D. at 390 P.S.I.

. P barrels of oil per hours (pumping or flowing)

Mcf of gas per hours.

barrels of water per hours, or % W.C.

(OVER)

MAR02-1270

INITIAL PRODUCTION—(Continued)

ial 10-day average production_____(bbl./day) (if taken)
ssures (if measured): Tubing_____psi flowing; _____ psi shut-in
Casing_____psi flowing; _____ psi shut-in
vity_____° API (corrected to 60° F.)

DRILL STEM TESTS

S.T. No.	From	To	Tool Open (Min.)	Shut-In	F.P.	S.I.P.	Recovery	Cushion
	None							

LOGS RUN

Type	Intervals	
	From	To
Gamma Ray Neutron	949	700

FORMATION RECORD

From	To	SAMPLE AND CORE NO. AND DESCRIPTION	Top of Formation

MAR02-1271

Form No. 1

LEASE NUMBER
[illegible]

(SUBMIT IN QUADRUPLICATE)

TO

OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

NOTICE
(THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE COMMISSION

SUNDRY NOTICES AND REPORT OF WELLS

Notice of Intention to Drill	Subsequent Report of Water Shut-off
Notice of Intention to Change Plans	Subsequent Report of Shooting, Acidizing, Cementing
Notice of Intention to Test Water Shut-off	Subsequent Report of Altering Casing
Notice of Intention to Redrill or Repair Well	Subsequent Report of Redrilling or Repair
Notice of Intention to Shoot, Acidize or Cement	Subsequent Report of Abandonment
Notice of Intention to Pull or Alter Casing	Supplementary Well History
Notice of Intention to Abandon Well Test X	Report of Fracturing

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

REGULATORY

July 18, 1984

Following is a notice of intention to do work or land owned described as follows:

LEASE Biere

MONTANA (State) Roosevelt (County) Poplar (Field)

Well No. Biere #A-1 (SWD) 22 (Sec.) 23N (Township) 51E (Range) (Meridian)

The well is located 1750 ft from S line and 140 ft from E line of Sec. 22

LOCATE ACCURATELY ON PLAT ON BACK OF THIS FORM THE WELL LOCATION, AND SHOW LEASE BOUNDARY

The elevation of the derrick floor above the sea level is 2087' KB

READ CAREFULLY — DETAILS OF PLAN OF WORK — READ CAREFULLY

(State names of and expected depths to objective sands; show sizes, weights, and lengths of proposed casings, indicate mudding jobs, cementing points, and all other important proposed work; particularly all details regarding Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

Mesa Petroleum Co. proposes to plug this well as the Biere 1-22 oil well is no longer economic to produce. Subject well was TDed at 998', with 8 5/8" casing set at 998', and 5 1/2" casing set at 749'. Mesa proposes to set a cast iron bridge plug at 740', above perforations at 796'-834'. Fill 5 1/2" casing with cement from 740' to surface. Set dry hole marker. Both 8 5/8" and 5 1/2" casings were cemented to surface.

RECEIVED
JUL 31 1984

Approved subject to conditions on reverse of form

Date JUL 23 1984
ORIGINAL COPY SIGNED BY:
By Clare F. Naughton, Field Supervisor
District Office Agent Title

Company Mesa Petroleum Co.
By [signature]
Title Regulatory Coordinator
Address P. O. Box 2009 / Amarillo, Texas 79189

COMMISSION USE ONLY
API WELL NUMBER

NOTE—Signature on the front of this notice is to be considered as the District Agent has approved in Quadruplicate which used as permit to drill. This expires 90 days from date of approval.

OVER

CC: MOGCC (Bill), CEN RCDS, LOCTC, WELL FILE, DRAFTER, PARTNERS, RES

MAR02-1272

LOCATE WELL CORRECTLY

Form No. 4
(Form Rule 300 3 & 311)

(SUBMIT IN TRIPLICATE)
TO
OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

LOG OF WELL

Company MESA PETROLEUM CO. Lease Biere Well No. SWD #1

Address P. O. Box 2009 Amarillo, Texas Field (or Area) Poplar

The well is located 1750 ft. from (S) line and 140 ft. from (W) line of Sec. 22

Sec. 22; T. 28N; R. 51E; County Roosevelt; Elevation 2087 R.B. (D.F., R.B. or G.L.)

Commenced drilling June 24, 1970, 19__; Completed July 9, 1970

The information given herewith is a complete and correct record of the well. The summary on this page is for the condition of the well at the above date.

Completed as Salt Water Disposal (oil well, gas well, dry hole)

Signed [illegible]

Title Consultant

Date July 17, 1970

IMPORTANT ZONES OF POROSITY

(denote oil by O, gas by G, water by W; state formation if known)

From ____ to ____ From ____ to ____
From ____ to ____ From ____ to ____
From ____ to ____ From ____ to ____
From ____ to ____ From ____ to ____

CASING RECORD

Size Casing	Weight Per Ft.	Grade	Thread	Casing Set	From	To	Sacks of Cement	Cut and Pulled from
8-5/8	24#	J-55	8 Rd	988			500	

TUBING RECORD

Size Tubing	Weight Per Ft.	Grade	Thread	Amount	Perforations
2½ E.U.E.	6.5#	J-55	8 Rd	790	796-800, 804-808, 812-320, 2 P.F. 825-834

COMPLETION RECORD

Rotary tools were used from 0 to 998
Cable tools were used from ____ to ____
Total depth 998 ft.; Plugged back to 990 T.D.; Open hole from ____ to ____

PERFORATIONS			ACIDIZED, SHOT, SAND FRACED, CEMENTED			
Interval From	Interval To	Number and Size and Type	Interval From	Interval To	Amount of Material Used	Pressure
796	800	9-3/8 Jet	796	800	500 Gal. 15% HCl	4000
804	808	9-3/8 Jet				
812	820	17-3/8 Jet				
825	834	19-3/8 Jet				

(If P&A show plugs above)

INITIAL ~~PRODUCTION~~ S.W.D.

Well is ~~producing from~~ injecting in Judith River (pool) formation. Initial injection 966 S.W.D. at 390 P.S.I.

I.P. ____ barrels of oil per ____ hours ____ (pumping or flowing)

____ Mcf of gas per ____ hours.

____ barrels of water per ____ hours, or ____ % W.C.

(OVER)

MAR02-1273

Form No. 8

GENERAL RULES
Rel. No. 311,
216 219 2221

(SUBMIT IN QUADRUPLICATE)

TO

OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

NOTICE
THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE COMMISSION

SUNDRY NOTICES AND REPORT OF WELLS

Notice of Intention to Drill	Subsequent Report of Water Shut-off
Notice of Intention to Change Plans	Subsequent Report of Shooting, Acidizing, Cementing
Notice of Intention to Test Water Shut-off	Subsequent Report of Altering Casing
Notice of Intention to Redrill or Repair Well	Subsequent Report of Redrilling or Repair
Notice of Intention to Shoot, Acidize or Cement	Subsequent Report of Abandonment X
Notice of Intention to Pull or Alter Casing	Supplementary Well History
Notice of Intention to Abandon Well	Report of Fracturing

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

September 26, 19 84

Following is a ~~report of work done~~ on land ~~owned~~ described as follows:

LEASE Biere

MONTANA (State) Roosevelt (County) Poplar (Field)

Well No. Biere #A-1 (SWD) 22 (Well No.) 28N (Township) 51E (Range) (Meridian)

The well is located 1750 ft from N/S line and 140 ft from E/W line of Sec 22

LOCATE ACCURATELY ON PLAT ON BACK OF THIS FORM THE WELL LOCATION, AND SHOW LEASE BOUNDARY

The elevation of the derrick floor above the sea level is 2087' KB.

READ CAREFULLY **DETAILS OF PLAN OF WORK** READ CAREFULLY

(State names of and expected depths to objective sands; show sizes, weights, and lengths of proposed casings; indicate mudding jobs, cementing points, and all other important proposed work; particularly all details results Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

Subject well was plugged on 9/15/84 by filling 5-1/2" casing and tubing with 250 sxs Cl "H" cement. Cut casing 4' below ground level. Welded cap on casing.

RECEIVED

SEP 27 1984

PRODUCTION RECORDS

Approved by: Date: Title:

by: District Office Agent Title:

Company: Mesa Petroleum Co.

By: [signature]

Title: Regulatory Agent

Address: P.O. Box 2009, Amarillo, TX 79105

COORDINATE LOCATION OF WELL SURFACE

Township Range County Well

Still subject to the approval of the District Agent or Supervisor

WHEN USED AS PERMIT TO DRILL THIS EXPIRES 90 DAYS FROM DATE OF APPROVAL

OVER

cc: Cent Rods, Denver, Partners, Well File, Acctg, RN, EPA 0+1

MAR02-1274

Form No. 2

GENERAL RULES
201, 202, 213,
216, 219, 233.1

(SUBMIT IN QUADRUPLICATE)
TO
OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

NOTICE
THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE COMMISSION.

RECEIVED JUN 1970 OIL AND GAS CONS. COMM. STATE OF MONT. BILLINGS

SUNDRY NOTICES AND REPORT OF WELLS

Notice of Intention to Drill Water Injection X		Subsequent Report of Water Shut-off	
Notice of Intention to Change Plans		Subsequent Report of Shooting, Acidizing, Cementing	
Notice of Intention to Test Water Shut-off		Subsequent Report of Altering Casing	
Notice of Intention to Redrill or Repair Well		Subsequent Report of Redrilling or Repair	
Notice of Intention to Shoot, Acidize, or Cement		Subsequent Report of Abandonment	
Notice of Intention to Pull or Alter Casing		Supplementary Well History	
Notice of Intention to Abandon Well		Report of Fracturing	

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

June 16, 1970

Following is a {notice of intention to do work} on land {~~owned~~ leased} described as follows:

LEASE Biere

MONTANA (State) Roosevelt (County) Poplar (Field)

Well No. 1 - W 22 (m. sec.) 28 N. (Township) 51 E. (Range) (Meridian)

The well is located 1750 ft. from {~~N~~ S} line and 140 ft. from {~~E~~ W} line of Sec. 22

LOCATE ACCURATELY ON PLAT ON BACK OF THIS FORM THE WELL LOCATION, AND SHOW LEASE BOUNDARY

The elevation of the ground above the sea level is 2075

READ CAREFULLY **DETAILS OF PLAN OF WORK** READ CAREFULLY

(State names of and expected depths to objective sands; show size, weights, and lengths of proposed casings; indicate mudding jobs, cementing points, and all other important proposed work, particularly all details results Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

MAR02-1275

Objective sand - Judith River

Casing - 8 -5/8" cemented to surface from approximately 1000'

AMOUNT RECEIVED —0—
DRILLING PERMIT NO. S5622
RECEIPT NO. — Water Injection Well

CORES AND CUTTINGS NOT REQUIRED.

Approved subject to conditions on reverse of form

Date 6-18-70

By Herbert D. Hadley, Geologist
District Office Agent Title

Company MESA PETROLEUM COMPANY

By [signature]

Title Petroleum Engineer Consultant

Address 250 Securities Bldg., Billings, Montana 59101

COMMISSION USE ONLY
API WELL NUMBER

25	7815	21649
STATE	COUNTY	WELL

NOTE:—Reports on this form to be submitted to the District Agent for Approval in Quadruplicate

WHEN USED AS PERMIT TO DRILL, THIS EXPIRES 90 DAYS FROM DATE OF APPROVAL.

OVER

Form No. 1

NOTICE
THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE BOARD.

(SUBMIT IN QUADRUPLICATE)
TO
BOARD OF OIL AND GAS CONSERVATION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

MAC 36-3.18(10)-818020
MAC 36-3.18(10)-818030
MAC 36-3.18(10)-818140
MAC 36-3.18(10)-818170
MAC 36-3.18(10)-818200
MAC 36-3.18(10)-818310
MAC 36-3.18(10)-818330
MAC 36-3.18(14)-818380

SUNDRY NOTICES AND REPORT OF WELLS

Notice of Intention to Drill		Subsequent Report of Water Shut-off	
Notice of Intention to Change Plans		Subsequent Report of Shooting, Acidizing, Cementing	
Notice of Intention to Test Water Shut-off		Subsequent Report of Altering Casing	
Notice of Intention to Redrill or Repair Well		Subsequent Report of Redrilling or Repair	
Notice of Intention to Shoot, Acidize, or Cement		Subsequent Report of Abandonment	X
Notice of Intention to Pull or Alter Casing		Supplementary Well History	
Notice of Intention to Abandon Well		Report of Fracturing	

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

October 5, 1984

Following is a {notice of intention to do work / report of work done} on land {owned / leased} described as follows:

LEASE Biere

MONTANA Roosevelt (County) Poplar (Field)

Well No. Biere #A-1 (SWD) 22 (m. sec.) 28N (Township) 51E (Range) (Meridian)

The well is located 1750 ft. from {N / S} line and 140 ft. from {E / W} line of Sec. 22

LOCATE WELL SITE ACCURATELY ON PLAT ON BACK OF THIS FORM.

The elevation of the ground or K.B. above the sea level is 2087' XB

READ CAREFULLY **DETAILS OF PLAN OF WORK** READ CAREFULLY

(State names of and expected depths to objective sands; show sizes, weights and lengths of proposed casings, cementing points and all other important proposed work, particularly all details of Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

Subject well was plugged on 9/15/84 by squeezing perfs w/140 sxs class "H" cement and filling 5½" casing and tubing w/110 sxs class "H" cement. Cut casing 4' below ground level. Welded cap on casing.

RECEIVED
OCT 5 1984
PRODUCTION RECORDS

MAR02-1276

Approved subject to conditions on reverse of form

Date

By District Office Agent Title

Company Mesa Petroleum Co.

By Randy Nordsven
Randy Nordsven

Title Regulatory Agent

Address P. O. Box 2009 Amarillo TX 79189

BOARD USE ONLY
API WELL NUMBER

NOTE—Approval on this form is to be submitted to the appropriate District for approval.

WHEN USED AS PERMIT TO DRILL, PERMIT EXPIRES 90 DAYS FROM DATE OF APPROVAL IF WELL NOT SPUDDED OR EXTENSION REQUESTED.

Form No. 2

GENERAL RULES
201, 202, 213,
216, 219, 233.1

(SUBMIT IN QUADRUPLICATE)

TO

OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA
BILLINGS OR SHELBY

RECEIVED
JUL 1984
OIL & GAS CONS. COMM.
STATE OF MONT.
BILLINGS

NOTICE
THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE COMMISSION.

5-23-89 incorrect location Tank (water) J. D. Hodges well proposal - converting Hodges well still on location. Contact

SUNDRY NOTICES AND REPORT OF WELLS

Notice of Intention to Drill		Subsequent Report of Water Shut-off	
Notice of Intention to Change Plans		Subsequent Report of Shooting, Acidizing, Cementing	
Notice of Intention to Test Water Shut-off		Subsequent Report of Altering Casing	
Notice of Intention to Redrill or Repair Well		Subsequent Report of Redrilling or Repair	
Notice of Intention to Shoot, Acidize, or Cement		Subsequent Report of Abandonment	
Notice of Intention to Pull or Alter Casing		Supplementary Well History	
Notice of Intention to Abandon Well SWD	X	Report of Fracturing	

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

July 18, 1984

Following is a {notice of intention to do work} on land {owned} described as follows:

LEASE Biere

MONTANA (State) Roosevelt (County) Poplar (Field)

Well No. Biere #A-1 (SWD) NWSW 22 (m. sec.) 28N (Township) 51E (Range) (Meridian)

The well is located 1750 ft. from {S} line and 140 ft. from {W} line of Sec. 22

LOCATE ACCURATELY ON PLAT ON BACK OF THIS FORM THE WELL LOCATION, AND SHOW LEASE BOUNDARY

The elevation of the derrick floor above the sea level is 2087' RB.

READ CAREFULLY **DETAILS OF PLAN OF WORK** READ CAREFULLY

(State names of and expected depths to objective sands; show size, weights, and lengths of proposed casings; indicate mudding jobs, cementing points, and all other important proposed work, particularly all details results Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

Mesa Petroleum Co. proposes to plug this well as the Biere 1-22 oil well is no longer economic to produce. Subject well was TDed at 998', with 8 5/8" casing set at 998', and 5 1/2" casing set at 749'. Mesa proposes to set a cast iron bridge plug at 740', above perforations at 796'-834'. Fill 5 1/2" casing with cement from 740' to surface. Set dry hole marker. Both 8 5/8" and 5 1/2" casings were cemented to surface.

MAR02-1277

Approved subject to conditions on reverse of form

Date JUL 23 1984

By Claire Hampton District Office Agent Title

Company Mesa Petroleum Co.

By Randy J. Nordone

Title Regulatory Coordinator

Address P. O. Box 2009 / Amarillo, Texas 79189

COMMISSION USE ONLY
API WELL NUMBER
25

NOTE:—Reports on this form to be submitted to the District Agent for Approval in Quadruplicate

WHEN USED AS PERMIT TO DRILL, THIS EXPIRES 90 DAYS FROM DATE OF APPROVAL.

OVER

Form No 2 R 4-85

(SUBMIT IN QUADRUPLICATE)

TO

BOARD OF OIL AND GAS CONSERVATION
OF THE STATE OF MONTANA

BILLINGS OR SHELBY

SUNDRY NOTICES AND REPORT OF WELLS

NOTICE
THIS FORM BECOMES A PERMIT WHEN STAMPED APPROVED BY AN AGENT OF THE BOARD.

ARM 36.22.307 ARM 36.22.1003
ARM 36.22.601 ARM 36.22.1004
ARM 36.22.602 ARM 36.22.1013
ARM 36.22.603 ARM 36.22.1301
ARM 36.22.604 ARM 36.22.1306
ARM 36.22.605 ARM 36.22.1309

Notice of Intention to Drill *		Subsequent Report of Water Shut-off	
Notice of Intention to Change Plans		Subsequent Report of Shooting, Acidizing, Cementing	
Notice of Intention to Test Water Shut-off		Subsequent Report of Altering Casing	
Notice of Intention to Redrill or Repair Well		Subsequent Report of Redrilling or Repair	
Notice of Intention to Shoot, Acidize, or Cement		Subsequent Report of Abandonment	X
Notice of Intention to Pull or Alter Casing		Supplementary Well History	
Notice of Intention to Abandon Well		Report of Fracturing	

(Indicate Above by Check Mark Nature of Report, Notice, or Other Data)

February 5, 19 91

Following is a ~~xxxxxxxxxxxxxxxxxxxxxxxxxxxx~~ report of work done on land owned ~~xxxxxx~~ described as follows:

LEASE TYPE ..... (Private, State, Federal, Indian) LEASE BIERE

MONTANA (State) ROOSEVELT (County) POPLAR (Field)

Well No. BIERE # A-1 (SWD) (m. sec.) SEC. 22 T28N R51E (Township) (Range) (Meridian)

The well is located 1750 ft. from XX N S line and 140 ft. from XXX E W line of Sec. 22

* For notice of intention to drill, write the API# or the well name of another well on this lease if one exists

LOCATE WELL SITE ACCURATELY ON PLAT ON BACK OF THIS FORM.

The elevation of the ground or K.B. above the sea level is 2087'

READ CAREFULLY **DETAILS OF PLAN OF WORK** READ CAREFULLY

(State names of and expected depths to objective sands; show size, weights, and lengths of proposed casings, cementing points, and all other important proposed work, particularly all details of Shooting, Acidizing, Fracturing.)

DETAILS OF WORK
RESULT

Subject well was plugged and abandoned on September 15, 1984 by filling the 5½" casing and tubing with 250 sx Class "H" cement. Cut casing 4' below ground level and welded cap on casing. Well P&A 9/15/84

LOCATION INSPECTED & APPROVED

Approved subject to conditions on reverse of form

Date FEB [illegible]

By [signature] District Office Agent [signature] Title

Company MESA OPERATING LTD PARTNERSHIP

By Carolyn L. McKee

Title Sr. Regulatory Analyst

Address P.O. Box 2009, Amarillo, Texas 79189

BOARD USE ONLY
API WELL NUMBER

2 5	785	2 16 49
STATE	COUNTY	WELL

NOTE:—Reports on this form to be submitted to the appropriate District for approval.
DRILLING PERMIT EXPIRES SIX MONTHS FROM DATE OF APPROVAL.

MAR02-1278

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

BOARD OF OIL AND GAS CONSERVATION

STAN STEPHENS, GOVERNOR

OIL AND GAS CONSERVATION DIVISION

STATE OF MONTANA

January 16, 1991

Mesa Petroleum Company
P.O. Box 2009
Amarillo, Texas 79189

Attention Carolyn L. McKee
Regulatory Analyst

Dear Ms. McKee:

Our records show that the following report/reports are delinquent regarding your Biere #A-1 SWD well located NW SW 22-28N-51E, Roosevelt County, Montana, API No. 25-085-21049.

Form No. 2 Subsequent Report of Abandonment

Form No. _____

Please request any of the required State forms that you do not have in supply.

Thanks for your prompt attention to this matter.

Sincerely,

Ethel Rogers

Ethel Rogers
Secretary

er

Ms. McKee: On May 14, 1990, I wrote you a letter requesting that you submit a Form #2 (Subsequent Report of Abandonment) on the above well. Without this report, this well remains on your bond and the file incomplete. Please comply with this request promptly.

MAR02-1279

DIVISION OFFICE
1520 E. SIXTH AVENUE
HELENA, MONTANA 59620-2301
(406) 444-6675

TECHNICAL AND SOUTHERN FIELD OFFICE
2535 ST. JOHNS AVENUE
BILLINGS, MONTANA 59102
(406) 656-0040

NORTHERN FIELD OFFICE
218 MAIN STREET
P.O. BOX 690
SHELBY, MONTANA 59474
(406) 434-2422

MESA

JAN 1991

January 23, 1991

State of Montana
Oil & Gas Conservation Division
2535 St. Johns Avenue
Billings, Montana 59102

Attention: Ethel Rogers

Dear Ms. Rogers:

Subject: Biere # A-1 SWD
Sec. 22-28N-51E
Roosevelt Co., Montana

Please find enclosed copies of Form No. 2 "Subsequent Report of Abandonment" which was mailed to your office in September of 1984. I hope this copy is good enough for you because our file has been microfilmed and this is the best copy I can obtain.

Sincerely,

Carolyn McKee

Carolyn L. McKee
Sr. Regulatory Analyst

clm;s

MAR02-1280

MESA LIMITED PARTNERSHIP
POST OFFICE BOX 2009 / 806 372-1809 / AMARILLO, TEXAS 79189-2009

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
BOARD OF OIL AND GAS CONSERVATION

STAN STEPHENS, GOVERNOR

OIL AND GAS CONSERVATION DIVISION

STATE OF MONTANA

January 30, 1991

Mesa Petroleum Company
P.O. Box 2009
Amarillo, Texas 79189

Attention Carolyn L. McKee
Regulatory Analyst

Re: Sec. 22-28N-51E, Roosevelt Co.

Dear Ms. McKee:

In answer to your letter of January 23, 1991, please be advised that the copy of a Subsequent Report of Abandonment on the Biere A-1 SWD which you enclosed was never received or approved by our office.

Therefore, please send us a new Subsequent Report of Abandonment on the enclosed sundry and forward to us for approval and removal of this well from your bond.

Thanks for your cooperation on this matter.

Sincerely,

Ethel Rogers

Ethel Rogers
Secretary

er
enc

MAR02-1281

DIVISION OFFICE
1520 E. SIXTH AVENUE
HELENA, MONTANA 59620-2301
(406) 444-6675

TECHNICAL AND
SOUTHERN FIELD OFFICE
2535 ST. JOHNS AVENUE
BILLINGS, MONTANA 59102
(406) 656-0040

NORTHERN FIELD OFFICE
218 MAIN STREET
P.O. BOX 690
SHELBY, MONTANA 59474
(406) 434-2422

MESA

May 8, 1990

State of Montana
2535 St. Johns Avenue
Billings, Montana 59102

Attention: Floyd Podoll
Chief Field Inspector

Dear Mr. Podoll:

Subject: Biere # A-1 SWD
Sec. 22-28N-51E
Roosevelt Co., MT

Pursuant to your letter of February 13, 1990 requesting a Form No. 2 "Subsequent Report of Abandonment" be filed on the above well, please find enclosed a microfilm copy of Form No. 2 on the plug and abandonment of the Biere # A-1 SWD. This form was filed in September, 1984 and again in October, 1984. This file has been microfilmed. If there is any further information you require, I will attempt to retrieve it.

Sincerely,

Carolyn L. McKee
Regulatory Analyst

clm;s

MAR02-1282

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
BOARD OF OIL AND GAS CONSERVATION

STAN STEPHENS, GOVERNOR

OIL AND GAS CONSERVATION DIVISION

STATE OF MONTANA

May 14, 1990

Mesa Petroleum Company
P.O. Box 2009
Amarillo, Texas 79189

Attention Carolyn L. McKee
Regulatory Analyst

Dear Ms. McKee:

Thank you for your letter of May 8, 1990, in answer to our letter requesting a Subsequent Report of Abandonment.

We have no record of ever receiving this report in our file. Inasmuch as the copy you sent was not approved, perhaps it was never submitted to our office for some reason.

If you could submit it on the enclosed Form 2 in quadruplicate along with the cementing ticket for the procedure, we will process and remove the well from your bond.

Thanks for your prompt attention to this matter.

Sincerely,

Ethel Rogers

Enclosures

MAR02-1283

DIVISION OFFICE
1520 E. SIXTH AVENUE
HELENA, MONTANA 59620-2301
(406) 444-6675

TECHNICAL AND
SOUTHERN FIELD OFFICE
2535 ST. JOHNS AVENUE
BILLINGS, MONTANA 59102
(406) 656-0040

NORTHERN FIELD OFFICE
218 MAIN STREET
P.O. BOX 690
SHELBY, MONTANA 59474
(406) 434-2422

BEFORE THE OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA

IN THE MATTER OF THE APPLICATION) OF MESA PETROLEUM COMPANY FOR) AN ORDER PERMITTING UNDERGROUND) DISPOSAL OF WATER FROM THE) CHARLES 'C' ZONE OF THE POPLAR) FIELD, ROOSEVELT COUNTY, MONTANA)	ORDER NO. 15-70A ADMINISTRATIVE

In this matter, Mesa Petroleum Company, applicant, seeks permission from the Commission to dispose of salt water produced in the Poplar Field, Roosevelt County, Montana. The application is dated June 16, 1970, and was received by the Commission on June 16, 1970.

The application is complete in all respects, and the same satisfies all of the provisions and requirements of Commission Rule No. 228.3 and all sub-paragraphs thereunder. All pertinent information concerning said application has been supplied to the Commission, and the same does not pertain to secondary recovery of a waterflood plan.

The applicant states that the proposed disposal well will be located 1750 feet from the south line and 140 feet from the west line of Section 22, Township 28 North, Range 51 East, Roosevelt County, Montana. The proposed formation of injection is the Judith River Zone. Applicant proposes to inject approximately 1,000 barrels of water per day.

Applicant states there are no drilling or producing wells or wells which have produced, other than applicant's Biere No. 1-22, within a one-half mile radius of the proposed salt water disposal well.

IT IS THEREFORE ORDERED by the Oil and Gas Conservation Commission of the State of Montana that the application of Mesa Petroleum Company to dispose of salt water produced in the Poplar Field, Roosevelt County, Montana, be, and the same is hereby approved, and that the applicant be permitted to dispose of said salt water by injection into its well as designated in the above order.

IT IS FURTHER ORDERED that at such time as injection is commenced, that the operator instigate its Report of Subsurface Injections, through the use of Commission Form No. 5 to be submitted to the Commission office in Helena, Montana.

Dated at Helena, Montana, this 22nd day of June, 1970.

OIL AND GAS CONSERVATION COMMISSION
OF THE STATE OF MONTANA

Norman J. Beaudry
Executive Secretary

(SEAL)

MAR02-1284

15 Poly Drive
Billings, Montana 59101
June 18, 1970

Mr. Ronald D. Ragland
Petroleum Engineering & Management Corporation
250 Securities Building
Billings, Montana 59101

Dear Sir:

Your request of June 16 for administrative approval for a salt water disposal well in the NW/4 SW/4 of Section 22, Township 28 North, Range 51 East, Roosevelt County has received favorable consideration.

The Administrative Order approving your request will be issued by our Helena Office. In the meantime since you have a rig immediately available, you may proceed with this program.

I am returning your check for $25 since there is no permit fee for a disposal well.

Very truly yours,

Herbert D. Hadley
Geologist

HDH:sms

Enclosure

cc: Mr. Norman J. Beaudry
Helena, Montana

MAR02-1285

The
Petroleum Engineering and Management
Corporation

250 Securities Building
BILLINGS, MONTANA 59101
Telephone 406-248-7395

June 16, 1970

RECEIVED
JUN 17 1970
OIL & GAS CONS. COMM.
STATE OF MONT.
BILLINGS

Montana Oil & Gas Conservation Commission
P. O. Box 217
Helena, Montana 59601

Gentlemen:

Enclosed herewith is an application submitted on behalf of Mesa Petroleum Company to inject water into the Judith River Formation, Poplar Field, Roosevelt County, Montana. Also enclosed is Sundry Notices and Report of Wells, Form 2, requesting a permit to drill the disposal well together with a check in the amount of $25.00 for the permit.

There are no drilling or producing wells, or wells which have produced within one-half mile radius of the proposed input well, other than the Mesa Petroleum Biere No. 1-22. It is Mesa's intention to use the rig presently stacked on the Biere 1-22 well location for the drilling of the proposed salt water disposal well. Inasmuch as there are no other operators of producing wells within one-half miles of the proposed input well, it is respectfully requested that the commission grant administrative approval to drill the salt water disposal well at the earliest possible date, before a need is found for the rig presently stacked at the Biere No. 1-22 location.

Very truly yours,

PETROLEUM ENGINEERING & MANAGEMENT
CORPORATION

Ronald D. Ragland

RONALD D. RAGLAND
for MESA PETROLEUM

RDR:kw

enc.

MAR02-1286

HALLIBURTON SERVICES

A DIVISION OF HALLIBURTON COMPANY
FORM 1906-R1

SEND ALL REMITTANCES TO
P. O. DRAWER 1431
DUNCAN, OKLAHOMA 73533

PAGE 1 OF 1 PAGES

INVOICE & TICKET NO. 283397

22-28N-51E

D. AND FARM: Fiss Sw.D.	COUNTY: Musselshell	STATE: Montana	DATE: 7-3-78
	CONTRACTOR: None		DUNCAN USE ONLY
TO: Mess Pr. Company	DELIVERED TO:	LOCATION 1	CODE
S: Lodge Amarillo, Texas	SHIPPED VIA	LOCATION 2	CODE
	CUST. INV. REQ. ORIG. & ☐ 1 ☐ 2 ☐ 3 ☐ 4 / REQUISITION	LOCATION 3	CODE
	ORDER NO.	BULK MATERIAL DELIVERY TICKET NO. B-	
	TOTAL ACID - 30 DAYS: 500 1/2	WELL TYPE: Swd Injection	CODE
	NO. COPIES		

ND PURPOSE OF JOB

TERMS: DUE BY THE 20TH OF FOLLOWING MONTH. INTEREST CHARGED AFTER 60 DAYS FROM DATE OF INVOICE.

$_____ Cash discount allowed if paid by due date...

$_____ Tax adjustment may be deducted if discounted.

PRICE REFERENCE	SECONDARY REF. OR PART NO.	CODE L	CODE D	DESCRIPTION	UNITS 1 QTY.	UNITS 1 MEAS.	UNITS 2 QTY.	UNITS 2 MEAS.
[illegible]				Mileage Charge	100	Miles		
1.024				Reg HCl	500	Gal		
1.075				HAI-50 (Inhibitor)	1	Gal		
[illegible]				Pump charge	1	Job		
7.506				Manual Tubing				
[illegible]				Rod Balls 7/8"	25	Each		
				SERVICE CHARGE ON MATERIALS RETURNED		CU. FT.		
				SERVICE CHARGE		CU. FT.		
				TOTAL WEIGHT / LOADED MILES		TON MILES		

TAX REFERENCES

SL

.S JOB SATISFACTORILY COMPLETED?_____

.S OPERATION OF EQUIPMENT SATISFACTORY?_____

.S PERFORMANCE OF PERSONNEL SATISFACTORY?_____

Customer or His Agent

Halliburton Operator

MAR02-1287

HALLIBURTON SERVICES

A DIVISION OF HALLIBURTON COMPANY
FORM 1906-R1

SEND ALL REMITTANCES TO
P. O. DRAWER 1431
DUNCAN, OKLAHOMA 73533

22-28N-51E

PAGE 1 OF 2 PAGES

INVOICE & TICKET NO. 283588

NO. AND FARM	COUNTY	STATE	DATE
1 Biere	Roosevelt	Mont	6-25-70

	CONTRACTOR	DUNCAN USE ONLY
esa Pet Corp.	Calvert Drlg Co.	

E TO	DELIVERED TO	LOCATION	CODE
Mesa Pet Corp		1 Glendive Mt	55530

SS	SHIPPED VIA	LOCATION	CODE
x 2009 Amarillo, Texas		2	

CUST. INV. REQ. ORIG. &	REQUISITION	LOCATION	CODE
☐ 1 ☐ 2 ☐ 3 ☐ 4		3	

ORDER NO.	BULK MATERIAL DELIVERY TICKET NO.
	B-53451

TOTAL ACID - 30 DAYS	WELL TYPE	CODE
	Wildcat / Salt Wtr Disposal	10/C

NO. COPIES

AND PURPOSE OF JOB: Cmt Surface Csg

TERMS: DUE BY THE 20TH OF FOLLOWING MONTH. INTEREST CHARGED AFTER 60 DAYS FROM DATE OF INVOICE.

$ _____ Cash discount allowed if paid by due date.

$ _____ Tax adjustment may be deducted if discounted.

PRICE REFERENCE	SECONDARY REF. OR PART NO.	CODE L	CODE D	DESCRIPTION	UNITS 1 QTY.	UNITS 1 MEAS.	UNITS 2 QTY.	UNITS 2 MEAS.	UNIT PRICE
1 032				Pump Charge	1000	Ft			
0 117				Mileage	30	mi			.85
20 502				Top Wood Plug (LA-10)	1	EA	8 3/8	IN	
				400 Cu. Ft Pozmix					
				Cmt Consisting of					
05 040				Perm. Class "B" Cmt	200	Sks			1.81
06 105				Pozmix "A"	200	Sks			1.27
9 406				CA-Cl Mixed 2% w/400sks	8	Sks			8.03
7 202				Flocele Mixed 1/4 # P.S. w/100sks	25	lbs			.43
5 040				Perm. Class "B" Cmt	100	Sks			1.81
				Ticket Continuation Page "2"					
				SERVICE CHARGE ON MATERIALS RETURNED		CU. FT.			
7				SERVICE CHARGE	516	CU. FT.			.40
14				43.665 TOTAL WEIGHT 130 LOADED MILES	283.23	TON MILES			.26

TAX REFERENCES

SUB TOTAL

WAS JOB SATISFACTORILY COMPLETED? _____ TAX

WAS OPERATION OF EQUIPMENT SATISFACTORY? _____ TAX

WAS PERFORMANCE OF PERSONNEL SATISFACTORY? _____ TAX

X [signature] Customer or His Agent

[signature] Halliburton Operator

TOTAL

MAR02-1288

Form Approved. OMB No. 2040-0042. Expires 9-30-86

Form 4 UIC

EPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

UNDERGROUND INJECTION CONTROL PERMIT APPLICATION

(Collected under the authority of the Safe Drinking Water Act, Sections 1421, 1422, 40 CFR 144)

I. EPA ID NUMBER: U

T/A | C

READ ATTACHED INSTRUCTIONS BEFORE STARTING

FOR OFFICIAL USE ONLY

Application approved mo	day	year	Date Received mo	day	year	Permit/Well Number	Comments

II. FACILITY NAME AND ADDRESS

Facility Name: Biere #A-1 (SWD)

Street Address: Poplar Field

City: | State: | ZIP Code:

III. OWNER/OPERATOR AND ADDRESS

Owner/Operator Name: Mesa Petroleum Co.

Street Address: P. O. Box 2009

City: Amarillo | State: TX | ZIP Code: 79189

IV. OWNERSHIP STATUS *(Mark 'x')*

☐ A. Federal ☐ B. State ☒ C. Private

☐ D. Public ☐ E. Other *(Explain)*

V. SIC CODES

1311 | 1382

VI. WELL STATUS *(Mark 'x')*

☒ A. Operating — Date Started: mo 7, day 4, year 70

☐ B. Modification/Conversion ☐ C. Proposed

VII. TYPE OF PERMIT REQUESTED *(Mark 'x' and specify if required)*

☒ A. Individual ☐ B. Area

Number of Existing wells: | Number of Proposed wells: | Name(s) of field(s) or project(s):

VIII. CLASS AND TYPE OF WELL *(see reverse)*

A. Class(es) *(enter code(s))*	B. Type(s) *(enter code(s))*	C. If class is "other" or type is code 'x,' explain	D. Number of wells per type (if area permit)
II	D	N/A	N/A

IX. LOCATION OF WELL(S) OR APPROXIMATE CENTER OF FIELD OR PROJECT

C	A. Latitude Deg	Min	Sec	B. Longitude Deg	Min	Sec	Township and Range Twsp	Range	Sec	¼ Sec	Feet from	Line	Feet from	Line
I							28N	51E	22	SW	1750	S	140	W

X. INDIAN LANDS *(Mark 'x')*

☐ Yes ☒ No

XI. ATTACHMENTS

(Complete the following questions on a separate sheet(s) and number accordingly; see instructions)

FOR CLASSES I, II, III (and other classes) complete and submit on separate sheet(s) Attachments A — U (pp 2-6) as appropriate. Attach maps where required. List attachments by letter which are applicable and are included with your application:

XII. CERTIFICATION

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

A. Name and Title *(Type or Print)*: Randy Z. Nordsven, Regulatory Coordinator

B. Phone No. *(Area Code and No.)*: (806) 378-4887

C. Signature: Randy Z. Nordsven

MAR02-1289

D. Date Signed: 7-17-84

HALLIBURTON®

Halliburton Energy Services, Inc.

Remit to: P.O. Box 951046
Dallas, TX 75395-1046

INVOICE

Site/Well Address:	DIRECT CORRESPONDENCE TO:	Invoice No.	Date
MARATHON BASTON A#32, PARK BASTON A-32 LYLE HUFF CODY WY 82414	PO Box 1510 Evansville, WY 82636-1510 (307) 473 8200	90293966	02/05/2000
		Customer PO No.	Date
		AGL#9364	
		Delivery No.	Date
		80519331	02/04/2000

TO:	Job Location	Order/Ticket No.	Date
MARATHON OIL CO HO2184 1501 STAMPEDE AVE CODY WY 82414	Land	420042	02/02/2000
	Shipping Point	Manual Ticket No.	
	CASPER Shipping Poin		
	Service Location	Customer No.	
	Casper, WY, USA	303697	
	Payment Terms	Payment Due Date	
	Net due in 20 days	02/25/2000	

Reference Number	Description	QTY	U/M	Unit Price	Amount
7521	PSL-CMT Cement Surface Casing-BOM JP010	1	JOB		
1	MILEAGE FROM NEAREST HES BASE,/UNIT,ZI	180	MI	3.65	657.00
	Discount : $262.80- With the following configuration:				
	Number of Units 000-117	1	unit		
2	MILEAGE FOR CEMENTING CREW,ZI	180	MI	2.15	387.00
	Discount : $154.80- With the following configuration:				
	Number of Units 000-119	1	unit		
11	CEMENT CASING DEPTH CHARGE	1	UN	1,996.00	1,996.00
	Discount : $798.40- With the following configuration:				
	CHARGE BY FT OR RANGE OF FEET 001-016	300	ft		

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1290

Continuation

Invoice No.	Date
90293966	02/05/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
7	ENVIRONMENTAL SURCHARGE,/JOB,ZI	1	JOB	55.00	55.00
	Discount : $22.00-				
	000-150				
8	IRON SAFETY INSPECTION SURCHARGE /JOB ZI	1	JOB	33.00	33.00
	Discount : $13.20-				
	000-151				
139	ADC (AUTO DENSITY CTRL) SYS, /JOB,ZI	1	JOB	920.00	920.00
	Discount : $368.00-				
	With the following configuration:				
	NUMBER OF UNITS	1	each		
	046-050				
90	QUICK LATCH ATTACHMENT	1	JOB	248.00	248.00
	Discount : $99.20-				
	With the following configuration:				
	INCHES	9.625	in		
	019-251				
88	PLUG CONTAINER RENTAL-1st Day	1	EA	533.00	533.00
	Discount : $213.20-				
	With the following configuration:				
	NUMBER OF DAYS	1	Days		
	019-248				
100064173	CEMENT - CLASS G - 94 LB BAG	180	SK	13.04	2,347.20
	Discount : $938.88-				
	516.00999				
	CEMENT - CLASS G - 94 LB BAG				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1291

Continuation	
Invoice No.	Date
90293966	02/05/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
100005049	FLOCELE - 3/8 - 25 LB SACK	45	LB	2.37	106.65
	Discount : $42.66-				
	XXXXXXX 890.50071				
	FLOCELE - 3/8 - 25 LB SACK				
100003652	SALT - MORTON - PUREX - FINE - 80# BAG	226	LB	0.36	81.36
	Discount : $32.54-				
	XXXXXXX 516.00158				
	SALT - MORTON - PUREX - FINE - 80# BAG				
100007865	CHEMICAL - VERSASET - 50 LB SACK	51	LB	4.50	229.50
	Discount : $91.80-				
	516.00789				
	CHEMICAL - VERSASET - 50 LB SACK				
3965	HANDLE&DUMP SVC CHRG, CMT&ADDITIVES,ZI	187	CF	1.66	310.42
	Discount : $124.17-				
	With the following configuration:				
	NUMBER OF EACH	1	each		
	500-207				
3975	MILEAGE,CMTG MTLS DEL/RETURNED,ZI	776	TMI	1.25	970.00
	Discount : $388.00-				
	With the following configuration:				
	NUMBER OF TONS	1.00	ton		
	500-306				
100004728	SHOE - GUIDE - 9-5/8 BRD	1	EA	274.00	274.00
	Discount : $109.60-				
	12A - 825.221				
	SHOE - GUIDE - 9-5/8 BRD				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1292

Continuation

Invoice No.	Date
90293966	02/05/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
100004485	CENTRALIZER ASSY - API - 9-5/8 CSG X	4	EA	95.00	380.00
	Discount : $152.00- *806.60065* *CENTRALIZER ASSY - API - 9-5/8 CSG X* *12-1/4 HOLE - HINGED - W/WELDED* *IMPERIAL BOWS*				
100004629	CLAMP - LIMIT - 9-5/8 - HINGED -	1	EA	19.95	19.95
	Discount : $7.98- *CLAMP - LIMIT - 9-5/8 - HINGED -* *FRICTION GRIP W/DRAW BOLT*				
100005045	HALLIBURTON WELD-A KIT	2	EA	18.43	36.86
	Discount : $14.74- *HALLIBURTON WELD-A KIT*				
100004871	COLLAR-VS FLOAT- 9-5/8 8RD - 8.927 MIN	1	EA	554.40	554.40
	Discount : $221.76- *836.90600* *COLLAR-VS FLOAT- 9-5/8 8RD - 8.927 MIN* *ID*				
100003158	PLUG - CMTG - TOP ALUM - 9-5/8	1	EA	165.00	165.00
	Discount : $66.00- *402.1531* *PLUG - CMTG - TOP ALUM - 9-5/8* *29.3-53.5#*				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1293

Continuation

Invoice No.	Date
90293966	02/05/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

AGL 93604

Reference Number	Description	QTY	U/M	Unit Price	Amount
	INVOICE SUBTOTAL				10,304.34
	DISCOUNT				4,121.73
	INVOICE AMOUNT				6,182.61
	Sales Tax - State				243.34
	INVOICE TOTAL - PLEASE PAY THIS AMOUNT				6,425.95

Rocky Mt'n Region

FEB 11 2000

Financial Accounting

302020-14

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1294

HALLIBURTON®

Halliburton Energy Services, Inc.

TICKET TYPE	COMPANY CODE	HALLIBURTON ORDER NO.
Services	1100	420042
CUSTOMER P.O. NO.	JOB DATE	PRIMARY SERVICE LOC.
AGL#9364	02/02/2000	Casper, WY, USA

SOLD TO

MARATHON OIL CO
539 S MAIN
FINDLAY OH 45840
USA

SHIP TO

WELL OPERATOR
MARATHON BASTON A#32, PARK
LEASE NAME / OFFSHORE AREA
BASTON
WELL NUMBER
A #32
WELL PERMIT NO.

ADDRESS

CITY, STATE, ZIP CODE
CODY WY 82414 US

SALES OFFICE	WELL TYPE	WELL CATEGORY	RIG NAME / NO.
Rocky Mountains BD	Oil	Development	MARATHON OIL CO

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
10	7521		PSL-CMT Cement Surface Casing-BOM				
		Casper, WY, USA		1.00	JOB	0.00	0.00
			JP010				
20	1		MILEAGE FROM NEAREST HES BASE,/UNIT,ZI				
		Casper, WY, USA		180	MI	3.65	657.00
				180	MI	1.46-	262.80-
				180	MI	2.19	394.20
			000-117				
		With the following configuration:					
		Number of Units		1	unit		
30	2		MILEAGE FOR CEMENTING CREW,ZI				
		Casper, WY, USA		180	MI	2.15	387.00
				180	MI	0.86-	154.80-
				180	MI	1.29	232.20
			000-119				
		With the following configuration:					
		Number of Units		1	unit		

Correct Version

INVOICE INSTRUCTIONS

PAYMENT TERMS
Net due in 20 days

HALLIBURTON OPERATOR / ENGINEER

HALLIBURTON APPROVAL

CUSTOMER SIGNATURE

TOTAL FROM THIS PAGE	626.40
TOTAL FROM NEXT PAGE(S)	5,556.21
SUBTOTAL	6,182.61
TAXES	243.34
GRAND TOTAL	6,425.95 US Dollars

MAR02-1295

HALLIBURTON®

Halliburton Energy Services, Inc.

TICKET TYPE	COMPANY CODE	HALLIBURTON ORDER NO.
Services	1100	420042
CUSTOMER P.O. NO.	JOB DATE	PRIMARY SERVICE LOC.
AGL#9364	02/02/2000	Casper, WY, USA

SOLD TO

MARATHON OIL CO
539 S MAIN
FINDLAY OH 45840
USA

SHIP TO

WELL OPERATOR
MARATHON BASTON A#32, PARK
LEASE NAME / OFFSHORE AREA
BASTON
WELL NUMBER
A #32
WELL PERMIT NO.
ADDRESS
-
CITY, STATE, ZIP CODE
CODY WY 82414 US

MAR02-1296

SALES OFFICE	WELL TYPE	WELL CATEGORY	RIG NAME / NO.
Rocky Mountains BD	Oil	Development	MARATHON OIL CO

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
10	7521	PSL-CMT Cement Surface Casing-BOM				
	Casper, WY, USA		1.00	JOB	0.00	0.00
		JP010				
20	1	MILEAGE FROM NEAREST HES BASE,/UNIT,ZI				
	Casper, WY, USA		180	MI	3.65	657.00
			180	MI	1.46-	262.80-
			180	MI	2.19	394.20
		000-117				
	With the following configuration:					
	Number of Units		1	unit		
30	2	MILEAGE FOR CEMENTING CREW,ZI				
	Casper, WY, USA		180	MI	2.15	387.00
			180	MI	0.86-	154.80-
			180	MI	1.29	232.20
		000-117				
	With the following configuration:					
	Number of Units		1	unit		

REC'D BY [signature] DATE 2/3/00
AFE # 2640-00 CHARGE
ACCT. CAT. 81 DF 0091
APPROVED
APPRV. FOR DATE

INVOICE INSTRUCTIONS

PAYMENT TERMS
Net due in 20 days

HALLIBURTON APPROVAL

HALLIBURTON OPERATOR / ENGINEER [signature]

CUSTOMER SIGNATURE

TOTAL FROM THIS PAGE	626.40
TOTAL FROM NEXT PAGE(S)	5575.21 ~~5,727.21~~
SUBTOTAL	6201.61 ~~6,353.61~~
TAXES	248.25 ~~250.18~~
GRAND TOTAL	6449.67 ~~6,603.79~~ US Dollars

HALLIBURTON®

Halliburton Energy Services, Inc.

MAR02-1297

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
40	11		CEMENT CASING DEPTH CHARGE				
		Casper, WY, USA		1.00	UN	1,996.00	1,996.00
				1.00	UN	798.40-	798.40-
				1.00	UN	1,197.60	1,197.60
			001-016				
		With the following configuration:					
		CHARGE BY FT OR RANGE OF FEET		300	ft		
50	7		ENVIRONMENTAL SURCHARGE,/JOB,ZI				
		Casper, WY, USA		1.00	JOB	55.00	55.00
				1.00	JOB	22.00-	22.00-
				1.00	JOB	33.00	33.00
			000-150				
60	8		IRON SAFETY INSPECTION SURCHARGE /JOB ZI				
		Casper, WY, USA		1.00	JOB	33.00	33.00
				1.00	JOB	13.20-	13.20-
				1.00	JOB	19.80	19.80
			000-151				
70	139		ADC (AUTO DENSITY CTRL) SYS, /JOB,ZI				
		Casper, WY, USA		1.00	JOB	920.00	920.00
				1.00	JOB	368.00-	368.00-
				1.00	JOB	552.00	552.00
			046-050				
		With the following configuration:					
		NUMBER OF UNITS		1	each		
80	90		QUICK LATCH ATTACHMENT				
		Casper, WY, USA		1.00	JOB	248.00	248.00
				1.00	JOB	99.20-	99.20-
				1.00	JOB	148.80	148.80
			019-251				
		With the following configuration:					
		INCHES		9.625	in		

HALLIBURTON®

Halliburton Energy Services, Inc.

MAR02-1298

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY. UNIT	UNIT PRICE	AMOUNT
90	88	PLUG CONTAINER RENTAL-1st Day			
	Casper, WY, USA		1.00 EA	533.00	533.00
			1.00 EA	213.20-	213.20-
			1.00 EA	319.80	319.80
		019-248			
	With the following configuration:				
	NUMBER OF DAYS		1 Days		
100	100064173	CEMENT - CLASS G - 94 LB BAG			
	Casper, WY, USA		180.00 SK	13.04	2,347.20
			180.00 SK	5.22-	938.88-
			180.00 SK	7.82	1,408.32
		516.00999			
		CEMENT - CLASS G - 94 LB BAG			
110	100005049	FLOCELE - 3/8 - 25 LB SACK			
	Casper, WY, USA		45.00 LB	2.37	106.65
			45.00 LB	0.95-	42.66-
			45.00 LB	1.42	63.99
		XXXXXXX 890.50071			
		FLOCELE - 3/8 - 25 LB SACK			
120	100003652	SALT - MORTON - PUREX - FINE - 80# BAG			
	Casper, WY, USA		226.00 LB	0.36	81.36
			226.00 LB	0.14-	32.54-
			226.00 LB	0.22	48.82
		XXXXXXX 516.00158			
		SALT - MORTON - PUREX - FINE - 80# BAG			
130	100007865	CHEMICAL - VERSASET - 50 LB SACK			
	Casper, WY, USA		51.00 LB	4.50	229.50
			51.00 LB	1.80-	91.80-
			51.00 LB	2.70	137.70
		516.00789			
		CHEMICAL - VERSASET - 50 LB SACK			

HALLIBURTON®

Halliburton Energy Services, Inc.

MAR02-1299

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
140	3965	HANDLE&DUMP SVC CHRG, CMT&ADDITIVES,ZI				
	Casper, WY, USA		187.00	CF	1.66	310.42
			187.00	CF	0.66-	124.17-
			187.00	CF	1.00	186.25
		500-207				
	With the following configuration:					
	NUMBER OF EACH		1	each		
150	3975	MILEAGE,CMTG MTLS DEL/RETURNED,ZI				
	Casper, WY, USA		776.0	TMI	1.25	970.00
			776.0	TMI	0.50-	388.00-
			776.0	TMI	0.75	582.00
		500-306				
	With the following configuration:					
	NUMBER OF TONS		1.00	ton		
160	100004728	SHOE - GUIDE - 9-5/8 8RD				
	Casper, WY, USA		1.00	EA	274.00	274.00
			1.00	EA	109.60-	109.60-
			1.00	EA	164.40	164.40
		12A - 825.221				
		SHOE - GUIDE - 9-5/8 8RD				
170	100004485	CENTRALIZER ASSY - API - 9-5/8 CSG X				
	Casper, WY, USA		4 ~~7.00~~	~~EA~~	95.00	380 ~~665.00~~
			4 ~~7.00~~	~~EA~~	38.00-	152 ~~266.00~~
			4 ~~7.00~~	~~EA~~	57.00	228 ~~399.00~~
		806.60065				
		CENTRALIZER ASSY - API - 9-5/8 CSG X				
		12-1/4 HOLE - HINGED - W/WELDED				
		IMPERIAL BOWS				
180	100004629	CLAMP - LIMIT - 9-5/8 - HINGED -				
	Casper, WY, USA		1.00	EA	19.95	19.95
			1.00	EA	7.98-	7.98-
			1.00	EA	11.97	11.97
		CLAMP - LIMIT - 9-5/8 - HINGED -				
		FRICTION GRIP W/DRAW BOLT				

MAR02-1300

HALLIBURTON®

Halliburton Energy Services, Inc.

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
190	100005045	HALLIBURTON WELD-A KIT				
	Casper, WY, USA		2.00	EA	18.43	36.86
			2.00	EA	7.37-	14.74-
			2.00	EA	11.06	22.12
		HALLIBURTON WELD-A KIT				
200	100004871	COLLAR-VS FLOAT- 9-5/8 8RD - 8.927 MIN				
	Casper, WY, USA		1.00	EA	554.40	554.40
			1.00	EA	221.76-	221.76-
			1.00	EA	332.64	332.64
		836.90600				
		COLLAR-VS FLOAT- 9-5/8 8RD - 8.927 MIN				
		ID				
210	100003158	PLUG - CMTG - TOP ALUM - 9-5/8				
	Casper, WY, USA		1.00	EA	165.00	165.00
			1.00	EA	66.00-	66.00-
			1.00	EA	99.00	99.00
		402.1531				
		PLUG - CMTG - TOP ALUM - 9-5/8				
		29.3-53.5#				
		INVOICE AMOUNT				6201.61 ~~6,353.61~~
		Sales Tax - State				248.06 ~~250.18~~
		INVOICE TOTAL				6449.67 ~~6,603.79~~ US Dollars

Rocky Mt'n Region

FEB 10 2000

Financial Accounting

INVOICE

HALLIBURTON®

Halliburton Energy Services, Inc.

Remit to: P.O. Box 951046
Dallas, TX 75395-1046

Site/Well Address:
MARATHON BASTON A#32, PARK
BASTON A #32
LYLE HUFF
CODY WY 82414

DIRECT CORRESPONDENCE TO:
PO Box 1510
Evansville, WY 82636-1510
(307) 473 8200

Invoice No.	Date
90304200	02/14/2000
Customer PO No.	**Date**
AGL# 9364	
Delivery No.	**Date**
80548216	02/14/2000

TO:
MARATHON OIL CO
HO2184
1501 STAMPEDE AVE
CODY WY 82414

Job Location	Order/Ticket No.	Date
Land	436572	02/10/2000
Shipping Point	**Manual Ticket No.**	**Compt Date**
CASPER Shipping Poin		02/11/2000
Service Location	**Customer No.**	
Casper, WY, USA	303697	
Payment Terms	**Payment Due Date**	
Net due in 20 days	03/05/2000	

Reference Number	Description	QTY	U/M	Unit Price	Amount
7523	PSL-CMT CEMENT PRODUCTION CASING-BOM *JP035*	1	JOB		
1	MILEAGE FROM NEAREST HES BASE,/UNIT,ZI	180	MI	3.65	657.00
	Discount : $262.80- With the following configuration: Number of Units *000-117*	1	unit		
2	MILEAGE FOR CEMENTING CREW,ZI	180	MI	2.15	387.00
	Discount : $154.80- With the following configuration: Number of Units *000-119*	1	unit		
7	ENVIRONMENTAL SURCHARGE,/JOB,ZI	1	JOB	55.00	55.00
	Discount : $22.00- *000-150*				
8	IRON SAFETY INSPECTION SURCHARGE /JOB ZI	1	JOB	33.00	33.00
	Discount : $13.20- *000-151*				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1301

Continuation

Invoice No.	Date
90304200	02/14/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
3965	HANDLE&DUMP SVC CHRG, CMT&ADDITIVES,ZI	553	CF	1.66	917.98
	Discount : $367.19-				
	With the following configuration:				
	NUMBER OF EACH	1	each		
	500-207				
3975	MILEAGE,CMTG MTLS DEL/RETURNED,ZI	2,273	TMI	1.25	2,841.25
	Discount : $1,136.50-				
	With the following configuration:				
	NUMBER OF TONS	1.00	ton		
	500-306				
132	PORTABLE DAS,/DAY/JOB,ZI	1	JOB	760.00	760.00
	Discount : $304.00-				
	With the following configuration:				
	NUMBER OF DAYS	1	Days		
	045-050				
15	MULTIPLE STAGE CEMENTING - 1ST STAGE	1	UN	2,726.00	2,726.00
	Discount : $1,090.40-				
	With the following configuration:				
	CHARGE BY FT OR RANGE OF FEET	4,120	ft		
	007-013				
16	MULTIPLE STAGE CEMENTING - 2ND STAGE	1	STG	2,045.00	2,045.00
	Discount : $818.00-				
	With the following configuration:				
	Number of Units	1	unit		
	007-161				
17	MSC ON SITE,ADD HR,ZI	4	H	363.00	1,452.00
	Discount : $580.80-				
	With the following configuration:				
	Number of Units	1	unit		
	007-203				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1302

Continuation

Invoice No.	Date
90304200	02/14/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
139	ADC (AUTO DENSITY CTRL) SYS, /JOB,ZI	1	JOB	920.00	920.00
	Discount : $368.00-				
	With the following configuration:				
	NUMBER OF UNITS	1	each		
	046-050				
114	R/A DENSOMETER W/CHART RECORDER,/JOB,ZI	1	JOB	380.00	380.00
	Discount : $152.00-				
	With the following configuration:				
	NUMBER OF UNITS	1	each		
	019-500				
88	PLUG CONTAINER RENTAL-1st Day	1	EA	533.00	533.00
	Discount : $213.20-				
	With the following configuration:				
	NUMBER OF DAYS	1	Days		
	019-248				
90	QUICK LATCH ATTACHMENT	1	JOB	198.00	198.00
	Discount : $79.20-				
	With the following configuration:				
	INCHES	7.000	in		
	019-251				
100013920	CEMENTER - TYPE P ES - 7 IN. 8RD	1	EA	3,568.00	3,568.00
	Discount : $1,427.20-				
	71813.56625				
	CEMENTER - TYPE P ES - 7 IN. 8RD				
	20-26# - SUITABLE F/USE W/K-55				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1303

Continuation

Invoice No.	Date
90304200	02/14/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
100004673	PLUG SET - FREE FALL - 7 IN. 8RD &	1	EA	851.00	851.00
	Discount : $340.40- *813.16571* *PLUG SET - FREE FALL - 7 IN. 8RD &* *BUTTRESS 20-38# 2-STAGE CMTR - W/3.80* *ID BAFFLE*				
100004480	CENTRALIZER ASSY - API - 7 CSG X 8-1/2	39	EA	77.00	3,003.00
	Discount : $1,201.20- *806.60043* *CENTRALIZER ASSY - API - 7 CSG X 8-1/2* *HOLE - HINGED - W/WELDED IMPERIAL* *BOWS*				
100004626	CLAMP - LIMIT - 7 - HINGED -	3	EA	14.10	42.30
	Discount : $16.92- *CLAMP - LIMIT - 7 - HINGED -* *FRICTION GRIP W/DRAW BOLT*				
100005045	HALLIBURTON WELD-A KIT	3	EA	18.43	55.29
	Discount : $22.12- *HALLIBURTON WELD-A KIT*				
100004908	SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL	1	EA	330.05	330.05
	Discount : $132.02- *5A - 837.14100* *SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL* *II VALVE*				
100004781	COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4	1	EA	399.05	399.05
	Discount : $159.62- *4A - 836.14100* *COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4* *SUPER SEAL II VALVE*				

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1304

Continuation.

Invoice No.	Date
90304200	02/14/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

Reference Number	Description	QTY	U/M	Unit Price	Amount
12311	SBM CEMENT-HALLIBURTON LIGHT PREMIUM Discount : $2,253.24- *504-118*	495	SK	11.38	5,633.10
13383	SBM MUD FLUSH,ZI Discount : $134.40- *018-315*	420	GAL	0.80	336.00
100064173	CEMENT - CLASS G - 94 LB BAG Discount : $260.80- *516.00999* *CEMENT - CLASS G - 94 LB BAG*	50	SK	13.04	652.00
100005049	FLOCELE - 3/8 - 25 LB SACK Discount : $130.82- *XXXXXXX 890.50071* *FLOCELE - 3/8 - 25 LB SACK*	138	LB	2.37	327.06
100005051	CAL-SEAL - 100# BAG Discount : $64.00- *XXXXXXX 890.50131* *CAL-SEAL - 100# BAG*	5	SK	32.00	160.00
100003682	CHEM, BENTONITE, HALGEL (BULK) Discount : $9.24- *506-121516.00259* *CHEMICAL - BENTONITE - HALLIBURTON GEL BULK*	1	SK	23.11	23.11

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1305

Continuation

Invoice No.	Date
90304200	02/14/2000

HALLIBURTON®

INVOICE

Halliburton Energy Services, Inc.

AGL9364

Reference Number	Description	QTY	U/M	Unit Price	Amount
	INVOICE SUBTOTAL				29,285.19
	DISCOUNT				11,714.07
	INVOICE AMOUNT				17,571.12
	Sales Tax - State				702.83
	INVOICE TOTAL - PLEASE PAY THIS AMOUNT				18,273.95

303/04

Terms: If customer does not have an approved open account with Halliburton, all sums are payable in cash at the time of performance of services or delivery of equipment, products, or materials. If customer has an approved open account, invoices are payable on the twentieth day after date of invoice. Customer agrees to pay interest on unpaid balance from the date payable until paid at the highest lawful contract rate applicable, but never to exceed 18% per annum. In the event Halliburton employs an attorney for collection of any amount, Customer agrees to pay attorney fees of 20% of the unpaid account, plus all collection and court costs.

MAR02-1306

HALLIBURTON®

Halliburton Energy Services, Inc.

TICKET TYPE	COMPANY CODE	HALLIBURTON ORDER NO.
Services	1100	436572
CUSTOMER P.O. NO.	JOB DATE	PRIMARY SERVICE LOC.
AGL# 9364	02/09/2000	Casper, WY, USA

SOLD TO

MARATHON OIL CO
539 S MAIN
FINDLAY OH 45840
USA

SHIP TO

WELL OPERATOR
MARATHON BASTON A#32, PARK
LEASE NAME / OFFSHORE AREA
BASTON
WELL NUMBER
A #32
WELL PERMIT NO.
ADDRESS
-
CITY, STATE, ZIP CODE
CODY WY 82414 US

MAR02-1307

SALES OFFICE	WELL TYPE	WELL CATEGORY	RIG NAME / NO.
Rocky Mountains BD	Oil	Development	MARATHON OIL CO

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
10	7523	PSL-CMT CEMENT PRODUCTION CASING-BOM				
	Casper, WY, USA		1.00	JOB	0.00	0.00
		JP035				
20	1	MILEAGE FROM NEAREST HES BASE,/UNIT,ZI				
	Casper, WY, USA		180	MI	3.65	657.00
			180	MI	1.46-	262.80-
			180	MI	2.19	394.20
		000-117				
	With the following configuration:					
	Number of Units		1	unit		
30	2	MILEAGE FOR CEMENTING CREW,ZI				
	Casper, WY, USA		180	MI	2.15	387.00
			180	MI	0.86-	154.80-
			180	MI	1.29	232.20
		000-119				
	With the following configuration:					
	Number of Units		1	unit		

INVOICE INSTRUCTIONS

PAYMENT TERMS
Net due in 20 days

HALLIBURTON APPROVAL

HALLIBURTON OPERATOR / ENGINEER
Bryan Sephetti

CUSTOMER SIGNATURE

TOTAL FROM THIS PAGE	626.40
TOTAL FROM NEXT PAGE(S)	17,103.72
SUBTOTAL	17571.72 ~~17,730.12~~
TAXES	702.87 ~~709.19~~
GRAND TOTAL	18274.59 ~~18,439.31~~
	US Dollars

HALLIBURTON®

Halliburton Energy Services, Inc.

MAR02-1308

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
60	7		ENVIRONMENTAL SURCHARGE,/JOB,ZI				
		Casper, WY, USA		1.00	JOB	55.00	55.00
				1.00	JOB	22.00-	22.00-
				1.00	JOB	33.00	33.00
			000-150				
70	8		IRON SAFETY INSPECTION SURCHARGE /JOB ZI				
		Casper, WY, USA		1.00	JOB	33.00	33.00
				1.00	JOB	13.20-	13.20-
				1.00	JOB	19.80	19.80
			000-151				
90	3958		FIELD STORAGE BIN ON SITE >8 HRS,DAY,ZI				
		Casper, WY, USA		1	DAY	265.00	265.00
				1	DAY	106.00-	106.00-
				1	DAY	159.00	159.00
			500-038				
		With the following configuration:					
		NUMBER OF UNITS		1	each		
100	3965		HANDLE&DUMP SVC CHRG, CMT&ADDITIVES,ZI				
		Casper, WY, USA		553.00	CF	1.66	917.98
				553.00	CF	0.66-	367.19-
				553.00	CF	1.00	550.79
			500-207				
		With the following configuration:					
		NUMBER OF EACH		1	each		
110	3975		MILEAGE,CMTG MTLS DEL/RETURNED,ZI				
		Casper, WY, USA		2,273.0	TMI	1.25	2,841.25
				2,273.0	TMI	0.50-	1,136.50-
				2,273.0	TMI	0.75	1,704.75
			500-306				
		With the following configuration:					
		NUMBER OF TONS		1.00	ton		

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MAR02-1309

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY.	UNIT	UNIT PRICE	AMOUNT
130	132		PORTABLE DAS,/DAY/JOB,ZI				
		Casper, WY, USA		1.00	JOB	760.00	760.00
				1.00	JOB	304.00-	304.00-
				1.00	JOB	456.00	456.00
			045-050				
		With the following configuration:					
		NUMBER OF DAYS		1	Days		
140	15		MULTIPLE STAGE CEMENTING - 1ST STAGE				
		Casper, WY, USA		1.00	UN	2,726.00	2,726.00
				1.00	UN	1,090.40-	1,090.40-
				1.00	UN	1,635.60	1,635.60
			007-013				
		With the following configuration:					
		CHARGE BY FT OR RANGE OF FEET		4,120	ft		
150	16		MULTIPLE STAGE CEMENTING - 2ND STAGE				
		Casper, WY, USA		1.00	STG	2,045.00	2,045.00
				1.00	STG	818.00-	818.00-
				1.00	STG	1,227.00	1,227.00
			007-161				
		With the following configuration:					
		Number of Units		1	unit		
160	17		MSC ON SITE,ADD HR,ZI				
		Casper, WY, USA		4.000	H	363.00	1,452.00
				4.000	H	145.20-	580.80-
				4.000	H	217.80	871.20
			007-203				
		With the following configuration:					
		Number of Units		1	unit		
170	139		ADC (AUTO DENSITY CTRL) SYS, /JOB,ZI				
		Casper, WY, USA		1.00	JOB	920.00	920.00
				1.00	JOB	368.00-	368.00-
				1.00	JOB	552.00	552.00
			046-050				
		With the following configuration:					

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MAR02-1310

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
	NUMBER OF UNITS		1	each		
180	114	R/A DENSOMETER W/CHART RECORDER,/JOB,ZI				
	Casper, WY, USA:		1.00	JOB	380.00	380.00
			1.00	JOB	152.00-	152.00-
			1.00	JOB	228.00	228.00
		019-500				
	With the following configuration:					
	NUMBER OF UNITS		1	each		
190	88	PLUG CONTAINER RENTAL-1st Day				
	Casper, WY, USA		1.00	EA	533.00	533.00
			1.00	EA	213.20-	213.20-
			1.00	EA	319.80	319.80
		019-248				
	With the following configuration:					
	NUMBER OF DAYS		1	Days		
200	90	QUICK LATCH ATTACHMENT				
	Casper, WY, USA		1.00	JOB	198.00	198.00
			1.00	JOB	79.20-	79.20-
			1.00	JOB	118.80	118.80
		019-251				
	With the following configuration:					
	INCHES		7.000	in		
210	100013920	CEMENTER - TYPE P ES - 7 IN. 8RD				
	Casper, WY, USA		1.00	EA	3,568.00	3,568.00
			1.00	EA	1,427.20-	1,427.20-
			1.00	EA	2,140.80	2,140.80
		71813.56625				
		CEMENTER - TYPE P ES - 7 IN. 8RD				
		20-26# - SUITABLE F/USE W/K-55				
220	100004673	PLUG SET - FREE FALL - 7 IN. 8RD &				
	Casper, WY, USA		1.00	EA	851.00	851.00
			1.00	EA	340.40-	340.40-
			1.00	EA	510.60	510.60
		813.16571				

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MAR02-1311

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
		PLUG SET - FREE FALL - 7 IN. 8RD & BUTTRESS 20-38# 2-STAGE CMTR - W/3.80 ID BAFFLE				
230	100004480	CENTRALIZER ASSY - API - 7 CSG X 8-1/2				
	Casper, WY, USA		39.00	EA	77.00	3,003.00
			39.00	EA	30.80-	1,201.20-
			39.00	EA	46.20	1,801.80
		806.60043 CENTRALIZER ASSY - API - 7 CSG X 8-1/2 HOLE - HINGED - W/WELDED IMPERIAL BOWS				
240	100004626	CLAMP - LIMIT - 7 - HINGED -				
	Casper, WY, USA		3.00	EA	14.10	42.30
			3.00	EA	5.64-	16.92-
			3.00	EA	8.46	25.38
		CLAMP - LIMIT - 7 - HINGED - FRICTION GRIP W/DRAW BOLT				
250	100005045	HALLIBURTON WELD-A KIT				
	Casper, WY, USA		3.00	EA	18.43	55.29
			3.00	EA	7.37-	22.12-
			3.00	EA	11.06	33.17
		HALLIBURTON WELD-A KIT				
260	100004908	SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL				
	Casper, WY, USA		1.00	EA	330.05	330.05
			1.00	EA	132.02-	132.02-
			1.00	EA	198.03	198.03
		5A - 837.14100 SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL II VALVE				
270	100004781	COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4				
	Casper, WY, USA		1.00	EA	399.05	399.05
			1.00	EA	159.62-	159.62-
			1.00	EA	239.43	239.43
		4A - 836.14100				

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MAR02-1312

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY.	UNIT	UNIT PRICE	AMOUNT
		COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4				
		SUPER SEAL II VALVE				
290	12311	SBM CEMENT-HALLIBURTON LIGHT PREMIUM				
	Casper, WY, USA		495.00	SK	11.38	5,633.10
			495.00	SK	4.55-	2,253.24-
			495.00	SK	6.83	3,379.86
		504-118				
330	13383	SBM MUD FLUSH,ZI				
	Casper, WY, USA		420.00	GAL	0.80	336.00
			420.00	GAL	0.32-	134.40-
			420.00	GAL	0.48	201.60
		018-315				
360	100064173	CEMENT - CLASS G - 94 LB BAG				
	Casper, WY, USA		50.00	SK	13.04	652.00
			50.00	SK	5.22-	260.80-
			50.00	SK	7.82	391.20
		516.00999				
		CEMENT - CLASS G - 94 LB BAG				
370	100005049	FLOCELE - 3/8 - 25 LB SACK				
	Casper, WY, USA		138.00	LB	2.37	327.06
			138.00	LB	0.95-	130.82-
			138.00	LB	1.42	196.24
		XXXXXXX 890.50071				
		FLOCELE - 3/8 - 25 LB SACK				
380	100005051	CAL-SEAL - 100# BAG				
	Casper, WY, USA		5.00	SK	32.00	160.00
			5.00	SK	12.80-	64.00-
			5.00	SK	19.20	96.00
		XXXXXXX 890.50131				
		CAL-SEAL - 100# BAG				

HALLIBURTON®

HALLIBURTON ORDER NO: 436572 Cont. MARATHON OIL CO

MAR02-1313

Halliburton Energy Services, Inc.

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
390	100003682	CHEM, BENTONITE, HALGEL (BULK)				
	Casper, WY, USA		1.00	SK	23.11	23.11
			1.00	SK	9.24-	9.24-
			1.00	SK	13.87	13.87
		506-121516.00259				
		CHEMICAL - BENTONITE - HALLIBURTON GEL BULK				
		INVOICE AMOUNT			17571.72	~~17,730.12~~
		Sales Tax - State			702.87	~~709.19~~
		INVOICE TOTAL			18274.59	~~18,439.31~~ US Dollars

HALLIBURTON®

Halliburton Energy Services, Inc.

TICKET TYPE	COMPANY CODE	HALLIBURTON ORDER NO.
Services	1100	436572
CUSTOMER P.O. NO.	JOB DATE	PRIMARY SERVICE LOC.
AGL# 9364	02/09/2000	Casper, WY, USA

SOLD TO

MARATHON OIL CO
539 S MAIN
FINDLAY OH 45840
USA

Rocky Mt'n Region
FEB 14 2000
Financial Accounting

SHIP TO

WELL OPERATOR
MARATHON BASTON A#32, PARK
LEASE NAME / OFFSHORE AREA
BASTON
WELL NUMBER
A #32
WELL PERMIT NO.
ADDRESS
-
CITY, STATE, ZIP CODE
CODY WY 82414 US

MAR02-1314

SALES OFFICE	WELL TYPE	WELL CATEGORY	RIG NAME / NO.
Rocky Mountains BD	Oil	Development	MARATHON OIL CO

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
10	7523	PSL-CMT CEMENT PRODUCTION CASING-BOM				
	Casper, WY, USA		1.00	JOB	0.00	0.00
		JP035				
20	1	MILEAGE FROM NEAREST HES BASE,/UNIT,ZI				
	Casper, WY, USA		180	MI	3.65	657.00
			180	MI	1.46-	262.80-
			180	MI	2.19	394.20
		000-117				
	With the following configuration:					
	Number of Units					
30	2	MILEAGE FOR CEMENTING CREW,ZI				
	Casper, WY, USA		180	MI	2.15	387.00
					0.86-	154.80-
			180	MI	1.29	232.20
		000-119				
	With the following configuration:					
	Number of Units		1	unit		

REC'D BY [illegible] DATE 2/11/00
AFE # [illegible] CHARGE
ACCT. CAT. 81 DF 91
APPROVED
APPRV. FOR DATE

INVOICE INSTRUCTIONS	
PAYMENT TERMS: Net due in 20 days	HALLIBURTON APPROVAL
HALLIBURTON OPERATOR / ENGINEER: Bryan Seghetti	CUSTOMER SIGNATURE

TOTAL FROM THIS PAGE	626.40
TOTAL FROM NEXT PAGE(S)	17,103.72
SUBTOTAL	17571.72 ~~17,730.12~~
TAXES	702.87 ~~709.19~~
GRAND TOTAL	19274.59 ~~18,439.31~~ US Dollars

17571.
702.
18273.

HALLIBURTON®

Halliburton Energy Services, Inc.

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
60	7		ENVIRONMENTAL SURCHARGE,/JOB,ZI				
		Casper, WY, USA		1.00	JOB	55.00	55.00
				1.00	JOB	22.00-	22.00-
				1.00	JOB	33.00	33.00
			000-150				
70	8		IRON SAFETY INSPECTION SURCHARGE /JOB ZI				
		Casper, WY, USA		1.00	JOB	33.00	33.00
				1.00	JOB	13.20-	13.20-
				1.00	JOB	19.80	19.80
			000-151				
90	3958		FIELD STORAGE BIN ON SITE >8 HRS,DAY,ZI				
		Casper, WY, USA		1	DAY	265.00	~~265.00~~
				1	DAY	106.00-	~~106.00-~~
				1	DAY	159.00	~~159.00~~
			500-038				
		With the following configuration:					
		NUMBER OF UNITS		1	each		
100	3965		HANDLE&DUMP SVC CHRG, CMT&ADDITIVES,ZI				
		Casper, WY, USA		553.00	CF	1.66	917.98
				553.00	CF	0.66-	367.19-
				553.00	CF	1.00	550.79
			500-207				
		With the following configuration:					
		NUMBER OF EACH		1	each		
110	3975		MILEAGE,CMTG MTLS DEL/RETURNED,ZI				
		Casper, WY, USA		2,273.0	TMI	1.25	2,841.25
				2,273.0	TMI	0.50-	1,136.50-
				2,273.0	TMI	0.75	1,704.75
			500-306				
		With the following configuration:					
		NUMBER OF TONS		1.00	ton		

MAR02-1315

HALLIBURTON®

Halliburton Energy Services, Inc.

ITEM	MATERIAL	LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
130	132		PORTABLE DAS,/DAY/JOB,ZI				
		Casper, WY, USA		1.00	JOB	760.00	760.00
				1.00	JOB	304.00-	304.00-
				1.00	JOB	456.00	456.00
			045-050				
		With the following configuration:					
		NUMBER OF DAYS		1	Days		
140	15		MULTIPLE STAGE CEMENTING - 1ST STAGE				
		Casper, WY, USA		1.00	UN	2,726.00	2,726.00
				1.00	UN	1,090.40-	1,090.40-
				1.00	UN	1,635.60	1,635.60
			007-013				
		With the following configuration:					
		CHARGE BY FT OR RANGE OF FEET		4,120	ft		
150	16		MULTIPLE STAGE CEMENTING - 2ND STAGE				
		Casper, WY, USA		1.00	STG	2,045.00	2,045.00
				1.00	STG	818.00-	818.00-
				1.00	STG	1,227.00	1,227.00
			007-161				
		With the following configuration:					
		Number of Units		1	unit		
160	17		MSC ON SITE,ADD HR,ZI				
		Casper, WY, USA		4.000	H	363.00	1,452.00
				4.000	H	145.20-	580.80-
				4.000	H	217.80	871.20
			007-203				
		With the following configuration:					
		Number of Units		1	unit		
170	139		ADC (AUTO DENSITY CTRL) SYS, /JOB,ZI				
		Casper, WY, USA		1.00	JOB	920.00	920.00
				1.00	JOB	368.00-	368.00-
				1.00	JOB	552.00	552.00
			046-050				
		With the following configuration:					

MAR02-1316

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MAR02-1317

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY.	UNIT	UNIT PRICE	AMOUNT
	NUMBER OF UNITS		1	each		
180	114	R/A DENSOMETER W/CHART RECORDER,/JOB,ZI				
	Casper, WY, USA		1.00	JOB	380.00	380.00
			1.00	JOB	152.00-	152.00-
			1.00	JOB	228.00	228.00
		019-500				
	With the following configuration:					
	NUMBER OF UNITS		1	each		
190	88	PLUG CONTAINER RENTAL-1st Day				
	Casper, WY, USA		1.00	EA	533.00	533.00
			1.00	EA	213.20-	213.20-
			1.00	EA	319.80	319.80
		019-248				
	With the following configuration:					
	NUMBER OF DAYS		1	Days		
200	90	QUICK LATCH ATTACHMENT				
	Casper, WY, USA		1.00	JOB	198.00	198.00
			1.00	JOB	79.20-	79.20-
			1.00	JOB	118.80	118.80
		019-251				
	With the following configuration:					
	INCHES		7.000	in		
210	100013920	CEMENTER - TYPE P ES - 7 IN. 8RD				
	Casper, WY, USA		1.00	EA	3,568.00	3,568.00
			1.00	EA	1,427.20-	1,427.20-
			1.00	EA	2,140.80	2,140.80
		71813.56625				
		CEMENTER - TYPE P ES - 7 IN. 8RD				
		20-26# - SUITABLE F/USE W/K-55				
220	100004673	PLUG SET - FREE FALL - 7 IN. 8RD &				
	Casper, WY, USA		1.00	EA	851.00	851.00
			1.00	EA	340.40-	340.40-
			1.00	EA	510.60	510.60
		813.16571				

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MAR02-1318

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY	UNIT	UNIT PRICE	AMOUNT
		PLUG SET - FREE FALL - 7 IN. 8RD & BUTTRESS 20-38# 2-STAGE CMTR - W/3.80 ID BAFFLE				
230	100004480	CENTRALIZER ASSY - API - 7 CSG X 8-1/2				
	Casper, WY, USA		39.00	EA	77.00	3,003.00
			39.00	EA	30.80-	1,201.20-
			39.00	EA	46.20	1,801.80
		806.60043 CENTRALIZER ASSY - API - 7 CSG X 8-1/2 HOLE - HINGED - W/WELDED IMPERIAL BOWS				
240	100004626	CLAMP - LIMIT - 7 - HINGED -				
	Casper, WY, USA		3.00	EA	14.10	42.30
			3.00	EA	5.64-	16.92-
			3.00	EA	8.46	25.38
		CLAMP - LIMIT - 7 - HINGED - FRICTION GRIP W/DRAW BOLT				
250	100005045	HALLIBURTON WELD-A KIT				
	Casper, WY, USA		3.00	EA	18.43	55.29
			3.00	EA	7.37-	22.12-
			3.00	EA	11.06	33.17
		HALLIBURTON WELD-A KIT				
260	100004908	SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL				
	Casper, WY, USA		1.00	EA	330.05	330.05
			1.00	EA	132.02-	132.02-
			1.00	EA	198.03	198.03
		5A - 837.14100 SHOE-FLOAT- 7 8RD - 2-3/4 SUPER SEAL II VALVE				
270	100004781	COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4				
	Casper, WY, USA		1.00	EA	399.05	399.05
			1.00	EA	159.62-	159.62-
			1.00	EA	239.43	239.43
		4A - 836.14100				

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Halliburton Energy Services, Inc.

MAR02-1319

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY.	UNIT	UNIT PRICE	AMOUNT
		COLLAR-FLOAT- 7 8RD 17-26#/FT - 2-3/4				
		SUPER SEAL II VALVE				
290	12311	SBM CEMENT-HALLIBURTON LIGHT PREMIUM				
	Casper, WY, USA		495.00	SK	11.38	5,633.10
			495.00	SK	4.55-	2,253.24-
			495.00	SK	6.83	3,379.86
		504-118				
330	13383	SBM MUD FLUSH,ZI				
	Casper, WY, USA		420.00	GAL	0.80	336.00
			420.00	GAL	0.32-	134.40-
			420.00	GAL	0.48	201.60
		018-315				
360	100064173	CEMENT - CLASS G - 94 LB BAG				
	Casper, WY, USA		50.00	SK	13.04	652.00
			50.00	SK	5.22-	260.80-
			50.00	SK	7.82	391.20
		516.00999				
		CEMENT - CLASS G - 94 LB BAG				
370	100005049	FLOCELE - 3/8 - 25 LB SACK				
	Casper, WY, USA		138.00	LB	2.37	327.06
			138.00	LB	0.95-	130.82-
			138.00	LB	1.42	196.24
		XXXXXXX 890.50071				
		FLOCELE - 3/8 - 25 LB SACK				
380	100005051	CAL-SEAL - 100# BAG				
	Casper, WY, USA		5.00	SK	32.00	160.00
			5.00	SK	12.80-	64.00-
			5.00	SK	19.20	96.00
		XXXXXXX 890.50131				
		CAL-SEAL - 100# BAG				

HALLIBURTON®

Halliburton Energy Services, Inc.

ITEM	MATERIAL / LOCATION	DESCRIPTION	QTY.	UNIT	UNIT PRICE	AMOUNT
390	100003682	CHEM, BENTONITE, HALGEL (BULK)				
	Casper, WY, USA		1.00	SK	23.11	23.11
			1.00	SK	9.24-	9.24-
			1.00	SK	13.87	13.87
		506-121516.00259				
		CHEMICAL - BENTONITE - HALLIBURTON GEL BULK				
		INVOICE AMOUNT			17571.72	~~17,730.12~~
		Sales Tax - State			702.87	~~709.19~~
		INVOICE TOTAL			18274.59	~~18,439.31~~ US Dollars

MAR02-1320

900

MAR02-1321

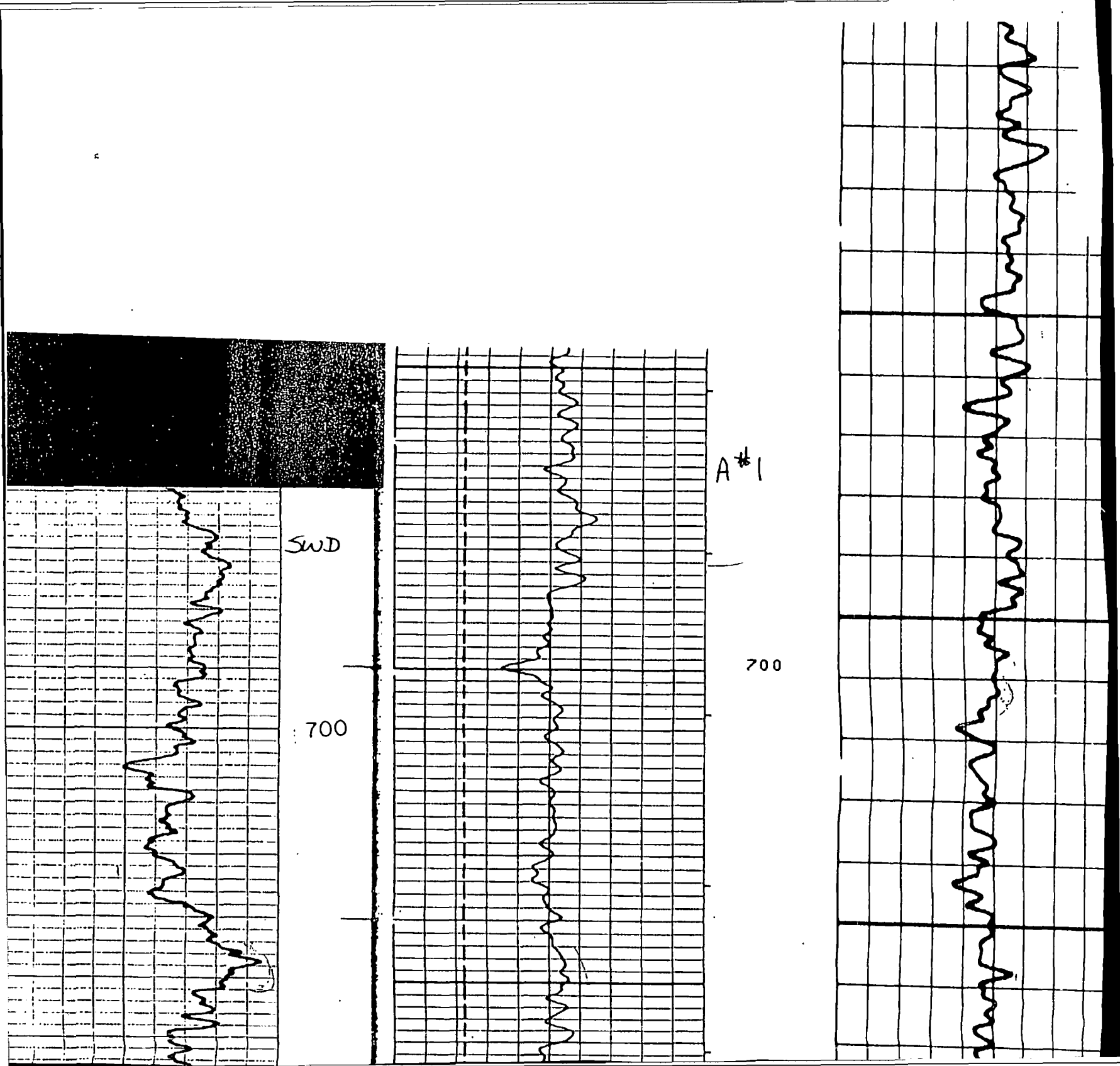
B#1

700

800

Buckles B1

Reduce to 8 X 14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700
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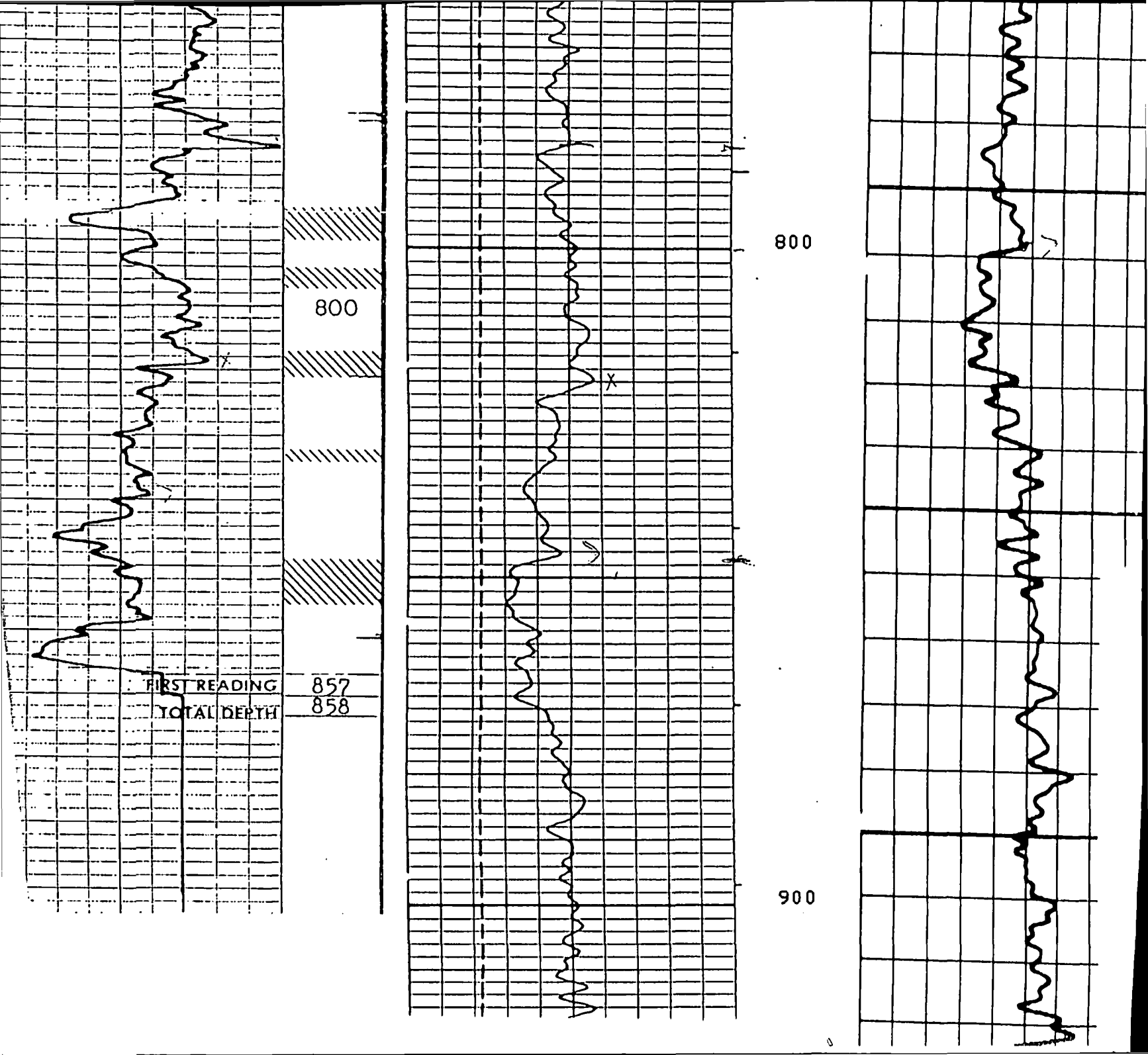
800
FIRST READING 857
TOTAL DEPTH 858
800
900

Water-Resources Investigation 97-4000

Title

Saline-water contamination in Quaternary deposits and the Poplar River, East Poplar Oil Field, northeastern Montana

Author

Joanna N. Thamke and Steven D. Craigg

Availability

U.S. Geological Survey Earth Science Information Center Open-File Reports Section Box 25286, MS 517 Denver Federal Center Denver, CO 80225 USGS Water-Resources Investigations Report 97-4000 37 p., 3 plates, 20 figs.

Abstract

The extent of saline-water contamination in Quaternary deposits in and near the East Poplar oil field may be as much as 12.4 square miles and appears to be present throughout the entire saturated zone. The saline-water contamination affects 9-60 billion gallons of ground water. Saline- contaminated water moves westward through Quaternary glacial deposits and merges with southward-flowing water in Quaternary alluvium in the Poplar River valley. Saline ground water discharges into the Poplar River, and increases the dissolved-solids and chloride concentrations of the river. The probable source of saline-water contamination in the Quaternary deposits is brine that is a byproduct of the production of crude oil in the East Poplar oil field study area.

Keywords

Saline-water contamination, East Poplar oil field, Northeastern Montana, Brine, Electromagnetic geophysics

State

MT

Watershed

10060003

Year

1997

Source

SWRA 1997

Water Search Form *Help!*

MAR02-1322

MERIT.EXF
(3/4/99)

MAR02-1323

EXHIBIT "F"

Attached To and Made a Part of That Certain
Purchase and Sale Agreement
By and Between
Marathon Oil Company, as Seller
and
Merit Partners, L.P., et al, as Purchaser
Valuation Date: January 1, 1999.

[closing date], 1999

[name and address
of the
purchaser of production]

Re: Purchase and Sale Agreement dated March ____, 1999, with a Valuation Date of January 1, 1999, by and between Marathon Oil Company, as Seller, and Merit Partners, L.P., et al, as Purchaser.

Gentlemen:

On [closing date], 1999 Marathon Oil Company ("MOC") sold to Merit Partners, L.P., et al ("Purchaser") all of its right, title and interest in certain producing properties in the state of Wyoming. MOC has heretofore been responsible for the payment of proceeds to those entitled thereto from the properties, or a portion thereof, both as to liquid and gaseous hydrocarbons.

As it is essential that there be no interruption in payments to third parties entitled to portions of such proceeds from production because of MOC's sale to Purchaser, MOC will handle disbursements in its normal course of business for all oil and liquid hydrocarbons produced and sold from the subject properties through ["A" last day of the month, sixty days from 1st day of month following Closing], 199__, and for all gas and gaseous hydrocarbons produced and sold from the subject properties through [same as "A"], 199__. Thereafter, Purchaser shall assume responsibility for such disbursements. If requested by MOC, Purchaser agrees to provide MOC with any information in its possession which will assist MOC in performing the service contemplated herein.

During the term of this agreement, Purchaser agrees to direct the current remitter of proceeds to continue remitting such proceeds to MOC. If Purchaser causes the remitter of proceeds to cease to remit proceeds for such production as to the subject properties to MOC, MOC shall immediately cease to be responsible for disbursements of proceeds from such production.

Any cross accounting for proceeds for production heretofore received by MOC subsequent to the Valuation Date of such sale and the present time shall be accounted for between Purchaser and MOC in accordance with the Purchase and Sale Agreement. This shall include any operating costs or expenses which MOC may have incurred during such period as well.

At such time as MOC ceases to be responsible for such disbursements, MOC will promptly turn over to Purchaser all records as to changes in title which MOC may have acquired during such period of time, together with all funds which MOC may have in suspense due third parties from such production, together

Water-Resources Investigation 84-4174

Title

Reconnaissance Evaluation of Contamination of the Alluvial Aquifer in the East Poplar Oil Field, Roosevelt County, Montana

Author

Levings, G.W.

Corporate Author

Geological Survey Helena, MT. Water Resources Div.

Availability

Available from: OFSS, USGS Box 25425 Lakewood, CO 80225. USGS Water-Resources Investigations Report 84-4174, 1984. 29 p, 10 fig, 4 tab, 12 ref.

Abstract

Water moving from north to south in the alluvial aquifer of the Poplar River valley becomes contaminated with sodium chloride in the area underlain by the East Poplar oil fields. Four types of ground water were identified in the study area. Type 1 is sodium bicarbonate water. Type 2 is sodium chloride water with varying quantities of calcium and magnesium. Type 3 water contains sodium and chloride in significantly larger concentrations than Type 2. Type 4 water is the brine being injected into brine-disposal wells. Contamination of the alluvial aquifer is indicated by a brine-freshwater interface in the alluvium, by downstream increase in chloride concentration of the Poplar River, and by downstream change in water type of the Poplar River. Contamination also may be indicated by the distribution of iron and manganese concentrations in water from wells near a brine-disposal well. Possible sources of sodium chloride contamination in the alluvium are brine-disposal wells, pipelines, and storage or evaporation pits. The contamination can occur from leaks in the casing of disposal wells or in pipelines caused by the corrosive nature of the brine or from storage or evaporation pits that have been improperly sealed or have sustained tears in the sealing material. (USGS)

Keywords

Groundwater Brine disposal Groundwater pollution Montana Oil field wastes Water pollution sources Water quality Observation wells Surface water Data collections Poplar River Valley Poplar River East Poplar oil field

Year

1984

Source

SWRA 1997

MAR02-1324

W-057720	USA	The Ohio Oil Company	1/1/58	Township 48 North, Range 99 West, 6th PM Section 12: SE/4 NE/4, E/2 SE/4	
W-059284	USA	Grass Creek Oil Company	8/25/40	Township 48 North, Range 99 West, 6th PM Section 13: SW/4 NE/4, W/2 SE/4	
W-27490	USA	Pan American Petroleum Corporation	3/1/71	Township 48 North, Range 98 West, 6th PM Section 30: NE/4 NW/4 (AKA Tr. 81-B)	05/205
W-08061	USA	Gerald J. Kellog	6/1/51	Township 48 North, Range 98 West, 6th PM Section 21: Lots 9 & 10	
W-0228	USA	Fred M. Manning Co.	5/1/50	Township 48 North, Range 98 West, 6th PM Section 17: NE/4 NW/4	
W-048807	USA	The Ohio Oil Co., et al	2/19/41	Township 48 North, Range 98 West, 6th PM Section 18: NE/4 NE/4	
W-01003	USA	Fred M. Manning Co.	7/1/50	Township 48 North, Range 98 West, 6th PM Section 21: Lots 3 & 7 Section 29: Tract 53-D (42.92)	
W-01003-A	USA	Fred M. Manning Co.	7/1/50	Township 48 North, Range 98 West, 6th PM Section 29: Tracts 53A (43.69)	
Cheyenne 078448	USA	Fred M. Manning Co.	4/1/50	Township 48 North, Range 99 West, 6th PM Section 24: SE/4 NE/4	
W-012153	USA	D. G. Gordon	4/1/52	Township 48 North, Range 98 West, 6th PM Section 20: Lot 3 (39.69)	

MINERAL INTERESTS

The Midwest Refining Company	Standolind Oil and Gas Company	11/1/32	Township 48 North, Range 98 West, 6th PM Section 28: SE/4 NW/4, S/2 NE/4 & NE/4 SE/4	21/284
The Midwest Refining Company	Standolind Oil and Gas Company	11/1/32	Township 48 North, Range 98 West, 6th PM Section 28: SW/4 NW/4	21/287

Exhibit A

MAR 04 '99 12:33PM HOWELL CORP 18TH FL

MAR02-1325

Open-File Report 95-749

Title

Hydrologic data for the East Poplar Oil Field, Fort Peck Indian Reservation, northeastern Montana

Author

J. N. Thamke, S. D. Craigg, and T. M. Mendes

Availability

Available from USGS, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225, USGS Open-File Report 95-749, 92 p, 5 figs, 1-3.5" floppy disk.

Abstract

This report presents selected hydrologic data for the East Poplar oil field, located in the south-central part of the Fort Peck Indian Reservation in northeastern Montana. Data about the occurrence, quantity, and quality of ground and surface water are presented in tabular form. The tables contain records of privately owned wells (active and abandoned), monitoring wells installed by the U.S. Geological Survey and Montana Bureau of Mines and Geology, oil wells, and brine-injection wells; lithologic descriptions of drill cuttings and well-completion data from monitoring wells; data from two aquifer tests conducted in Quaternary alluvial and glacial deposits; chemical quality of ground water; and information on the quantity and chemical quality of surface water. Records of electromagnetic geophysical measurements collected throughout an area of about 20 square miles of the study area are compiled and included on a floppy disk. Illustrations in this report contain information about study area location, site- numbering system, general physical and cultural features, and construction of monitoring wells installed by the U.S. Geological Survey. plate-sized map presents additional information about privately owned wells, monitoring wells, oil wells, brine-injections wells, surface-water data-collection sites, and area of electromagnetic data collection. The data presented in this report provide a base with which to better define and interpret the occurrence, quantity, and quality of ground and surface water in the vicinity of the Poplar River Valley in the south-central part of the Fort Peck Indian Reservation. The data can be used to help delineate the occurrence of brine and saline water in Quaternary alluvial and glacial deposits in the East Poplar oil field.

Keywords

Saline water, Ground water, Water Quality, Electromagnetic

State

MT

Watershed

10060003

MAR02-1326

FROM: Howell Corp.

13 PAGES

EXHIBIT "A"

GRASS CREEK UNIT
HOT SPRINGS COUNTY, WYOMING

Government Lease Number	Lessor	Lessee	Date	Description	Recorded Book/Page
LEASEHOLD INTERESTS (Including Royalty and Overriding Royalty Interests)					
Cheyenne 044182	USA	Grass Creek Oil and Gas Company	8/25/40	Township 46 North, Range 98 West, 6th PM Section 7: Lot 4, SE/4 SW/4 Township 46 North, Range 99 West, 6th PM Section 13: W/2 NE/4 NE/4, SE/4 NE/4, E/2 SE/4 Seller's Interest: Lease provides for a 12.5% graduating royalty. Based on a 12.5% Lessor's royalty, Seller's interest is 100% W.I. and 77.5% N.R.I. subject to a $.05 per barrel production payment. Lessor's current royalty burden for the Curtis Unit is 6.1% and 2.9% for the Frontier Unit.	
Cheyenne 045461	USA	Standolind Oil and Gas Company	7/1/40	Township 46 North, Range 98 West, 6th PM Section 30: NW/4 NE/4 (AKA Tr. 61A)	
Buffalo #20	S. L. Willey, et al	B. H. Hopkins	6/16/14	Township 46 North, Range 98 West, 6th PM Section 18: W/2 SW/4 (Lots 3 & 4)	1/432
0-1913	State of Wyoming	Standolind Oil and Gas Company	3/2/43	Township 46 North, Range 98 West, 6th PM Section 19: N/2 SE/4 (Resurvey Tr. 58-A,B)	17/138
0-1914	State of Wyoming	Standolind Oil and Gas Company	3/2/43	Township 46 North, Range 98 West, 6th PM Section 19: N/2 NE/4 (Survey Tr. 58-A,B)	17/131
	John S. Pinckard	E. O. Orchard	5/27/15	Township 46 North, Range 98 West, 6th PM	4/131

MAR02-1327

SALINE-WATER CONTAMINATION IN QUATERNARY DEPOSITS AND THE POPLAR RIVER, EAST POPLAR OIL FIELD, NORTHEASTERN MONTANA

By Joanna N. Thamke and Steven D. Craigg

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 97-4000

Prepared in cooperation with the
WATER RESOURCES OFFICE of the FORT PECK TRIBES

Helena, Montana
May 1997

MAR02-1328

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

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U.S. Geological Survey
Federal Building, Drawer 10076
Helena, MT 59626-0076

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

MAR02-1329

CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and scope	2
Location and geographic setting	2
Brief history of the East Poplar oil field	2
Previous investigations	8
Methods of investigation	8
Site-identification systems	9
Acknowledgments	10
Geologic setting	10
Mississippian Madison Group	12
Cretaceous rocks	12
Lakota Formation--Fall River Sandstone--"Dakota Sandstone"	12
Judith River Formation	13
Bearpaw Shale	13
Quaternary deposits	13
General hydrogeology of Quaternary deposits	14
Ground-water occurrence and movement	14
Hydraulic characteristics	14
Ground-water quality	15
Electromagnetic apparent conductivity	16
General hydrology of the Poplar River	21
Saline-water contamination	21
Quaternary deposits	22
Lateral extent	22
Vertical extent	24
Magnitude	25
Movement	25
Poplar River	28
Possible sources	31
General sources	31
Specific source areas	31
Summary and conclusions	32
Selected references	33

MAR02-1330

ILLUSTRATIONS

Page

Plate 1. Contains figures 6, 7, 8, 16 ..... in pocket
Plate 2. Contains figures 10, 11, 12, 13, 14, 15 ..... in pocket
Plate 3. Map showing location of possible and confirmed saline-water plumes, surface-water data-collection sites, known brine-injection wells, oil wells, pipelines, storage-tank facilities, and brine-evaporation or storage pits in the East Poplar oil field study area, northeastern Montana ..... in pocket

Figure 1. Map showing location of the East Poplar oil field study area, northeastern Montana 3
2. Photographs showing general physiographic features of the East Poplar oil field study area 4
3. Photographs showing various surface structures associated with oil production in the East Poplar oil field study area 5
4. Diagram showing site-numbering system for wells 9

5-8. Maps showing:
5. Location of Williston Basin, major structural features, and East Poplar oil field study area 11
6. Potentiometric surface, generalized direction of water movement in Quaternary deposits, and generalized geology of the East Poplar oil field study area ..... plate 1
7. Thickness of Quaternary deposits and approximate altitude and configuration of the top of the Upper Cretaceous Bearpaw Shale in the East Poplar oil field study area ..... plate 1
8. Chemical composition and dissolved-solids concentration of water from Quaternary deposits, 1989-93, and of water from brine-injection wells, 1964-90, in the East Poplar oil field study area ..... plate 1

9. Photograph showing electromagnetic geophysical equipment in the horizontal-dipole orientation 19

10-16. Maps showing:
10. Electromagnetic apparent conductivity measurements for 10-meter intercoil spacing at the horizontal-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
11. Electromagnetic apparent conductivity measurements for 10-meter intercoil spacing at the vertical-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
12. Electromagnetic apparent conductivity measurements for 20-meter intercoil spacing at the horizontal-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
13. Electromagnetic apparent conductivity measurements for 20-meter intercoil spacing at the vertical-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
14. Electromagnetic apparent conductivity measurements for 40-meter intercoil spacing at the horizontal-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
15. Electromagnetic apparent conductivity measurements for 40-meter intercoil spacing at the vertical-dipole orientation, 1991-92, in the East Poplar oil field study area ..... plate 2
16. Subareas of low, moderate, and high electromagnetic apparent conductivity in Quaternary deposits, 1991-92, and types of water from Quaternary deposits, 1989-93, in the East Poplar oil field study area ..... plate 1

17-19. Diagrams showing chemical composition and dissolved-solids concentration of water sampled from wells:
17. M-25 in the East Poplar oil field study area 26
18. M-28 and M-31 in the East Poplar oil field study area 27
19. W-11, W-15, W-16, and FPB92-11 in the East Poplar oil field study area 28
20. Streamflow and chloride loads for selected sites along the Poplar River, 1981 and 1991, in the East Poplar oil field study area 30

MAR02-1331

TABLES

Page

Table 1. Generalized stratigraphic column for the Montana part of the Williston Basin 6
2. Approximate quantities of brine injected through brine-injection wells in the East Poplar oil field study area 7
3. Characteristics of water types and correlation of electromagnetic apparent conductivity used to delineate saline-water plumes in Quaternary deposits in the East Poplar oil field study area 17
4. Approximate effective depths of exploration at three intercoil spacings and dipole orientations for variable-depth ground-conductivity electromagnetic geophysical methods 19

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
barrel (42 gal) (bbl)	0.1590	cubic meter
barrel per day (bbl/d)	0.1590	cubic meter per day
barrel per year (bbl/yr)	0.1590	cubic meter per year
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.09290	meter squared per day
gallon (gal)	3.785	liter
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per year (gal/yr)	0.003785	cubic meter per year
gallon per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the equations:

$$°C = 5/9\ (°F - 32)$$

$$°F = 9/5\ (°C) + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated units and symbols used in this report:

µS/cm	microsiemen per centimeter at 25 degrees Celsius
mg/L	milligram per liter
g/mL	gram per milliliter
mmho/m	millimho per meter
≥	greater than or equal to
<	less than

Abbreviations used in this report:

BIA	Bureau of Indian Affairs, U.S. Department of the Interior
BLM	Bureau of Land Management, U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
MBMG	Montana Bureau of Mines and Geology
MCL	Maximum Contaminant Level
SMCL	Secondary Maximum Contaminant Level
USGS	U.S. Geological Survey

MAR02-1332

SALINE-WATER CONTAMINATION IN QUATERNARY DEPOSITS AND THE POPLAR RIVER, EAST POPLAR OIL FIELD, NORTHEASTERN MONTANA

By Joanna N. Thamke and Steven D. Craigg

Abstract

The extent of saline-water contamination in Quaternary deposits in and near the East Poplar oil field may be as much as 12.4 square miles and appears to be present throughout the entire saturated zone. The saline-water contamination affects 9-60 billion gallons of ground water. Saline-contaminated water in Quaternary deposits east of the Poplar River generally moves westward toward the river and then southward in the Poplar River valley. Saline ground water discharges into the Poplar River, and increases the dissolved-solids and chloride concentrations in the river. The probable source of saline-water contamination in the Quaternary deposits is brine that is a byproduct of the production of crude oil in the East Poplar oil field study area. There may be at least one source of saline-water contamination in the Quaternary deposits still contributing saline water to the aquifer.

Three types of water quality characterize the Quaternary deposits; a fourth type of water quality characterizes the brine. Type 1 is the uncontaminated water quality—principally sodium bicarbonate and sodium sulfate. Types 2 and 3 are contaminated ground-water quality—principally a sodium chloride, with dissolved-solids and chloride concentrations larger than in Type 1. The concentrations of dissolved-solids, sodium, and chloride are significantly larger in Type 3 than in Type 2 water quality, indicating considerably more contamination. Type 3 water quality is similar to Type 4, which represents the brine as it is injected into brine-injection wells.

Electromagnetic apparent conductivity data collected in an area of about 21.6 square miles correlate well with ground-water quality. These data were collected and interpreted in conjunction with water-quality data to delineate possible saline-water contamination plumes. Monitoring wells were subsequently drilled in some areas without existing water wells to confirm most of the delineated saline-water plumes; however, several possible plumes do not contain either existing water wells or monitoring wells. Analysis of ground-water samples from both existing and newly drilled monitoring wells confirms the presence of 7.3 square miles of contamination, as much as 2.0 square miles of which is considerably contaminated (Type 3). Electromagnetic apparent conductivity data in areas with no wells delineate an additional 5.1 square miles of possible contamination, 3.2 square miles of which might be considerably contaminated (Type 3). Brine-injection wells, oil wells, pipelines, and storage-tank facilities appear to be probable sources of the saline-water contamination in many of the plumes.

INTRODUCTION

The presence of saline-water contamination in Quaternary alluvium along the Poplar River was first noted in the late 1970's, when landowners reported increased salinity of their domestic well water. A reconnaissance investigation by Levings (1984) determined that water in the Quaternary alluvium was contaminated by brine (water having a dissolved-solids concentration greater than 35,000 mg/L) from the production of oil. Levings indicated that additional study was necessary to determine the areal extent of contamination, rates of movement of brine, geochemical reactions that may occur, and changes in water quality with depth in the alluvium.

In the late 1980's, other well owners indicated that water in Quaternary glacial deposits also was becoming more saline. In response to the reported increased salinity of ground water used for domestic

MAR02-1333

and stock supplies within and near the East Poplar oil field, the USGS, in cooperation with the Water Resources Office of the Fort Peck Tribes, conducted a follow-up investigation of shallow water in Quaternary alluvium and glacial deposits. This investigation not only expanded on the previous study of Levings (1984), but also extended that study area southward and eastward to include the glacial deposits east of the Poplar River.

Purpose and Scope

This report describes the results of an investigation to determine the extent, magnitude, and movement of saline-water contamination in Quaternary deposits and the Poplar River in the East Poplar oil field study area. Specifically, the report describes (1) the geologic setting of the East Poplar oil field study area, (2) the general hydrogeology of Quaternary deposits in terms of occurrence and movement of ground water, hydraulic characteristics of the deposits, water quality, and electromagnetic apparent conductivity, and (3) saline-water contamination in Quaternary deposits and the Poplar River, and possible sources of that contamination.

As part of this investigation, existing geologic and hydrologic data were compiled, additional wells were drilled and inventoried, water samples were collected, an electromagnetic geophysical survey was conducted, and streamflow of the Poplar River was measured. All data were analyzed to determine the extent, magnitude, and movement of saline-water contamination. This is the second report published during the investigation; the first report contained the hydrologic data that were collected (Thamke and others, 1996).

Location and Geographic Setting

The East Poplar oil field study area encompasses the East Poplar oil field (about 30 mi^2) and an additional 40 mi^2 around the oil field in northeastern Montana, on the Fort Peck Indian Reservation. The southern extent of the study area is about 2 mi north of the town of Poplar (fig. 1). The study area is located in Tps. 28 and 29 N., and Rs. 50 and 51 E., in and adjacent to the Poplar River valley. The Poplar River flows generally southward through the study area.

The study area is in the northern part of the Great Plains physiographic province, within the glaciated section of the Missouri Plateau (Fenneman, 1931). Topography of the study area consists of a broad glacial bench of relatively low relief, dissected by the Poplar River and its tributaries (fig. 2).

Dryland farming is practiced on the glacial bench and in some parts of the Poplar River valley. Livestock ranching also is practiced in parts of the study area. Oil wells, brine-injection wells, storage tanks, evaporation pits, pipelines, and various other structures associated with oil production are present throughout the study area (fig. 3).

Brief History of the East Poplar Oil Field

Oil production in the East Poplar oil field began in 1952 (Brunson, 1985, p. 889). The discovery well was drilled into Ordovician rocks to a depth below land surface of 9,163 ft and was completed on March 10, 1952 in the Mississippian Madison Group at depths of 5,524-5,827 ft (table 1 lists the generalized stratigraphic column). The major oil-producing formation is the Charles Formation of the Madison Group. A few wells were completed in the Mississippian Heath Formation and Kibbey Sandstone, the Mission Canyon Limestone of the Madison Group, and the Devonian Nisku Formation. Producing horizons typically are at depths of about 5,500-6,000 ft. The average production during 1985 was about 600 bbl/d of oil, with a 6.5 percent decline rate per year (Brunson, 1985, p. 890). Minor gas production has been obtained from the Upper Cretaceous Judith River Formation (Brunson, 1985, p. 890; Monson, 1989).

Along with the crude oil, brine (water having a dissolved-solids concentration greater than 35,000 mg/L) has been produced. The production of brine ranged from as much as 17,000 bbl/d, or 6.2 million bbl/yr, in 1985 to 5.5 million bbl/yr in 1995 (Brunson, 1985, p. 890; [Montana] Board of Oil and Gas Conservation, 1995a-d). The dissolved-solids concentration in the brine is as much as 201,000 mg/L (Thamke and others, 1996, table 6). Currently (1996), four brine-injection wells are active, although at least 16 others were active at times during the oil-field's history (Thamke and others, 1996, table 2; table 2 of this report). Of the four active brine-injection wells, one is completed in the Upper Cretaceous Judith River Formation and three are completed in a Lower Cretaceous sandstone that is called the "Dakota Sandstone" by the oil companies and the Fort Peck Tribes. Since 1985, a moratorium has been in effect on new permitting of brine-injection

MAR02-1334

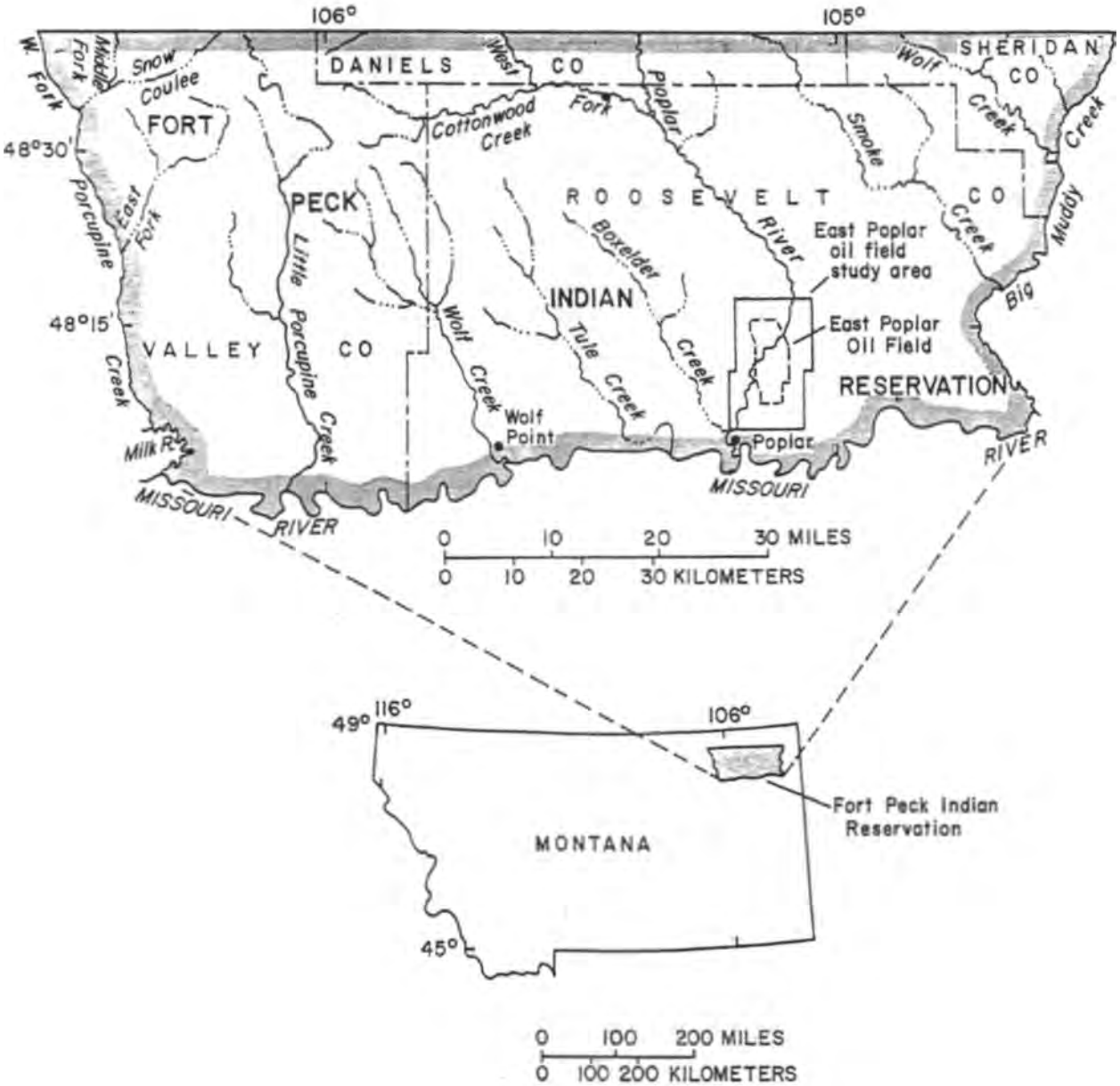


Figure 1. Location of the East Poplar oil field study area, northeastern Montana.

MAR02-1335

A

B

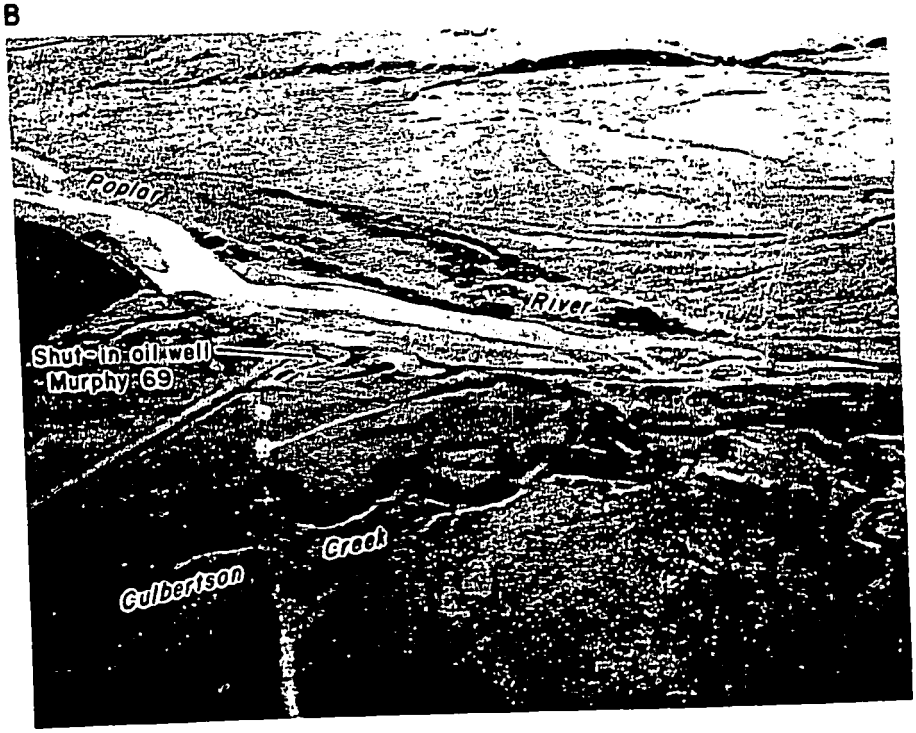
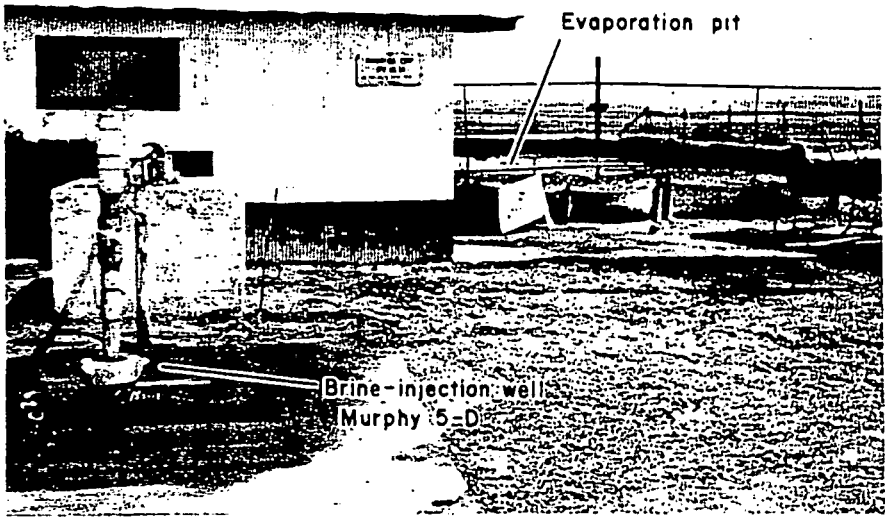


Figure 2. General physiographic features of the East Poplar oil field study area, northeastern Montana. (A) Aerial view north showing the low topographic relief of glacial deposits. (B) Aerial view southeast showing confluence of Culbertson Creek (foreground) and the Poplar River. Shut-in oil well Murphy 69 is on the north side of the river.

MAR02-1336

A



B

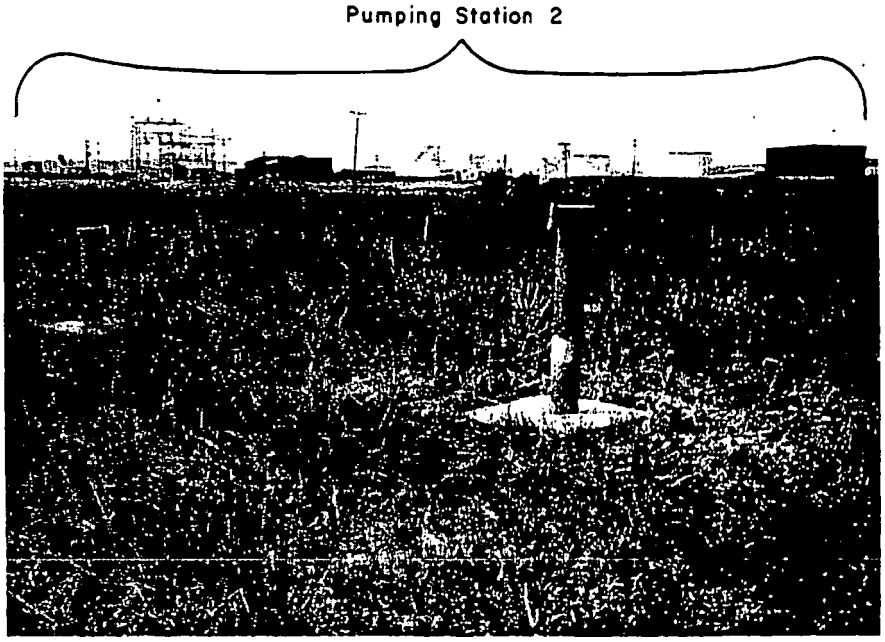


Figure 3. Various surface structures associated with oil production in the East Poplar oil field study area, northeastern Montana. (A) View east (from NE 1/4 NW 1/4 SE 1/4 SE 1/4, sec. 19, T. 29 N., R. 51 E.) of a brine-injection well (Murphy 5-D; pl. 3), and an evaporation pit (behind pump house). (B) View northwest (from NE 1/4 NW 1/4 NW 1/4 NW 1/4, sec. 32, T. 29 N., R. 51 E.) of monitoring wells (FPB92-1 and FPB93-2; Thamke and others, 1996, table 1) near storage tank facilities (Pumping Station 2).

MAR02-1337

MAR02-1338

Table 1. Generalized stratigraphic column for the Montana part of the Williston Basin (Modified from Balster, 1980, and Rice, 1976a)

Erathem	System	Series	Geologic unit		
Cenozoic	Quaternary	Holocene	Alluvium		Fan alluvium and colluvium, dune sand
		Pleistocene	Glacial deposits, Sprole Silt Wiota Gravel		
	Tertiary	Pliocene	Flaxville Formation		
		Paleocene	Fort Union Formation		
Mesozoic	Cretaceous	Upper Cretaceous	Hell Creek Formation		
			Montana Group	Fox Hills Sandstone	
				Bearpaw Shale	
				Judith River Formation	
				Claggett Shale	
				Eagle Sandstone	
				Telegraph Creek Formation	
			Colorado Group	Niobrara Formation	
				Carlile Shale	
				Greenhorn Formation	
				Belle Fourche Shale	
		Lower Cretaceous		Mowry Shale	
				Newcastle Sandstone	
				Skull Creek Shale	
				Fall River Sandstone	"Dakota Sandstone"
			Fuson Shale		
			Lakota Formation		

Erathem	System	Series	Geologic unit		
Mesozoic	Jurassic	Upper Jurassic	Morrison Formation		
			Ellis Group	Swift Formation	
		Middle Jurassic		Rierdon Formation	
				Piper Formation	
			Nesson Formation		
	Triassic		Spearfish Formation		
Paleozoic	Permian		Minnekahta Limestone		
			Opeche Formation		
	Pennsylvanian		Minnelusa Sandstone		
			Tyler Formation		
	Mississippian		Big Snowy Group	Heath Formation	
				Otter Formation	
				Kibbey Sandstone	
			Madison Group	Charles Formation	
				Mission Canyon Limestone	
				Lodgepole Limestone	
	Devonian, Silurian, Ordovician, and Cambrian rocks, undivided		Sedimentary rocks consisting of sandstone, siltstone, shale, limestone, and dolomite		
Precambrian			Crystalline igneous and metamorphic rocks		

Table 2. Approximate quantities of brine injected through brine-injection wells in the East Poplar oil field study area

[Site-numbering system illustrated in figure 4. Abbreviations: bbl/d, barrels per day; gal, gallon; gal/yr, gallons per year; Kjr, Judith River Formation (Upper Cretaceous); Kd, "Dakota Sandstone" (Lower Cretaceous); Mm, Madison Group (Mississippian); Mmc, Mission Canyon Limestone of Madison Group; Ab, abandoned; Ac, active. Symbol: --, no data or not applicable; ?, uncertain]

Site number and well name	Geologic unit receiving injected water	Well depth below land surface (feet)	Site status	Average injection rate of water (bbl/d)	Maximum injection rate of water (bbl/d)	Time interval during which injection occurred	Approximate quantity of brine injected over time interval (millions of gal)		Remarks
							Based on average injection rate	Based on maximum injection rate	
28N51E02ACDB01 Murphy 2-D	Kjr	834	Ab	--	--	01/62 - (?)	--	--	Reported injection test of 2,880 bbl/d of water in 1961; at this rate about 44,150,400 gal/yr would have been injected for an unknown number of years. Abandonment date unknown.
28N51E03BCAC01 Murphy 80-D	Kd	3,575	Ac	2,700	4,500	01/64 - present (12/95)	1,283	2,138	--
28N51E04BCAC01 Murphy 59-D	Kd	3,365	Ab	4,500	6,500	06/61 - 06/86	1,725	2,491	--
28N51E10ABAC01 Huber 4	Mm	6,063	Ab	--	--	10/70 - (?)	--	--	Injection rate and abandonment date unknown.
28N51E10ABAD01 Huber 1-W	Kjr	881	Ab	--	--	10/61 - (?)	--	--	Reported injection rate of 696 bbl/d of water; at this rate about 10,669,700 gal/yr would have been injected for an unknown number of years. Abandonment date unknown.
28N51E10DACA01 Grace 110X-D	Mmc	7,000	Ab	1,827	3,000	10/73 - 05/85	324	533	--
28N51E10DBAD01 Murphy 8-D	Kjr	780(?)	Ac	7,100	8,400	01/73 - present (12/95)	2,395	2,833	--
28N51E22BDBD01 TXO SWD-1	Kjr	850	Ab	--	--	05/81 - 06/84	--	--	Injection rate unknown.
28N51E22CBCB01 Mesa 1-W (Biere 1)	Kjr	998	Ab	--	--	07/70 - 09/84	--	--	Injection rate unknown.
29N50E11CDCA01 Grace (Goings Gov't) SWD-1	Kd	3,825(?)	Ab	--	--	03/77 - 08/90	--	--	Injection rate unknown.
29N50E25DCDB01 Murphy 46	Mm	5,864	Ab	--	--	04/56 - 08/59(?)	--	--	Reported injection rate of 2,302 bbl/d of water; at this rate about 117,515,000 gal total (or 35,290,000 gal/yr) would have been injected.
29N51E07BCDB01 Grace (Buck Elk) 2	Kjr	5,933	Ab	525	1,500	12/67 - 01/86	153	437	Brine reportedly was injected sporadically.
29N51E07BDB 01 Polumbus (Buck Elk) 1-W	Kjr	1,207	Ab	--	--	02/61 - 05/68	--	--	Reported injection rate of 600 bbl/d of water; at this rate about 73,584,000 gal total (or 9,198,000 gal/yr) would have been injected.
29N51E08DCCA01 Murphy (Empire State) Smith 1	Mm	5,982	Ab	--	--	08/60 - (?)	--	--	Injection rate and abandonment date unknown.
29N51E16BAC 01 Murphy (Empire State) Rehder 7	Mm	5,750	Ab	--	--	09/60 - (?)	--	--	Injection rate and abandonment date unknown.
29N51E16DDDB01 Murphy (Owens-Simons) 1	Mm	5,780	Ab	--	--	10/60 - (?)	--	--	Injection rate and abandonment date unknown.
29N51E19DDBA01 Murphy 5-D	Kd	3,583	Ac	3,000	5,000	02/76 - present (12/95)	912	1,520	--
29N51E28CC 01 Murphy 29-D	Kjr	--	Ab	3,225	4,725	04/81(?) - 10/87	321	471	--
29N51E30DDDD01 Murphy 1-D	Kd	3,431	Ac	4,500	7,500	09/57 - present (12/95)	2,639	4,398	--
29N51E33BBAB01 Murphy 6-D	--	--	Ab	--	--	--	--	--	Injection rate and completion and abandonment dates unknown.

MAR02-1339

wells in the Judith River Formation. During 1993, about 6.1 million bbl of brine were disposed of through these four active brine-injection wells (Debi Madison, Fort Peck Tribes, Office of Environmental Protection, oral commun., 1994).

Historical data about the approximate quantities of brine injected through brine-injection wells were obtained from EPA and BLM well records, and are shown in table 2; the locations of known active and abandoned injection wells are shown on plate 3. Since brine injection began in the mid-1950's, reported average-daily injection rates for individual injection wells have ranged from 525 to 7,100 bbl/d of water (22,050-298,200 gal/d); reported maximum-daily injection rates have a range of 1,500-8,400 bbl/d (63,000-352,800 gal/d) of water (table 2). For most wells, the time interval for injection along with the approximate quantities of brine injected also are shown in table 2. Smaller, unknown quantities of brine have been directed into storage and evaporation pits (Levings, 1984). According to BLM records, minor attempts have been made to reinject brine into oil-producing zones for secondary recovery, but at present (1996) no such activity is occurring.

Murphy Oil USA, Inc. currently operates most of the wells in and near the East Poplar oil field, although various oil companies have been involved in past production activities. These companies include Ajax Oil Co., Amarco Resource Corp., Ashland Oil Inc., Carter Oil Co., Empire State Oil Co., Grace Petroleum Corp., Humble Oil and Refining Co., Juniper Petroleum Corp., MAPCO Production Co., Mesa Petroleum Co., Natol Petroleum Corp., Phillips Petroleum Corp., Richfield Oil Co., States Oil Co., Tenneco Oil Co., Texas Oil and Gas, and Union Oil Co. of California.

Previous Investigations

Several geologic investigations have been conducted in the vicinity of the study area, mainly because the East Poplar oil field lies at the western edge of the energy-rich Williston Basin. Listing all these investigations is beyond the scope of this report. However, some of the major reports on geologic structure, stratigraphy, and hydrogeology are cited in this section; other references are cited throughout the text and listed in the "Selected References" section.

In an early geologic investigation, Collier (1918) discussed the geology of northeastern Montana. The glacial geology of eastern Montana area was described by Alden (1932) and Howard (1960). The surface geology of the study area vicinity was mapped at a scale of 1:62,500 by Colton (1963a,b). Stratigraphic correlation charts of geologic formations that underlie the general vicinity of the study area were prepared by Rice (1976a) and Balster (1980). Stratigraphic studies include reports by Towse (1954), Gill and Cobban (1973), Rice (1976b), and Monson (1989). Geologic structure of the general area was identified by Jensen (1951), Dobbin and Erdmann (1955), and Colton and Bateman (1956). In a series of subsurface geologic maps, Feltis (1982a-i) published information for the altitudes of the tops and the thicknesses of major Cretaceous and Jurassic formations.

Several hydrogeologic investigations in the vicinity of the study area also have been conducted. Swenson (1955) discussed the geology and ground-water resources of the Missouri River valley in northeastern Montana. Feltis (1979) reported on shallow ground-water conditions in the upper part of the Poplar River basin. Levings (1982a,b) presented potentiometric-surface maps of water in major Cretaceous formations in the general vicinity of the study area. Donovan and Bergantino (1987) reported on ground-water resources of the Fort Peck Indian Reservation, emphasizing water in the preglacial Missouri River valley, and Donovan (1988) reported on the high-yield aquifers of northeastern Montana.

Specifically relating to the current study area, Levings (1984) conducted a reconnaissance investigation of saline-water contamination in alluvial deposits along a short reach of the Poplar River in the East Poplar oil field. The general hydrogeology of the Fort Peck Indian Reservation was discussed by Thamke (1991), and Thamke and Craigg (1993). Preliminary interpretations of saline-water contamination in the study area were given by Craigg and Thamke (1992, 1993, 1995), Mendes and others (1992), and Thamke and others (1992, 1993). Thamke and others (1996) published hydrologic data collected during this investigation.

Methods of Investigation

The investigation of saline-water contamination included a comprehensive review of existing data and extensive collection of additional field data. Existing data for water wells, monitoring wells, oil wells, brine-injection wells, and ground- and surface-water quality were obtained from various sources, including the

MAR02-1340

USGS, BLM, EPA, BIA, U.S. Public Health Service and Indian Health Service, Fort Peck Tribes (Water Resources Office, Minerals Office, and Office of Environmental Protection), Murphy Oil USA, Inc., and MBMG. Detailed information about the types of data obtained from these sources was presented in Thamke and others (1996).

As an initial step in this investigation, existing water wells were inventoried for physical parameters and water from privately owned wells in the study area was sampled and analyzed for chemical quality. To further delineate the lateral extent of potential saline-water contamination, an electromagnetic geophysical survey was conducted over an area of about 22 mi^2. Monitoring wells subsequently were installed and sampled in selected areas of high conductivity to confirm the existence of the saline-water plumes delineated by the geophysical methods. Selected monitoring wells also were used for aquifer testing to determine aquifer characteristics, which indicate the rate of ground-water flow. Streamflow and water quality of the Poplar River were measured to determine areas of saline-water discharge and effects on the river. These data and the methods used to collect them are discussed in detail in Thamke and others (1996); where appropriate, additional discussion is given in this report. Data from the well inventory, electromagnetic geophysical survey, monitoring-well installation, aquifer testing, streamflow measurements, and water-quality sampling were used to interpret the extent, magnitude, and movement of saline-water contamination in Quaternary deposits.

Site-Identification Systems

A site number is used as the primary identification for wells. This site number is based on the rectangular system for the subdivision of public lands (fig. 4); the number consists of as many as 14 characters and is assigned according to the location of a site within a given township, range, and section. The first three characters specify the township and its position north (N) of the Montana Base Line, whereas the next three characters specify the range and its position east (E) of the Montana Principal Meridian. The next two characters indicate the section; the next four characters indicate the position of the site within the section. The first letter denotes the quarter section (160-acre tract); the second letter denotes the quarter-quarter section (40-acre tract); the third letter denotes the quarter-quarter-

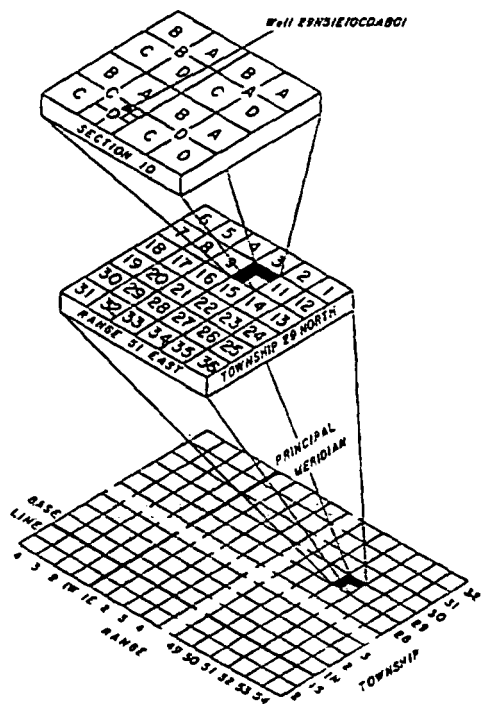


Figure 4. Site-numbering system for wells.

MAR02-1341

quarter section (10-acre tract); and the fourth letter denotes the quarter-quarter-quarter-quarter section (2.5-acre tract). These lettered subdivisions of the section are indicated as A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The last two characters form a sequence number based on the order that a site was inventoried in that tract. For example, site number 29N51E10CDAB01 represents the first well inventoried in the NW1/4 NE1/4 SE1/4 SW1/4 sec. 10, T. 29 N., R. 51 E.

Wells also are identified by an alpha-numeric well name, allowing for ease of cross reference between wells plotted on illustrations in this report and on relevant illustrations and tables given in Thamke and others (1996). The well name consists of as many as three alpha characters and as many as four numeric characters and an alpha character to designate the sequence during which wells were drilled. The alpha character denotes the well type: (FPB)--USGS monitoring well installed during this investigation; (W)--USGS monitoring well or privately owned well inventoried by Levings (1984); and (M)--privately owned well or MBMG observation well. The numeric characters for USGS-installed monitoring wells denote the sequence during which wells were drilled; for example, well FPB93-3 is the third well drilled in 1993 during this investigation. The numeric part of well names identified by the letter "M" is assigned only as a convenient cross reference between relevant illustrations and tables. Brine-injection wells and sampled oil wells are identified using the name assigned by the particular oil company; for example, Murphy 1-D is a brine-injection well, and Murphy 58 is an oil well.

Streamflow measurement sites along the Poplar River are identified by an alpha-numeric system. The alpha-numeric part of the site number follows the system used by Levings (1984) and is based on the downstream order of measurement, beginning with the farthest upstream site (PR-0) and ending with the farthest downstream site (PR-9) in the study area. One measurement site (PR-8) was located at a long-term USGS streamflow-gaging station (06181000), and one measurement site (PR-1) was located at a USGS miscellaneous streamflow-measurement station (06180600).

Acknowledgments

The authors thank the Fort Peck Tribes for their support extended to the USGS throughout this investigation. Special appreciation is given to the Water Resources Office and the Office of Environmental Protection of the Fort Peck Tribes for supplying data about existing domestic wells. We also wish to thank individual landowners in the reservation for their cooperation in allowing access to their lands for inventorying, sampling, or drilling wells and collecting electromagnetic-geophysical data, and for their valuable contributions of historical information about oil-field operations as well as the occurrence and use of water resources in the study area. Mr. O.A. (Bud) Lien, a private landowner in the reservation, deserves special thanks for allowing the use of his large garages for the storage of various drilling and well-completion materials, and for allowing parking of drill rigs, trailers, air compressors, and grouters. We also wish to thank the Lockman and Trottier families for their support extended during field operations. Thomas M. Mendes deserves special mention for the collection of electromagnetic-geophysical and water-level data and assisting in the preliminary interpretation of the data while employed with the USGS during summer 1991 and 1992. The authors also appreciate the technical advice provided by the employees of Geonics, Ltd.

GEOLOGIC SETTING

Regionally, the study area is located near the western edge of the Williston Basin, a broad, northwest-trending structural depression in eastern Montana, western North Dakota, northwestern South Dakota, southwestern Manitoba, and southeastern Saskatchewan. The Williston Basin (fig. 5), one of the largest structural basins in North America, is about 500 mi long and 300 mi wide, and encompasses an area of about 134,000 mi^2 (Hamke and others, 1966, p. 5). The basin also is one of the oldest structural basins in North America; it was subsiding and affecting sedimentation patterns throughout most of Paleozoic and early Mesozoic time. The basin ceased subsiding and exerting control on sedimentation by Cretaceous time (Rice and Shurr, 1978, p. 267). Present structural configuration and structural features of the Williston Basin (domes, anticlines, synclines) are a result of the Laramide Orogeny, during latest Cretaceous and early Paleocene time (Hamke and others, 1966; p. 24; Rice and Shurr, 1978, p. 267).

The study area lies atop the Poplar Dome (also referred to as the Poplar Anticline). The dome trends northwest and is about 30 mi long and 25 mi wide. As

MAR02-1342

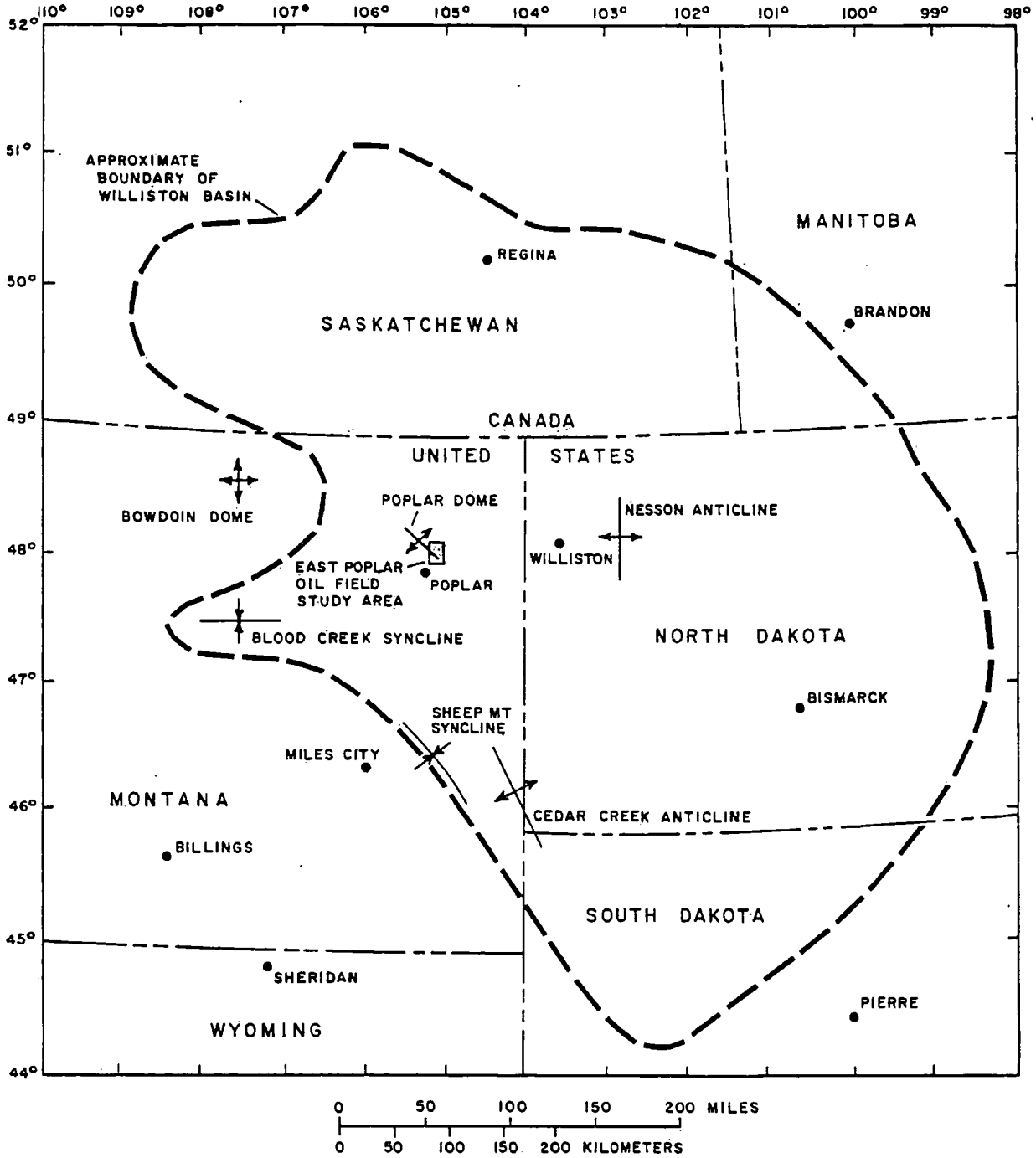


Figure 5. Location of Williston Basin, major structural features, and East Poplar oil field study area (modified from Hamke and others, 1966, fig. 1).

reported by Hamke and others (1966, p. 24), the dome consists of a principal domal structure with a structural closure of about 300 ft, and a smaller subsidiary dome with a structural closure of about 100 ft. When superimposed on the broad, regional structure of the Poplar Dome, the structural framework of the smaller East Poplar oil field study area is not complex. Geologic units essentially are flat-lying and no faults have been mapped (Colton and Bateman, 1956; Colton, 1963a,b).

Geologic units underlying the East Poplar oil field study area range in age from Precambrian through Cenozoic. Precambrian units consist solely of crystalline igneous and metamorphic rocks. Paleozoic through Cenozoic units consist of various sedimentary units; combined thickness of this sedimentary section probably is about 10,000 ft. The vertical distribution of these units is shown in table 1; detailed basin-wide geologic descriptions of these units were given by Hamke and others (1966). The principal geologic units that are exposed in the study area are the Upper Cretaceous Bearpaw Shale, Hell Creek Formation, and Fox Hills Sandstone; Tertiary Flaxville and Fort Union Forma-

MAR02-1343

tions; Quaternary glacial and related deposits; and Quaternary alluvial deposits.

Colton (1963a,b) mapped and described the geologic units exposed in the vicinity of the study area. The surface geology of the study area is shown in figure 6 (pl. 1). Detailed discussion of all geologic units is beyond the scope of this report; however, units that are most relevant for the purposes of this investigation are described in general terms below.

Mississippian Madison Group

The Madison Group consists of three formations deposited in marine environments. These are the Lodgepole Limestone, Mission Canyon Limestone, and Charles Formation (table 1). The Charles Formation is the major oil-producing unit of the East Poplar oil field (Brunson, 1985, p. 889), although minor zones in the Devonian Nisku Formation and the Mississippian Kibbey and Heath Formations also produce oil.

The Lodgepole Limestone was described by Hamke and others (1966, p. 16) as a generally brown to gray, dense, argillaceous, shaley, cherty limestone. Thickness of the Lodgepole, determined from the oil-well log of East Poplar oil field discovery well (Murphy 1, located in sec. 2, T. 28 N., R. 51 E.) is about 570 ft.

The Mission Canyon Limestone was described by Hamke and others (1966, p. 16) as a yellowish-gray and yellowish-brown, dense, massive limestone. Thickness of the Mission Canyon in the discovery well is about 760 ft.

The Charles Formation was described by Hamke and others (1966, p. 16-17) as principally an evaporitic unit, consisting mainly of massive salt beds, anhydrite, and limestone. Thickness of the Charles in the discovery well is about 400 ft.

Cretaceous Rocks

The vertical distribution of Cretaceous rocks in the study area is shown in table 1. The combined thickness of all Cretaceous units in the oil-field discovery well is about 3,500 ft. The Cretaceous rocks most relevant to this investigation are the Lakota Formation and Fall River Sandstone-"Dakota Sandstone", Judith River Formation, and Bearpaw Shale. General characteristics of these units are given below; Donovan (1988) gave concise descriptions of other Cretaceous rocks.

Lakota Formation–Fall River Sandstone–"Dakota Sandstone"

The Lower Cretaceous Lakota Formation generally consists of nonmarine, cross-bedded, coarse-grained sandstone that is conglomeratic in the basal part; reported maximum thickness is 110 ft, as described by Hamke and others (1966, p. 21). The reported thickness of the Lakota in the study area is between about 70 and 200 ft.

The Lower Cretaceous Fall River Sandstone (of the Colorado Group) in the Williston Basin consists of as much as 210 ft of fine-grained quartzose sandstone (Hamke and others, 1966, p. 21). The Fall River Sandstone of the Williston Basin occupies the same interval as the "Dakota Sandstone" of adjacent areas (see Balster, 1980). Although the USGS and the MBMG do not use the term "Dakota Sandstone" (Lower Cretaceous) in the Williston Basin (W.A. Bryant, U.S. Geological Survey, Denver, Colo., oral commun., 1994; Donovan, 1988, p. 18; and Bergantino, 1994), Ballard and others (1983) use the Dakota (Lower Cretaceous) terminology.

The Lakota Formation interval, as well as other parts of the Lower Cretaceous section (Fall River Sandstone and possibly parts of the Fuson Shale or its equivalent in the north-central Montana plains, the Kootenai Formation), have been referred to as "Dakota Sandstone" by drillers and oil-field geologists as well. In addition, the informal terms "Dakota silt" or "basal Colorado silt" have been applied to the interval above the Fall River Sandstone (essentially the interval occupied by the lower parts of the Skull Creek Shale in the Williston Basin). Use of this terminology has resulted in some confusion when referring to this stratigraphic interval, because at least four brine-injection wells are reported to have been completed in the "Dakota Sandstone" (Thamke and others, 1996, table 2). Depending on the nomenclature used, these four injection wells could have been completed in either the Fall River Sandstone, the "Dakota Sandstone," or the Lakota Formation. Therefore, to avoid further confusion and to follow the historical usage in the East Poplar oil field, the term "Dakota Sandstone" will be used in this report when referring to brine-injection wells completed in Lower Cretaceous rocks. Examination of oil-well logs in the East Poplar oil field indicate that most distances between the top of the unit picked as "Dakota Sandstone" and the top of the Upper Jurassic Morrison Formation are between about 350 and 400 ft. This

MAR02-1344

"thickness," however, includes any intervening Lower Cretaceous rocks.

Judith River Formation

The Upper Cretaceous Judith River Formation (of the Montana Group) consists of a sequence of interbedded, light-colored sandstone and sandy shale (Hamke and others, 1966, p. 22). Water in the Judith River Formation occurs under confined (artesian) conditions, according to BLM well records for well 29N51E19DCAC01. Thickness of the Judith River beneath the study area is about 100 ft; depth from land surface to the top of the formation, on the basis of oil-well logs in the study area, ranges from about 700 to 1,000 ft. The Judith River Formation has been a major unit for disposal of oil-field brine by subsurface injection in the past, but since 1985 no new brine-injection wells have been allowed to be completed in the formation; currently, only one brine-injection well completed in the formation in the oil field is active (Thamke and others, 1996, table 2). Minor production of natural gas also has been obtained from the Judith River Formation; this gas is used for operational purposes in the East Poplar oil field (Brunson, 1985, p. 890; Monson, 1989).

Bearpaw Shale

The Upper Cretaceous Bearpaw Shale (of the Montana Group) conformably overlies the Judith River Formation. The Bearpaw consists mainly of dark-gray marine shale and claystone. Bentonite is present as thin beds and also is disseminated throughout some shale zones; the upper part of the formation contains some beds of sandy shale (Colton, 1963a,b; Hamke and others, 1966, p. 22). Colton and Bateman (1956) also reported that the Bearpaw contains ironstone nodules and hard ellipsoidal concretions; many concretions may contain marine fossils. Minor fractures are present in the upper, eroded surface of the Bearpaw, as noted during field observations. On the basis of oil-well records in the study area, the approximate range of thickness of the Bearpaw Shale is about 700-1,000 ft. The depth to the top of the Bearpaw ranges from zero in outcrop areas to 120 ft (Colton, 1963a,b). The approximate subsurface altitude and configuration of the top of the Bearpaw are shown in figure 7 (pl. 1); the subsurface top of the formation lies between about 1,930 ft and 2,120 ft above sea level. The top surface of the Bearpaw east of the Poplar River appears to slope gently towards the west; the apparent trough beneath the Poplar River valley probably represents stream erosion concurrent with deposition of alluvium, rather than a geologic structure.

The Bearpaw Shale crops out mainly along low hills west of the Poplar River (fig. 6, 7); only about the upper 120 ft of the Bearpaw is exposed in the study area. Tertiary units in the study area are present in minor locations only in the northern part of the study area and are not relevant in this investigation; hence, these units are not discussed in this text. Throughout the rest of the study area, Quaternary deposits unconformably directly overlie the Bearpaw Shale. On the basis of lithologic descriptions from USGS monitoring wells, the depth to the top of the Bearpaw Shale in the study area has a range of about 22-55 ft (FPB92-14 and W-11, respectively) beneath alluvial deposits of the Poplar River valley, and about 56-99 ft (FPB93-3 and FPB93-5, respectively) beneath glacial deposits east of the river (Levings, 1984, table 3; Thamke and others, 1996, table 3).

Quaternary Deposits

Quaternary units in the study area include Wiota Gravel, Sprole Silt, glacial till, fan alluvium and colluvium, and alluvium (fig. 6). Minor thicknesses and extents of glacial outwash, lake deposits, and dune sand also are present, but are not discussed separately in this report (dune sand, however, is shown in fig. 6, the geologic map).

Pleistocene Wiota Gravel (shown as Qw in fig. 6) consists of unconsolidated deposits of clay, silt, and quartzitic sand and gravel. Thickness in the study area is uncertain, but Colton (1963a,b) reported a maximum thickness of 55 ft to the south of the study area.

Pleistocene Sprole Silt (shown as Qs in fig. 6) overlies the Wiota Gravel and consists of poorly bedded to massive deposits of silt. Colton (1963a,b) reported a maximum thickness of 100 ft for the Sprole Silt to the south of the study area.

Pleistocene glacial till (shown as Qt in fig. 6) is a complex, unstratified, and heterogeneous admixture of clay, silt, sand, gravel, and boulders deposited by glaciers. Colton (1963a,b) reported that thickness generally is about 15 ft, but locally may be as much as 250 ft. In the study area, till is present mainly beneath the topographic bench east of the Poplar River (fig. 6).

MAR02-1345

Pleistocene and Holocene fan alluvium and colluvium (shown as Qac in fig. 6) underlies flood plains and consists of slope-wash deposits derived from topographically higher deposits; lithologically the slope-wash deposits are similar to Holocene alluvium (described below). These deposits are not vertically extensive; Colton (1963a,b) reported that the maximum thickness is 20 ft. Laterally, however, these deposits can be more than 1 mi wide, although the average width is much smaller (fig. 6).

Holocene alluvium (shown as Qal in fig. 6) consists of stream-deposited clay, silt, sand, and gravel. The sand and gravel deposits typically occur as lenses of varying thickness. Detailed lithologic descriptions for 19 USGS monitoring wells completed in alluvium along the Poplar River are given in Thamke and others (1996, table 3).

For the purposes of this report, Pleistocene Wiota Gravel, Sprole Silt, glacial till, and dune sand are undifferentiated and are referred to as "glacial deposits"; Pleistocene and Holocene fan alluvium and colluvium and Holocene alluvium are undifferentiated and referred to as "alluvium." Lithologic logs from eight USGS monitoring wells drilled during this investigation indicate that the combined thickness of glacial deposits in the study area ranges from at least 56 to about 100 ft (Thamke and others, 1996, table 3). The combined thickness of alluvium ranges from 22 to 56 ft throughout the Poplar River valley (Thamke and others, 1996, table 3). Colton (1963a,b) reported that, in the vicinity of the study area, thickness of these deposits averages about 50 ft; Levings (1984, table 3) gave a range in thickness of 43-54 ft. Lithologic logs from monitoring wells drilled during this investigation indicate that, in most places, alluvium ranges in thickness from about 32 to 52 ft; a thickness of 22 ft, reported in USGS monitoring well FPB92-14 (located in NE1/4 SE1/4 NW1/4 NE1/4 sec. 21, T. 29 N., R. 51 W.), indicates a local subsurface high of the Bearpaw Shale (Thamke and others, 1996, table 3).

GENERAL HYDROGEOLOGY OF QUATERNARY DEPOSITS

The Quaternary deposits are the sole developed source of ground water for residents of the study area. In general, wells completed in Quaternary deposits provide sufficient yields and, in uncontaminated areas, potable water for domestic purposes. Few wells are completed below the Quaternary deposits because of the lack of water in the underlying Upper Cretaceous Bearpaw Shale which is 700-1,000 ft thick.

Ground-Water Occurrence and Movement

Water in Quaternary deposits occurs mainly under unconfined (water-table) conditions, although locally, conditions are semiconfined due to the heterogeneity of clays, silts, sands, and gravels. Depth to water below land surface in the study area generally ranges from about 5 to 44 ft in alluvium and about 7 to 130 ft in glacial deposits (Thamke and others, 1996, table 1). Fresh water in the Quaternary deposits in the study area is recharged by infiltration of precipitation, streamflow, and fresh water movement from upgradient areas. Water in the Quaternary deposits is discharged by streamflow, evapotranspiration, springs, and water withdrawals. Generalized potentiometric surface and direction of ground-water movement in Quaternary deposits are shown in figure 6 (pl. 1). The altitude of static water level in 1990-93 ranged from about 1,950 to 2,060 ft above sea level (Thamke and others, 1996, table 1). Water in Quaternary deposits east of the Poplar River generally moves westward toward the river where it merges with southward-flowing ground water in the Poplar River valley. Downward movement of water from Quaternary deposits into the underlying Bearpaw Shale probably is not significant because of the relatively impermeable nature of the Bearpaw; downward movement of water from Quaternary deposits into the Bearpaw probably occurs only locally to shallow depths, where minor fractures are present in the upper, eroded surface of the Bearpaw.

Hydraulic Characteristics

Two constant-discharge aquifer tests were conducted during August 1993 to determine general hydraulic characteristics of the Quaternary deposits. Because of the various deposits of clay, silt, sand, and gravel throughout the study area, the hydraulic characteristics may differ locally; hence, ranges are given for the selected hydraulic characteristics.

A constant-discharge aquifer test was conducted on August 18, 1993, in alluvium along the Poplar River, using one pumped well and three observation wells (NW1/4 NE 1/4 sec. 09, T. 29 N., R. 51 E. in Thamke and others, 1996, tables 1, 3, and 4; pl. 1). The general geology of the site consists of Holocene alluvium that unconformably overlies the Bearpaw Shale.

MAR02-1346

On the basis of lithologic logs of the USGS-installed wells used for the test (FPB92-15, FPB92-16, FPB92-17, and FPB93-1; Thamke and others, 1996, table 3), these deposits consist of interbedded sand of various grain sizes, gravelly sand, and gravel and cobbles; total thickness of the sequence ranges from about 37 to 42 ft. Because topographic relief at the test site is about 0.2 ft, the range in thickness indicates that the surface of the Bearpaw Shale is slightly irregular.

The other constant-discharge aquifer test was conducted on August 19, 1993, in glacial deposits east of the Poplar River, using one pumped well, two observation wells (SE1/4 SE1/4 sec. 33, T. 28 N., R. 51 E. in Thamke and others, 1996, tables 1, 3, and 5; pl. 1). The general geology of the site consists of Pleistocene glacial deposits that unconformably overlie the Bearpaw Shale. On the basis of lithologic logs of the USGS-installed wells used for the test (FPB93-4A, FPB93-4B, and FPB93-4C; Thamke and others, 1996, table 3), these deposits consist of interbedded and unconsolidated clay, silt, sand, and gravel of various sizes, with about 13-20 ft of gravel (Wiota Gravel) consistently present at the base; total thickness of the sequence of deposits is about 60 ft.

The aquifer-test data at the alluvium test site were analyzed using standard curve-matching procedures for unconfined aquifers (delayed gravity-response type curves) of Neuman (1972, 1975). The data plots for this site clearly indicate delayed yield from storage. At the alluvium test site, the mean transmissivity value computed for the three observation wells is 1,900 ft^2/d and the mean hydraulic conductivity value is 63 ft/d. The hydraulic conductivity value is based on a horizontal hydraulic gradient of one; the hydraulic gradient at this site is probably much smaller than one. These values are reasonable for an unconfined sand and gravel aquifer. The aquifer-test data at the glacial deposits test site were analyzed using Theis (1935) methods as described in Lohman (1972). At the glacial deposits test site, the value computed for transmissivity was 3,100 ft^2/d; the computed hydraulic conductivity at this site was 165 ft/d. The hydraulic conductivity value is based on a horizontal hydraulic gradient of one; the hydraulic gradient at this site is probably much smaller than one.

The computed values for storage coefficient are 0.001-0.004 at the site of the alluvium and 0.003-0.01 at the site of the glacial deposits and are anomalously small for an unconfined aquifer. Lohman (1972, p. 40) suggested that the reason for this type of anomaly is that in shorter term aquifer tests of unconfined aquifers, where early time data are used for analysis, "it (storage coefficient) is only an apparent value observed before gravity drainage (is) completed." Therefore, published values of storage coefficient averaging 0.21-0.27 for sand and 0.22-0.25 for gravels are considered to be more reliable than those computed for this study; for example, see Johnson (1967, p. D70).

Ground-Water Quality

The quality of water in Quaternary deposits in the study area is highly variable and is dependent on location relative to sources of contamination. Dissolved solids, reported in milligrams per liter, is the sum of all dissolved constituents in the water and is predominantly composed of the major ions in solution. Sodium, bicarbonate, and chloride are the dominant ions in water from most wells completed in the Quaternary deposits. Of these dominant ions, only chloride generally exhibits a conservative behavior and generally is present in natural water at low concentrations (Hem, 1985). Therefore, concentrations of dissolved solids and chloride ions are used in this investigation to classify types of ground water.

The EPA has established regulations and standards for public drinking-water supplies. These regulations and standards are not used to regulate the quality of water produced from individual privately owned wells, but to serve as guidelines with which to evaluate the water quality. Primary Drinking-Water Regulations[1] are not established for dissolved solids and chloride. However, Secondary Drinking-Water Standards[2] specify SMCL's of 500 mg/L for dissolved solids and 250 mg/L for chloride. Dissolved-solids concentrations in water sampled during 1989-93 from

[1]National Primary Drinking-Water Regulations are established for contaminants which, if present in drinking water, may cause adverse human health effects. Either a Maximum Contaminant Level (MCL) or a treatment technique is specified by these regulations for regulated contaminants. MCL's are health-based and enforceable (U.S. Environmental Protection Agency, 1996).

[2]Secondary Drinking-Water Standards are established for contaminants that can adversely affect the taste, odor, or appearance of water and result in discontinuation of use of the water. These regulations specify Secondary Maximum Contaminant Levels (SMCL), which are esthetically based and nonenforceable (U.S. Environmental Protection Agency, 1996).

MAR02-1347

wells completed in the Quaternary deposits ranged from 427 to 91,100 mg/L; 26 of the 27 privately owned wells contained water with dissolved-solids concentrations that exceed the SMCL (Thamke and others, 1996, table 6). Chloride concentrations in water sampled during 1989-93 from wells completed in the Quaternary deposits ranged from 7.3 to 58,000 mg/L; 15 of the 27 privately owned wells contained water with chloride concentrations that exceed the SMCL (Thamke and others, 1996, table 6).

On the basis of dominant ions and dissolved-solids concentration, Levings (1984) identified three principal water-quality types from alluvium in the Poplar River valley; a fourth water-quality type, representing the actual brine produced with the crude oil, also was identified. Distinguishing characteristics of the four water types are: Type 1 water is not dominated by the chloride anion and dissolved-solids and chloride concentrations are similar to water in Quaternary deposits in other parts of the reservation; Type 2 water is dominated by the chloride anion and the chloride concentration range typically is 330-4,800 mg/L; Type 3 water is dominated by the chloride anion and the chloride concentration is typically greater than 5,200 mg/L; Type 4 water is actual samples from brine-injection wells. These general water types have been defined in greater detail for this investigation and provide a useful classification to describe water-quality variability within the current study area. Water-quality diagrams (Stiff, 1951) illustrate these representative water-quality types (fig. 8, pl. 1). The water-quality diagrams represent unit concentrations of the major ions, in milliequivalents per liter. Unit concentrations take into account both mass and ionic charge and, therefore, the total milliequivalents per liter of cations (left side of graph) should equal that of the anions (right side of graph). The range in unit concentration of the major ions in water from the wells is too large to use the same scale for all diagrams; therefore, a different scale is used for each of the four water types in figure 8. The characteristics of these four water types are listed in table 3.

Type 1 water from wells completed in the Quaternary deposits is located mostly in the northern and southern thirds of the study area and represents the uncontaminated water quality (fig. 8). The chemical composition of Type 1 water ranges from a sodium bicarbonate to a sodium sulfate, with a few instances of magnesium sulfate, magnesium bicarbonate, or calcium bicarbonate chemical compositions. The dissolved-solids and chloride concentrations of Type 1 water range from 427 to 2,680 mg/L and 7.3 to 260 mg/L, respectively (Thamke and others, 1996, table 6; table 3 in this report). Privately owned wells completed in the Quaternary deposits with Type 1 water are used for drinking-water supply.

Type 2 water from wells completed in the Quaternary deposits is located in various parts of the study area and represents natural ground water that has been moderately contaminated by brine (fig. 8). The chemical composition of Type 2 water is sodium chloride. The dissolved-solids and chloride concentrations of Type 2 water range from 1,170 to 8,860 mg/L and 330 to 4,800 mg/L, respectively (Thamke and others, 1996, table 6; table 3 in this report). Privately owned wells completed in Quaternary deposits containing Type 2 water generally are not used for drinking-water purposes, because the large dissolved-solids and chloride concentrations make the water unpalatable.

Type 3 water from wells completed in the Quaternary deposits is located in two locations—one near the center and one near the southwest quarter of the study area. Type 3 water represents ground water that has been considerably contaminated by brine. The chemical composition of Type 3 water principally is sodium chloride with a few cases of magnesium chloride. The dissolved-solids and chloride concentrations in Type 3 are much larger than Type 2 water, ranging from 10,100 to 91,100 mg/L and 5,200 to 58,000 mg/L, respectively (Thamke and others, 1996, table 6). Privately owned wells completed in Quaternary deposits containing Type 3 water were used in the past for domestic purposes, but are now unused for any domestic purpose.

Type 4 water, which is very similar to Type 3 water, represents the actual brine that is disposed into brine-injection wells. The chemical composition of Type 4 water is sodium chloride. The dissolved-solids and chloride concentrations in brine range from 47,700 to 201,000 mg/L and 27,000 to 120,000 mg/L, respectively (Thamke and others, 1996, table 6).

Electromagnetic Apparent Conductivity

Electromagnetic geophysical methods can be used to measure the cumulative electrical conductivity of the soil and water matrix. The unit of conductivity for these methods is millimho per meter (mmho/m).

MAR02-1348

Table 3. Characteristics of water types and correlation of electromagnetic apparent conductivity used to delineate saline-water plumes in Quaternary deposits in the East Poplar oil field study area

[Abbreviations: Cl, chloride; HCO_3, bicarbonate; Mg, magnesium; Na, sodium; SO_4, sulfate; mg/L, milligrams per liter; mmho/m, millimho per meter; mi^2, square miles; N/A, not applicable; 10V, 10-meter, vertical-dipole orientation; 20H, 20-meter, horizontal-dipole orientation; 20V, 20-meter, vertical-dipole orientation; 40H, 40-meter, horizontal-dipole orientation. Symbols: ≥, greater than or equal to; <, less than]

Water type	Water use	Major ions	Dissolved-solids concentration range (mg/L)	Chloride concentration range (mg/L)	Electromagnetic apparent conductivity in Area 1 (fig. 11 and 12, pl. 2)	Electromagnetic apparent conductivity in Area 2 (fig. 13 and 14, pl. 2)	Subarea designation (fig. 16, pl. 1)	Saline-water plume type (pl. 3)	Areal extent within geophysical survey (mi^2)
Type 1–Uncontaminated	Suitable for most domestic purposes.	Na-HCO_3, Na-SO_4, Mg-SO_4, Mg-HCO_3, Ca-HCO_3	427-2,680	7.3-260	< 40 mmho/m (10V) or < 60 mmho/m (20H)	< 40 mmho/m (20V) or < 60 mmho/m (40H)	Subarea 1–low electromagnetic apparent conductivity	N/A	9.2
Type 2–Moderately contaminated ground water	Suitable for some domestic purposes; generally not used for drinking water.	Na-Cl	1,170-8,860	330-4,800	≥ 40 mmho/m (10V) and ≥ 60 mmho/m (20H); exclusive of subarea 3	≥ 40 mmho/m (20V) and ≥ 60 mmho/m (40H); exclusive of subarea 3	Subarea 2–moderate electromagnetic apparent conductivity	Type 2	7.6
Type 3–Considerably contaminated ground water	Unsuitable for any domestic purpose.	Na-Cl Mg-Cl	10,100-91,100	5,200-58,000	≥ 50 mmho/m (10V) and ≥ 70 mmho/m (20H)	≥ 50 mmho/m (20V) and ≥ 70 mmho/m (40H)	Subarea 3–high electromagnetic apparent conductivity	Type 3	5.0
Type 4–Brine (from oil production)	N/A	Na-Cl	47,700-201,000	27,000-120,000	N/A	N/A	N/A	N/A	N/A

MAR02-1349

The conductivity is affected by clay content and mineralogy, moisture saturation with depth, moisture salinity, and moisture temperature (McNeill, 1980a). Cultural features, such as metal fences, power lines, buried cables, wells, pipelines, and other conductive structures, also may affect conductivity readings. The conductivity is controlled more by porosity, water content, and water quality than by the conductivities of the rock matrix (Zohdy and others, 1974). Conductivity values are low for water with small concentrations of dissolved ions (small dissolved-solids concentrations) and conductivity can substantially increase for water with large concentrations of dissolved solids, because the ions in solution conduct the electrical current. For example, an aquifer containing saline water will have higher conductivities than if the same aquifer contained fresh water. Dissolved-solids concentrations of water sampled during 1989-93 from wells completed in Quaternary deposits in this study area range from 427 to 91,100 mg/L.

Electromagnetic geophysical methods have been used for geologic mapping, mapping the distribution of contaminants in ground water, identifying salinity levels in ground water, delineating areas of coastal saline-water intrusion, and mapping soil salinity. Many studies have successfully used electromagnetic geophysical methods to delineate areas where ground-water quality differs appreciably across the study area. For example, Grady and Haeni (1984) used electromagnetic geophysical methods to determine the extent of ground-water contamination at a municipal solid-waste landfill in Connecticut. Jansen and others (1992) also used these methods to locate areas of heavy-metal sludge disposal. In addition, saline-water migration in ground water was delineated using these methods in Kentucky by Lyverse and Unthank (1988), and in northeastern Montana by Reiten (1991). The success of these studies, in addition to the wide range of dissolved-solids concentrations sampled from wells completed in the Quaternary deposits in the East Poplar oil field study area, indicated that electromagnetic geophysical techniques would be useful in delineating large areas of saline-water contamination during this investigation.

The electromagnetic geophysical equipment used in this investigation consisted of electronic consoles, a transmitter coil, and a receiver coil all connected by a reference cable (fig. 9). The transmitter coil is energized with an alternating current at an audio frequency and placed on the land surface with the receiver coil located a short distance (10, 20, or 40 m) away. The alternating current passes through the transmitter coil, in the orientation of the dipole (which is perpendicular to the plane of the coil), and generates a primary magnetic field that penetrates the earth. This primary magnetic field induces a small current in the earth, which generates a secondary magnetic field out of phase with the first. The secondary magnetic field is a function of the intercoil spacing, the dipole orientation, the operating frequency, and the ground conductivity (McNeill, 1980b). The receiver coil senses both the primary and secondary magnetic fields and the measurement indicated by the instrument is the electromagnetic apparent conductivity. The intercoil spacing can be 10, 20, or 40 m. The two coils can be oriented with horizontal dipoles (coils up on edge and coplanar) or with vertical dipoles (coils flat on ground and coplanar). Figure 9 illustrates the instrument in the horizontal-dipole orientation.

The approximate effective depth of exploration for the horizontal-dipole orientation typically is 75 percent of the intercoil spacing distance. The approximate effective depth of exploration for the vertical-dipole orientation is 150 percent of the intercoil spacing distance (McNeill, 1980b, p. 6). The approximate effective depths of exploration at the three intercoil spacings for both dipole orientations are listed in table 4. The horizontal-dipole orientation is relatively sensitive to variations in the near-surface material (such as fences, power lines, buried metal), whereas the vertical-dipole orientation is relatively sensitive to vertical conductors (such as well casing).

Before conducting the electromagnetic geophysical survey, water from existing wells was sampled to determine salinity concentration of ground water in specific parts of the aquifer. General areas of saline water were delineated on the basis of the well data; this general delineation served as a guide for areas in which to conduct the electromagnetic geophysical survey. Electromagnetic apparent conductivity was measured in both known uncontaminated and known contaminated areas to ensure that the instruments could distinguish saline plumes. The development of the electromagnetic geophysical survey method and calibration techniques for the equipment were explained in Thamke and others (1996).

Measurement stations were spaced at intervals of either 0.1 or 0.2 mi. It was important to ensure that the

MAR02-1350

Figure 9. Electromagnetic geophysical equipment in the horizontal-dipole orientation.

Table 4. Approximate effective depths of exploration at three intercoil spacings and dipole orientations for variable-depth ground-conductivity electromagnetic geophysical methods

[Data from McNeill, 1980b]

Intercoil spacing		Exploration depth			
		Horizontal dipoles		Vertical dipoles	
Meters	Feet	Meters	Feet	Meters	Feet
10	33	7.5	25	15	49
20	66	15	49	30	98
40	131	30	98	60	197

soil matrix was relatively uniform between stations to avoid anomalous, localized effects. Before conducting the electromagnetic geophysical survey, local uniformity of the aquifer material was tested in several parts of the study area. To test for local uniformity, the center of the measurement station was identified, and electromagnetic apparent conductivity readings were taken at several intervals around the measurement station in a clockwise direction. Electromagnetic apparent conductivity values varied insignificantly between intervals. This test verified that differences in the electromagnetic apparent conductivity at various locations throughout the study area would most likely be due to differences in ground-water chemistry and that

MAR02-1351

the aquifer material is sufficiently homogeneous that local variations have little effect on electromagnetic apparent conductivity readings. Because contrasts in the chemistry of the ground water were large, the overall effect of geologic variations in the strata on the electromagnetic instrument readings was considered to be minimal.

Electromagnetic apparent conductivity data were recorded on field maps that contained pertinent information including topography and location of cultural features such as oil wells and pipelines. Anomalously high single conductivity values at or near oil wells and pipelines were not considered in the interpretations.

Electromagnetic apparent conductivity was measured in two areas (figs. 10-15, pl. 2). Area 1 is about 9.5 mi^2 and is underlain primarily by alluvium along the Poplar River and partly by a few glacial deposits along the area boundaries. Area 2 is about 12.1 mi^2 and is underlain primarily by glacial deposits and partly by alluvium along the Poplar River.

Electromagnetic geophysical measurements during summer 1991 were made with 10-m and 20-m intercoil spacings in Area 1 and 20-m and 40-m intercoil spacings in Area 2. During initial interpretation, data collected from all three spacings appeared to be relevant. Therefore, measurements during summer 1992 were made with 10-m, 20-m, and 40-m intercoil spacings at both areas. The electromagnetic apparent conductivity values during 1991-92 ranged from 10 mmho/m to 160 mmho/m. The contoured electromagnetic apparent conductivity values for each of the three intercoil spacings at both dipole orientations are shown in figures 10-15.

Interpretation of the electromagnetic geophysical data required determination and selection of the most relevant sets of measurements. Electromagnetic apparent conductivity values that measured conductivity over an effective depth of exploration that extended to the depth of the bottom of the saturated zone were assumed to be the most representative values for the entire thickness of the saturated zone. In addition, the electromagnetic apparent conductivity values associated with these depths correlated well with dissolved-solids and chloride concentrations in ground water. Consequently, effective depths of exploration of 15 m and 30 m were selected to represent the electromagnetic apparent conductivity of the entire saturated alluvium (Area 1) and glacial deposits (Area 2), respectively. Data from other effective depths of exploration other than 15 m were not used for interpretation in Area 1 because an effective depth of exploration of 7.5 m does not penetrate the entire depth of the saturated zone and effective depths of exploration of 30 m and 60 m are substantially deeper than the base of the saturated zone. Similarly, exploration depths other than 30 m were not used for interpretations in Area 2 because effective depths of exploration of 7.5 m and 15 m do not penetrate the entire depth of the saturated zone and an effective depth of exploration of 60 m is substantially deeper than the base of the saturated zone.

Three subareas (fig. 16, pl. 1)) of electromagnetic apparent conductivity were delineated using information from figures 11 and 12 (for Area 1) and figures 13 and 14 (for Area 2). Water wells sampled during 1989-93 and corresponding water type are also included in figure 16. Subarea 1 represents an area of low electromagnetic apparent conductivity; water from wells completed in this subarea generally was Type 1 (uncontaminated). Subarea 2 represents an area of moderate electromagnetic apparent conductivity; water from wells completed in this subarea generally was Type 2 (moderately contaminated). Subarea 3 represents an area of high electromagnetic apparent conductivity; water from wells completed in this subarea generally was Type 3 (considerably contaminated).

The relations between electromagnetic geophysical measurements of apparent conductivity and water quality are consistent almost everywhere; however, three anomalies exist in the relation derived for Area 1 and two anomalies exist in the relation derived for Area 2 (fig. 16). These anomalies exist most likely because of factors other than water quality that may affect electromagnetic apparent conductivity values, because delineation of saline-water contamination may be less accurate at the edges of the electromagnetic geophysical survey grid, or because delineation of water type is based on ranges of dissolved-solids and chloride concentrations which overlap.

In Area 1, in secs. 15, 16, and 21, T. 29 N., R. 51 E., water from wells M-52, M-54, and FPB92-14, which are located in subareas 2 and 3 (indicating moderate and high electromagnetic apparent conductivity), was Type 1 with chloride concentrations less than 16 mg/L. The lithologic descriptions of cuttings from these wells indicate that the Bearpaw Shale is about 25 ft shallower in this area than in other areas. The electromagnetic apparent conductivity patterns shown on figure 16 for these sections likely represent the influence from this shallow conductive Bearpaw Shale. The

MAR02-1352

second anomaly in Area 1 is in sec. 17 and exists for well W-4. The electromagnetic geophysical measurements indicate that the well is in a low electromagnetic apparent conductivity subarea (subarea 1); however, water from well W-4 was Type 2 with a chloride concentration of 3,000 mg/L in 1989. This well is near an area of moderate electromagnetic apparent conductivity (subarea 2) and the edge of the geophysical-survey grid, where delineation of saline-water contamination subareas evidently is less accurate. The third anomaly in the relation between electromagnetic conductivity and chloride concentration in Area 1 is in sec. 32 and exists for wells FPB92-4 and FPB92-5. The electromagnetic geophysical measurements indicate that these wells are in or near a moderate electromagnetic apparent conductivity subarea (subarea 2); however, water from both of these wells was Type 3 with chloride concentrations of 8,500 and 5,800 mg/L, respectively. The thick, unsaturated deposits (about 22 and 23 ft, respectively) may disproportionately lower the electromagnetic apparent conductivity relative to the Type 3 water in the relatively thin, saturated alluvium (about 4 and 2 ft, respectively).

In Area 2, monitoring well FPB92-12 located in sec. 22 is completed in an area of moderate electromagnetic apparent conductivity (subarea 2); however, water from this well was Type 1 with a chloride concentration of 15 mg/L. The lithologic description of cuttings from this well indicates 57 ft of relatively impermeable clay, which may cause moderate electromagnetic apparent conductivity values, or may cause contaminated water to flow preferentially around this clay. In the second anomaly, located in sec. 33, water from wells M-36 and M-38 completed just south of an area of moderate electromagnetic apparent conductivity (subarea 2) was Type 1 with chloride concentrations of 40 and 34 mg/L, respectively. The lithologic descriptions of cuttings from these wells indicate more than 70 ft of clay, which may cause moderate electromagnetic apparent conductivity values.

GENERAL HYDROLOGY OF THE POPLAR RIVER

The Poplar River, a tributary to the Missouri River, is perennial in the study area. Flow is partly regulated by a dam, constructed during the 1970's on the East Fork Poplar River, 2 mi north of the international boundary. Within the study area, tributaries that enter the Poplar River are intermittent or ephemeral.

Mean monthly discharge at site PR-8 (streamflow-gaging station 06181000) (pl. 3), computed from 17 years of streamflow data collected during 1975-79 and 1982-93, ranged from 6.1 ft^3/s in January to 399 ft^3/s in April (U.S. Geological Survey, published annually). About 64 percent of the annual streamflow occurred from March to April. Mean annual discharge during the period of record was 96 ft^3/s.

Water samples were collected periodically at site PR-1 (pl. 3) during 1979-93 and at site PR-8 during 1975-81 and 1986-94 (Thamke and others, 1996, table 12). Analysis of the major ions in the stream water indicates that the water is a sodium bicarbonate type (similar to Type 1 ground water) with a dissolved-solids concentration range of 553-1,030 mg/L at site PR-1 and 167-1,490 mg/L at site PR-8 during most streamflow conditions. At low flow conditions of less than about 15 ft^3/s, water at site PR-8 can become a sodium chloride type (similar to Type 2 ground water) with a dissolved-solids concentration range of 1,320-2,190 mg/L.

SALINE-WATER CONTAMINATION

The water-quality data collected from existing wells and surface-water sites confirm the presence of saline-water contamination in the Quaternary deposits and the Poplar River; however, the distribution of the wells alone was insufficient to determine lateral extent of contamination. To determine the lateral extent of the saline-water contamination, data from the electromagnetic geophysical survey were interpreted in conjunction with the water-quality information for existing wells and wells that were drilled subsequent to the electromagnetic geophysical survey. The vertical extent of saline-water contamination was interpreted from the water-quality information at sites that contained both shallow and deep wells. The magnitude of saline-water contamination was interpreted from the ground-water-quality data and hydraulic characteristics information. The movement of saline-water contamination was interpreted from ground-water hydraulic gradients, as well as historical ground-water-quality information. Streamflow and water-quality data for the Poplar River were interpreted in conjunction with ground-water-quality data to determine the effects of saline-water discharge on the Poplar River. The specific source areas of saline-water contamination were determined from the electromagnetic geophysical data and the locations of probable sources of contamination shown on plate 3.

MAR02-1353

Quaternary Deposits

The Quaternary deposits contain salinity levels representative of uncontaminated, moderately contaminated, and considerably contaminated water. Levings (1984) determined that saline contamination of the alluvial aquifer was from brine associated with oil production. Information collected during this investigation indicates that the lateral extent of saline contamination in the alluvial and glacial deposits is substantial, and that at least one specific source may still be contributing brine to the Quaternary deposits.

Lateral Extent

The lateral extent of saline-water contamination in the Quaternary deposits may be as much as about 12.4 mi^2 (pl. 3). This extent is within the boundary of the electromagnetic geophysical survey and is estimated on the basis of water-quality data and the electromagnetic apparent conductivity delineation of subareas 2 and 3 in figure 16. Small parts of subarea 1 that contain one or more water wells that produce Type 2 water are considered parts of confirmed saline-water plumes; subareas 2 and 3 that contain one or more water wells that produce Type 2 or Type 3 water are considered confirmed saline-water plumes; subareas 2 and 3 that do not contain water wells are considered possible saline-water plumes; and parts of or the entirety of subareas 2 and 3 that contain one or more water wells that produce Type 1 water are not considered saline-water plumes. The saline-water plumes are defined as Type 2 or Type 3, depending on the type of water derived from wells completed in these areas. The extent and number of plumes are discussed in relation to available water-quality information from sampled water wells.

The collective lateral extent of confirmed Type 2 saline-water contamination in the Quaternary deposits is 5.3 mi^2 (pl. 3). Four Type 2 saline-water plumes were confirmed. The northernmost confirmed Type 2 saline-water plume has an area of less than 0.1 mi^2 and is located in the southwestern part of sec. 16, T. 29 N., R. 51 E. Water from a 17-ft-deep privately owned well (W-9) completed in the shallow part of the alluvium on the edge of this plume in section 21 was Type 2 water with a chloride concentration of 1,100 mg/L; this well is unused. The second confirmed Type 2 saline-water plume has an area of 0.2 mi^2 and is located in the eastern part of sec. 20, T. 29 N., R. 51 E.; one water well is located near this plume, and one water well is located in this plume. Water from a 44-ft-deep privately owned well (W-6) completed in alluvium near this plume was Type 2 water with a chloride concentration of 2,300 mg/L in 1982; the well is now unused and is inaccessible for water-quality sampling. Water from a 56-ft-deep monitoring well (FPB92-13) completed in alluvium in this plume was Type 2 water with a chloride concentration of 4,600 mg/L. The third confirmed Type 2 saline-water plume has an area of 0.8 mi^2 and is located in secs. 19, 20, 29, 30, and 31, T. 29 N., R. 51 E. Water from a 45-ft-deep monitoring well (W-10) completed in alluvium in the northern part of this plume was Type 2 water with a chloride concentration of 3,400 mg/L in 1982; the well is now plugged and destroyed. Three monitoring wells (W-11, FPB92-6, and FPB92-10) completed at various depths in the alluvium in the southern part of this plume contained Type 2 water with chloride concentrations equal to 4,800 mg/L, 4,600 mg/L, and 2,100 mg/L, respectively. The southernmost, and largest, confirmed Type 2 saline-water plume has an area of 4.3 mi^2 and is located in the southern part of sec. 3, and parts of secs. 9, 10, 15, 16, 17, 20, 21, 22, 27, and 28, T. 28 N., R. 51 E. Water from privately owned and monitoring wells (M-14, M-15, M-18, M-20, M-22, M-24, M-25, and M-27) completed at various depths in this plume was Type 2 and contained chloride concentrations of 430-3,700 mg/L during 1989-91.

The collective lateral extent of possible Type 2 saline-water contamination in Quaternary deposits is 1.9 mi^2 (pl. 3). These areas are delineated by moderate electromagnetic apparent conductivity readings in areas that have no water wells for confirmation by analysis of water samples. Sixteen Type 2 saline-water plumes are possible, as shown on the following page.

MAR02-1354

Location	Plume area (square miles)
NE 1/4 sec. 8, T. 29 N., R. 51 E.	0.1
SW 1/4 sec. 8, NW 1/4 sec. 17, T. 29 N., R. 51 E.	0.1
North-central sec. 17, T. 29 N., R. 51 E.	less than 0.1
NE 1/4 sec. 19, T. 29 N., R. 51 E.	less than 0.1
SE 1/4 sec. 19, T. 29 N., R. 51 E.	less than 0.1
2 plumes—N 1/2 sec. 20, T. 29 N., R. 51 E.	less than 0.1
S 1/2 sec. 29, sec. 32, T. 29 N., R. 51 E.	0.3
West-central sec. 30, T. 29 N., R. 51 E.	less than 0.1
SW 1/4 sec. 31, T. 29 N., R. 51 E.	less than 0.1
W 1/2 sec. 34, T. 29 N., R. 51 E.	0.2
Central sec. 34, T. 29 N., R. 51 E.	less than 0.1
N 1/2 sec. 3, T. 28 N., R. 51 E.	0.1
E 1/2 sec. 3, T. 28 N., R. 51 E.	less than 0.1
NE 1/4 sec. 11, T. 28 N., R. 51 E.	less than 0.1
Sec. 11, E 1/2 sec. 15, T. 28 N., R. 51 E.	0.7

The collective lateral extent of confirmed Type 3 saline-water contamination in the Quaternary deposits may be as much as 2.0 mi^2 (pl. 3). Three Type 3 saline-water plumes were confirmed. The northern-most Type 3 saline-water plume has an area of 0.9 mi^2 and is located in secs. 31 and 32 and the southern edge of secs. 29 and 30, T. 29 N., R. 51 E. The Poplar River flows through the center of this plume. Ten monitoring wells completed at various depths in the alluvium in this plume contain Type 3 water with chloride concentrations of 7,700 mg/L or larger (wells W-15, FPB92-1, FPB92-2A, FPB92-3, FPB92-4, FPB92-5, FPB92-7, FPB92-8, FPB92-9, and FPB92-11). The second confirmed Type 3 saline-water plume has an area of 0.2 mi^2 and is located in the western and northern parts of sec. 9, T. 28 N., R. 51 E. Water from a 104-ft-deep monitoring well (FPB93-5 in this plume) is Type 3 with a chloride concentration of 6,300 mg/L. The southern-most confirmed Type 3 saline-water plume has an area of 0.9 mi^2 and is located in the central and southern parts of sec. 21, the southwestern part of sec. 22, the northwestern part of sec. 27, and the northern part of sec. 28, T. 28 N., R. 51 E. Water from two monitoring wells (FPB93-3 and FPB93-3A in this plume) completed in the top and the bottom of the saturated glacial deposits is Type 3 with chloride concentrations equal to or greater than 35,000 mg/L; water from two domestic wells (M-28 and M-31) completed in this plume is Type 3 with chloride concentrations equal to 7,900 mg/L and equal to or greater than 22,000 mg/L, respectively.

The collective lateral extent of possible Type 3 saline-water contamination in Quaternary deposits is 3.2 mi^2 (pl. 3). These areas are delineated by high electromagnetic apparent conductivity readings in areas that have no water wells for confirmation by analysis of water samples. Thirteen Type 3 saline-water plumes in Quaternary deposits are possible, as shown below.

Location	Plume area (square miles)
NW 1/4 sec. 17, SW 1/4 sec. 8, T. 29 N., R. 51 E.	less than 0.1
E 1/2 sec. 20, T. 29 N., R. 51 E.	less than 0.1
NE 1/4 sec. 30, NW 1/4 sec. 29, T. 29 N., R. 51 E.	0.2
Center sec. 3, T. 28 N., R. 51 E.	0.4
SW 1/4 sec. 3, sec. 10, sec. 11, sec. 15, sec., 16, T. 28 N., R. 51 E.	2.2
6 plumes—SE 1/4 sec. 11; NE 1/4 sec. 20; north-central and northeast sec. 21; and 2 plumes in north-central sec. 22, T. 28 N., R. 51 E.	0.2
W 1/2 sec. 27, T. 28 N., R. 51 E.	0.2
Center sec. 28, T. 28 N., R. 51 E.	less than 0.1

MAR02-1355

Vertical Extent

The vertical extent of saline-water contamination in the Quaternary deposits can be estimated using the water-quality information from the monitoring and privately owned wells completed in the plumes. Most monitoring wells drilled during this investigation were completed at the base of the Quaternary deposits, above the Bearpaw Shale, with a perforated interval at the base of the Quaternary deposits (Thamke and others, 1996, table 3). Three monitoring wells were completed within the top of the saturated Quaternary deposits; each near a well that was completed at the base of the Quaternary deposits. Privately owned wells, however, have been completed at various depths throughout the Quaternary deposits (Thamke and others, 1996, table 1). The depths of wells that confirm saline-water contamination plumes were included in the previous discussion to indicate the general depth of saline-water contamination in the different plumes.

Possible surface or subsurface sources of contamination, time of the source input (recent or old), and distance from the source may be indicated by characteristics of vertical stratification of chloride concentration and density. Saline water is more dense than fresh water and tends to migrate downward over time and distance from its source. Therefore, a recent surface source may be indicated by dense, saline water near the surface of the saturated deposits. A subsurface source may be indicated by dense, saline water near the source point(s), either at the bottom of the aquifer or in locations throughout the aquifer. Subsurface sources of saline water may result in deeper saline water being overlain by fresh water. Likewise, a long-term surface or shallow subsurface source that is still contributing saline water to the aquifer may be indicated by the presence of dense, saline water throughout the aquifer. A recent, nearby source (at any depth) may be indicated by vertical stratification of chloride and density, whereas an older, distant source may be indicated by either a lack of stratification due to dilution and dispersion or a vertical stratification where chloride concentration and water density increase with depth due to downward migration of dense, saline water.

The vertical extent of saline-water contamination was examined using water-quality information from three sets of wells (each set containing a deep and a shallow well) completed in Quaternary deposits (wells FPB92-2A and FPB92-2B at site 29N51E32BABB, FPB92-1 and FPB93-2 at site 29N51E32BBBA, and FPB93-3 and FPB93-3A in 28N51E22CBCB, Thamke and others, 1996, tables 1 and 3). The vertical extent of a confirmed Type 3 contamination plume in T. 29 N., R. 51 E., is delineated by two sets of wells located along the northern part of the plume. In the first set of wells, the deeper well FPB92-2A is 46 ft deep and is perforated at 31-41 ft below land surface, at the base of the alluvium; the shallower well, FPB92-2B was 27 ft deep and was perforated at 12-22 ft below land surface, within the top of the saturated alluvium (this well is now destroyed; Thamke and others, 1996, table 3). Water sampled from well FPB92-2A in July 1993 was Type 3 and had a dissolved-solids concentration of 46,100 mg/L, a chloride concentration of 35,000 mg/L, a density of 1.051 g/mL, and a specific conductance of 102,000 µS/cm. Water sampled from well FPB92-2B during initial well development in September 1992 had a specific conductance of 17,600 µS/cm. In the second set of wells, the deeper well FPB92-1 is 53 ft deep and is perforated at 38-48 ft below land surface, within the base of the alluvium; the shallower well, FPB93-2 is 27 ft deep and is perforated at 18-27 ft below land surface, within the top of the saturated alluvium. Water sampled from well FPB92-1 in July 1993 was Type 3 and had a dissolved-solids concentration of 91,100 mg/L, a chloride concentration of 58,000 mg/L, a density of 1.060 g/mL, and a specific conductance of 127,000 µS/cm. Water sampled from well FPB93-2 in July 1993 was Type 2 and had a dissolved-solids concentration of 6,450 mg/L, a chloride concentration of 3,200 mg/L, a density of 1.004 g/mL, and a specific conductance of 12,300 µS/cm. The water-quality information from these two sets of wells indicates that saline-water contamination is present throughout the entire vertical extent of the saturated zone, and that the chloride concentration and density of water in this saline-water contamination plume increase with depth in the alluvium. The vertical stratification of chloride concentration and density differences in the aquifer may have developed over time as the dense, saline water settled deeper in the aquifer, indicating an older source of saline contamination or the differences may indicate a subsurface source of contamination.

In the third set of wells, the deeper well FPB93-3 is 81 ft deep and is perforated at 52-57 ft below land surface, at the base of the glacial deposits; the shallower well, FPB93-3A is 49 ft deep and is perforated at 41-46 ft below land surface, at the top of the saturated glacial deposits. Water sampled from well FPB93-3

MAR02-1356

was Type 3 and had a dissolved-solids concentration of 58,700 mg/L, a chloride concentration of 35,000 mg/L, a density of 1.046 g/mL, and a specific conductance of 98,600 µS/cm. Water sampled from well FPB93-3A was also Type 3 and had a dissolved-solids concentration of 63,500 mg/L, a chloride concentration of 38,000 mg/L, a density of 1.045 g/mL, and a specific conductance of 97,200 µS/cm. The water-quality information from these two wells indicates that saline-water contamination is present throughout the entire depth of the saturated zone, and that the chloride concentrations decreased very slightly with depth. The density of water in this saline-water contamination plume varied insignificantly with depth in the glacial deposits. The presence of dense, saline water of similar characteristics throughout the aquifer may indicate that the source of saline contamination may still be contributing saline water to the aquifer or that the source inputs are recent enough that an insufficient period of time has elapsed to develop vertical chloride and density gradients.

Magnitude

The magnitude of the amount of water in the Quaternary deposits of the study area that is possibly affected by saline-water contamination ranges from about 9 to 60 billion gal (27,600-184,000 acre-ft). This volume is based on estimates of the saturated thickness of the Quaternary deposits for the lateral extent of confirmed and possible Type 2 and Type 3 saline-water contamination plumes and the porosity of the Quaternary deposits. The saturated thickness of the Quaternary deposits ranges from 17 to 46 ft; the lateral extent of the confirmed and possible Type 2 and Type 3 saline-water contamination plumes is 12.6 mi^2; and the porosity of gravels, sands, and clays (typically found in Quaternary deposits) has a range of 20-50 percent (Heath, 1983, p. 7).

Movement

Contaminated water in Quaternary deposits east of the Poplar River generally moves westward toward the river then southward in the Poplar River valley. The variation in water density from saline-water contamination in the Quaternary deposits may result in a significant downward vertical component of flow for the more dense contaminated water. Factors that may affect the vertical density gradients of contaminated ground water include the source of saline-water contamination (surface or subsurface) and the timing of saline-water contamination (a distinct vertical density gradient may have developed from an older saline-water contamination event, whereas little to no vertical density gradient may have developed from a recent or current saline-water contamination event). In isolated areas, dense, saline water may settle in small depressions on the surface of the Bearpaw Shale.

The effect of saline-water movement on water quality in Quaternary deposits is illustrated by water-quality diagrams shown in figures 17-19 for selected wells. The water-quality diagrams represent the chemical composition of selected water samples collected from wells completed in Quaternary deposits for confirmed Type 2 and Type 3 saline-water contamination plumes (Thamke and others, 1996, table 6; Levings, 1984, table 2).

The effect of saline-water movement into areas that have little or no contamination in Quaternary deposits is to increase dissolved-solids and chloride concentrations; the effect of saline-water movement away from contamination areas in Quaternary deposits is to decrease dissolved-solids and chloride concentrations. In some cases, the effects are more dramatic than others, depending on the chemical characteristics of the source, quantity of contaminated water, proximity to source, and ground-water flow characteristics in the area. The following three examples show the effects of saline-water movement into and out of areas over different periods of time.

In the first example, uncontaminated water became moderately contaminated within a 15-year period because of the movement of a moderately contaminated (Type 2) saline-water plume; this example is illustrated in the water-quality diagrams for well M-25 (fig. 17). Well M-25 is a privately owned well completed in Quaternary deposits of a confirmed Type 2 plume located in parts of secs. 3, 9, 10, 15, 16, 17, 20, 21, 22, 27, and 28, T. 28 N., R. 51 E. (pl. 3). Water collected from well M-25, which was uncontaminated in 1975, became moderately contaminated by 1990 as Type 2 saline water had moved into the area of the well.

In the second example, uncontaminated water became considerably contaminated within a 4-6 year period because of the movement of a considerably contaminated (Type 3) saline-water plume; this example is illustrated in the water-quality diagrams for wells M-28 and M-31 (fig. 18). Wells M-28 and M-31 are privately owned and completed in Quaternary deposits of a con-

MAR02-1357

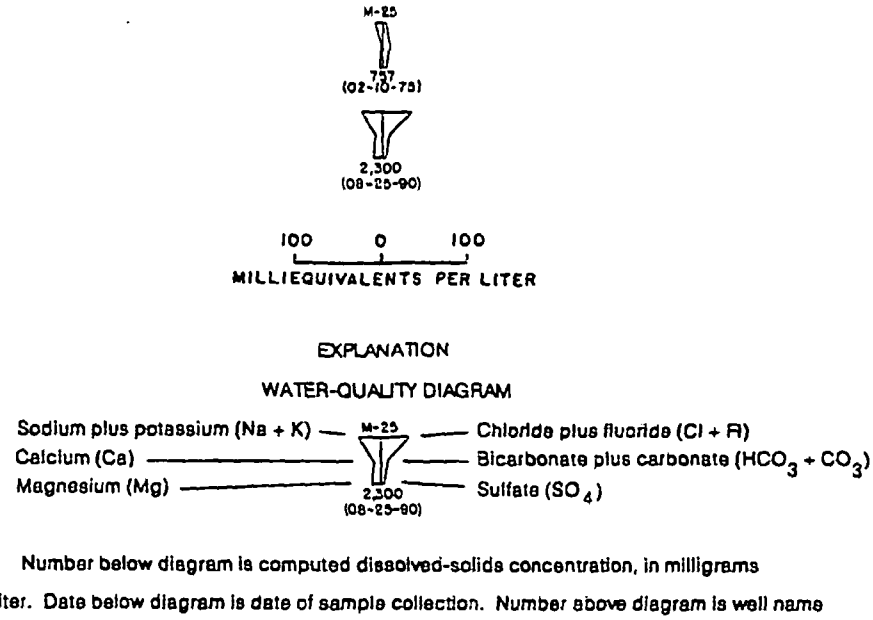


Figure 17. Chemical composition and dissolved-solids concentration of water sampled from well M-25 in the East Poplar oil field study area, northeastern Montana.

firmed Type 3 plume located in the central and southern parts of sec. 21, the southwestern part of sec. 22, the northwestern part of sec. 27, and the northern part of sec. 28, T. 28 N., R. 51 E. (pl. 3). Water collected from both wells during 1985 was uncontaminated. Water collected from well M-28 in 1989 was moderately contaminated. Water collected from well M-28 in 1991 and well M-31 in 1989 had become considerably contaminated. By 1993, water collected from well M-31 was similar to the brine produced from the oil field (Type 4). The increasing trend in dissolved-solids concentration in water from M-28 and M-31 may indicate that the source of the contamination was active during 1985-93. Because no further construction has occurred in this area (Debi Madison, Fort Peck Tribes, Office of Environmental Protection, oral commun., 1997), the source of the contamination may still be active.

In the third example, considerably contaminated ground water became less contaminated within a 7-11-year period because of the movement and dilution of a considerably contaminated (Type 3) saline-water plume; this example is illustrated in the water-quality diagrams for wells W-11, W-15, and W-16 (fig. 19). These wells are completed in Quaternary deposits of confirmed Type 2 and Type 3 plumes located in parts of secs. 19, 20, 29, 30, 32, and most of sec. 31, T. 29 N., R. 51 E. (pl. 3). Water collected from all three wells was considerably contaminated in 1982. In 1989, water collected from well W-11 had become moderately contaminated and water collected from well W-15 was still considerably contaminated; however, dissolved-solids and chloride concentrations had decreased substantially. Well W-16 was plugged and destroyed; then well FPB92-11 was drilled at the same site and perforated at the same interval as W-16. In 1993, based on water from well FPB92-11, water at the site was still considerably contaminated, but dissolved-solids and chloride concentrations had decreased substantially. Wells W-11 and W-15 are located on the upgradient edges of the plumes, and well FPB92-11 is located on the edge of the plume. In each of these wells, the decreasing dissolved-solids and chloride concentrations probably were due to dilution by fresh water as the plume moved towards the Poplar River and upgradient saline water source inputs were decreased or terminated. The quality of water in these wells had not returned to uncontaminated concentrations at the date of their most recent sampling. The density of water collected from wells in this plume increases with depth in the alluvium; therefore, movement of saline-water contamination may follow the top of the Bearpaw Shale and in isolated areas, may settle in small depressions. In this plume, the elevation of the top of the Bearpaw Shale is about 30 ft lower on the southeast side of the Poplar River compared to the northwest side. The plume also extends past the Poplar

MAR02-1358

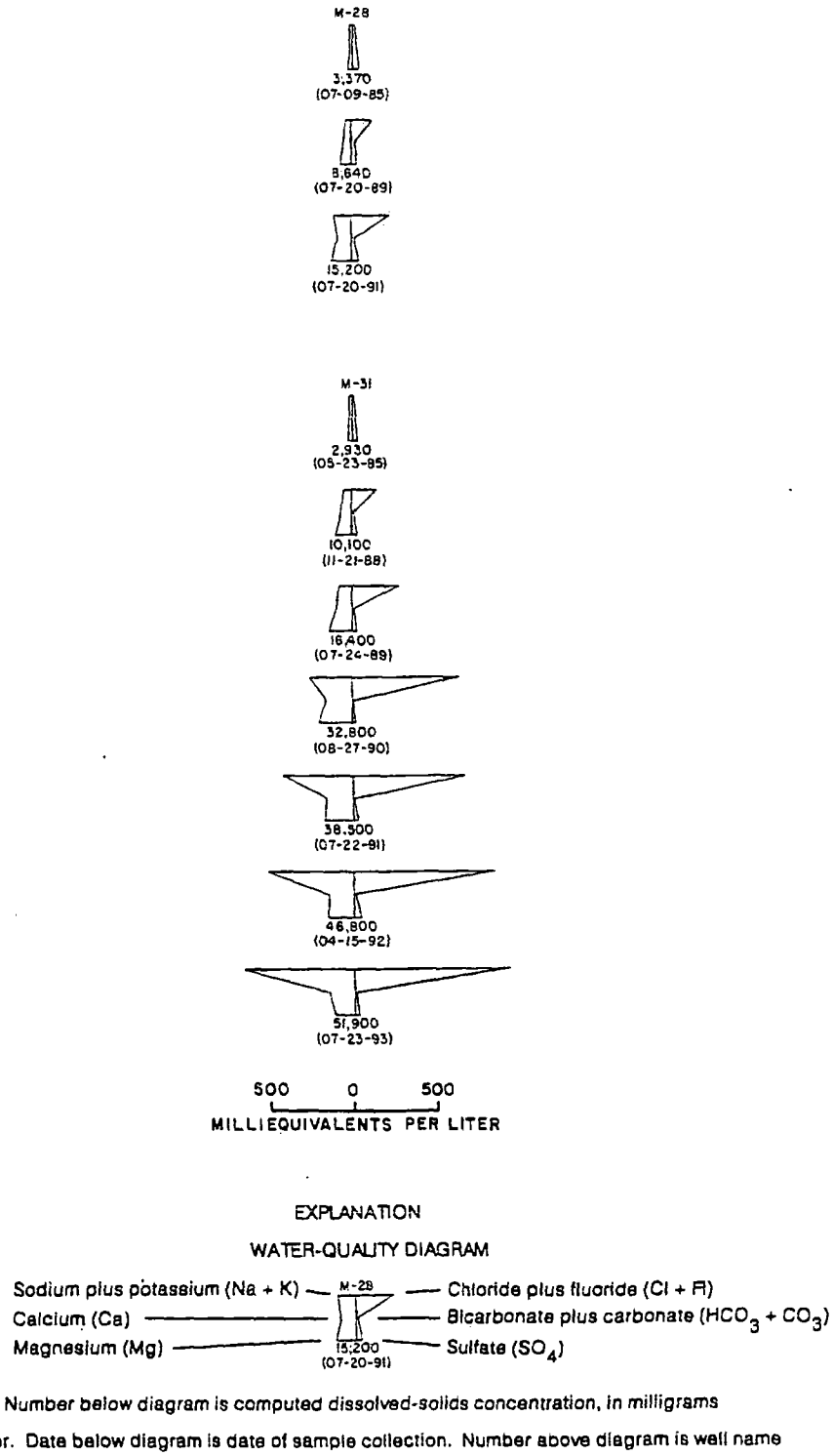


Figure 18. Chemical composition and dissolved-solids concentration of water sampled from wells M-28 and M-31 in the East Poplar oil field study area, northeastern Montana.

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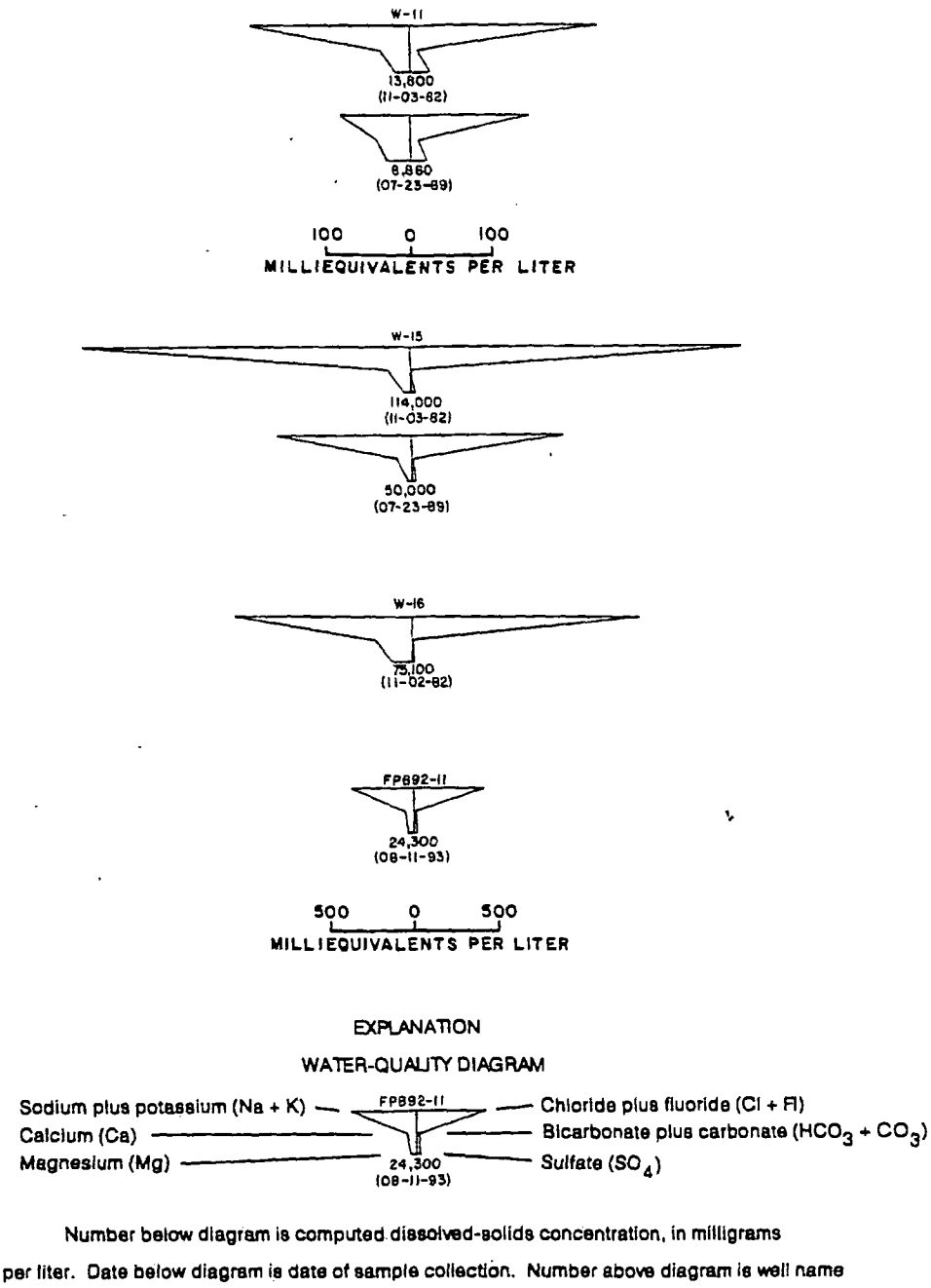

Figure 19. Chemical composition and dissolved-solids concentration of water sampled from wells W-11, W-15, W-16, and FPB92-11 in the East Poplar oil field study area, northeastern Montana.

River, indicating that some saline-water contamination may have moved beneath the river to the other side of the alluvial valley.

Poplar River

The Poplar River is and will continue to be the recipient of some if not most of the saline-water contamination in the Quaternary deposits of the study area because of ground-water discharge to the river. Levings (1984) determined that a downstream increase in chloride concentration and downstream change in water type from sodium bicarbonate to sodium chloride were indications of saline ground-water discharge to the Poplar River. Information collected during the cur-

MAR02-1360

rent investigation indicates that saline ground water is still discharging to the Poplar River; and there is a possibility that saline ground-water discharge to the Poplar River will occur in another downgradient area in the future.

Four sets of streamflow measurements and five sets of water-quality measurements were conducted along a 9-mi reach of the Poplar River valley to determine gains and losses in streamflow and changes in water quality (Thamke and others, 1996, pl. 1 and table 11). In general, the precision of streamflow measurements indicates that apparent gains or losses of about 5 percent or less might be the result of measurement error rather than actual gains or losses in streamflow. Chloride loads, in tons per day, were also computed for sites with measured streamflow and chloride concentrations to describe downstream variation along the Poplar River, according to the following equation:

$$L = Q \cdot C \cdot K \qquad (1)$$

where:

- L = chloride load, in tons per day;
- Q = streamflow, in cubic feet per second;
- C = chloride concentration, in milligrams per liter; and
- K = units conversion constant (0.0027).

In the first set of measurements, conducted during September 1981 as part of the investigation by Levings (1984), streamflow decreased from 1.7 to 0.7 ft^3/s and both the chloride concentration and load increased from 20 to 880 mg/L and 0.1 to 1.7 tons/day, respectively, between sites PR-1 and PR-5. In the second set of measurements, conducted during October 1990, the chloride concentration increased from 12 to 240 mg/L between sites PR-0 and PR-9. In the third set of measurements, conducted during April 1991, streamflow remained essentially constant among the sampling sites at 82-85 ft^3/s and both the chloride concentration and load increased from 11 to 29 mg/L and 2.4 to 6.7 tons/day, respectively, between sites PR-0 and PR-9. In the fourth set of measurements, conducted during July 1991, streamflow remained essentially constant at 44-47 ft^3/s and both the chloride concentration and load increased from 10 to 61 mg/L and 1.3 to 7.2 tons/day, respectively, between sites PR-0 and PR-8. In the fifth set of measurements, conducted during September 1991, streamflow varied slightly from 7.9 to 11 ft^3/s from site PR-1 to PR-8; while both the chloride concentration and load increased from 17 to 160 mg/L and 0.4 to 4.8 tons/day, respectively. On the basis of these five sets of measurements, chloride concentrations and loads consistently increased downstream regardless of gains or losses in streamflow.

The Poplar River flows through several areas underlain by two saline-water contamination plumes (pl. 3) that could be sources of saline ground-water discharge and that appear to affect the water quality of the river. Figure 20 illustrates streamflow and chloride loads along measured reaches of the Poplar River. The reach where the water quality of the Poplar River appears to be most affected is between sites PR-2 and PR-6 (Thamke and others, 1996, pl. 1 and table 11); a smaller part of this reach (PR-2 to PR-5) was first identified by Levings (1984). In 1981, chloride loads increased significantly between sites PR-1 and PR-3, indicating inputs of 2.2 tons/day from ground water in this reach. In 1991, chloride loads increased between PR-2 and PR-6; most significant increases were between PR-4 and PR-6. The reach between PR-2 and PR-5 of the Poplar River flows through a confirmed Type 2 (moderately contaminated) saline-water plume and a confirmed Type 3 (considerably contaminated) saline-water plume. Saline-water-plume delineation between PR-5 and PR-6 is unknown, due to the lack of electromagnetic geophysical measurements in this area; however, increased chloride loads during 1991 indicate possible saline ground-water discharge between these two sites. On the basis of streamflow and water-quality measurements collected from 1981 through 1991, the large downstream increase in chloride load indicates that saline ground water discharges to the Poplar River, presumably from the confirmed saline-water plumes.

Farther downstream, between PR-6 and PR-9, the Poplar River flows through or near a confirmed saline-water plume of moderate contamination (pl. 3) that may affect the water quality of the river in the future. Streamflow and water-quality measurements made during 1991 indicated that streamflow remained fairly constant, while chloride loads remained fairly constant or increased slightly (fig. 20). Chloride concentrations from a well completed in the downgradient part of this plume increased during 1975-90 (discussed in the 'Movement' section of 'Saline-Water Contamination'). A lack of appreciable downstream increases in chloride load between sites PR-6 and PR-9 indicates that, currently (1996), the confirmed Type 2 (moderately contaminated) saline-water plume may not be measurably affecting concentrations in the Poplar River; however, movement of saline-water contamination evidenced by

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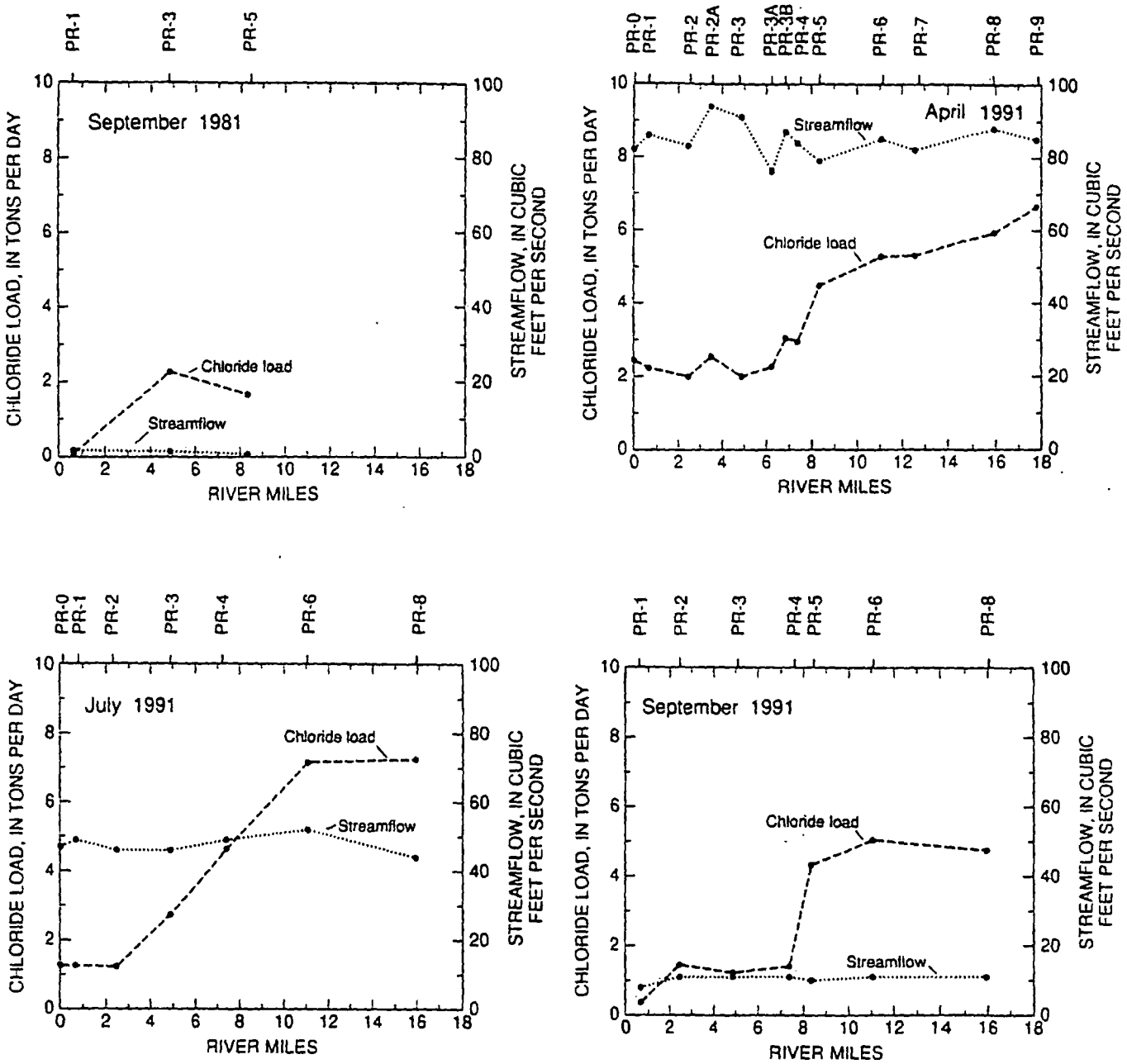

Figure 20. Streamflow and chloride loads for selected sites along the Poplar River, 1981 and 1991, in the East Poplar oil field study area, northeastern Montana.

MAR02-1362

increased salinity in a nearby well may increase the dissolved-solids and chloride concentrations of saline ground-water discharge to the river in the future.

Possible Sources

Water-quality information from wells in the Quaternary deposits and from sites along the Poplar River indicate that saline-water contamination has occurred in the study area. Three possible and general sources of saline water in Quaternary deposits in the study area are saline seeps, water from the underlying Bearpaw Shale, and brines from the production of oil. Specific sources of saline-water contamination plumes can be discerned from additional interpretation of electromagnetic geophysical data.

General Sources

Saline seeps are common in many parts of eastern Montana as a result of leaching of saline soils derived from marine shales. Typically, the major constituents in water from saline seeps are sodium, magnesium, and sulfate, and concentrations of chloride are low compared to concentrations of sulfate (Donovan and others, 1981; Halvorson, 1988). In contrast, contaminated ground water in the study area has a sodium chloride chemical composition with a large ratio of chloride to sulfate ions. Furthermore, no saline soils and relatively few areas of saline seeps have been mapped in the study area (U.S. Department of Agriculture, 1985; Miller and Bergantino, 1983). Therefore, saline seeps are not a likely source of saline-water contamination in the study area.

The Cretaceous Bearpaw Shale is relatively impermeable; therefore, wells in the study area are perforated in the overlying Quaternary deposits. However, it is possible that minor amounts of water from the small fractures and fissures in the Bearpaw Shale interact with water from Quaternary deposits, depending on vertical gradients in the ground water. Analyses of water from two wells completed in the Bearpaw Shale in the southwest part of the reservation are stored in the National Water Data Storage and Retrieval System (operated and maintained by the U.S. Geological Survey). The major constituents in water from the Bearpaw Shale for these two wells are sodium and sulfate, with chloride concentrations of 180 and 110 mg/L. In contrast, the major constituents in contaminated ground water in Quaternary deposits are sodium and chloride, with chloride concentrations greater than 330 mg/L. This difference in water chemistry, in addition to the impermeable nature of the Bearpaw Shale, indicates that water from the Bearpaw Shale is not a likely source of saline-water contamination in the study area.

Brine is a byproduct of most crude-oil production activities. Most of this brine originates from intraformational dissolution of halite in the oil-producing zone which, in the East Poplar oil field study area, mainly is the Charles Formation of the Mississippian Madison Group. The major constituents in brine are sodium and chloride, a composition that is similar to contaminated ground water in the study area. The strong similarity in water chemistry indicates that brine is a likely source of saline-water contamination in the study area.

Possible sources of the brine and resultant saline-water contamination in Quaternary deposits in the study area are brine-injection wells, oil-production wells, brine-evaporation pits, pipelines, storage tanks, and upward brine migration from subsurface zones through well casing or fractures, although no faults or fracture systems are known in the study area. The approximate quantities of brine injected through brine-injection wells throughout the oil-field's history, calculated from EPA and BLM well records, are shown in table 2; the locations of brine-injection wells, oil wells, brine-evaporation pits and other pits, pipelines, and storage tanks are shown on plate 3.

Specific Source Areas

In several of the saline-water plumes (pl. 3), some electromagnetic geophysical measurements were significantly higher than the measurements used to delineate the plumes. Contouring of these significantly high electromagnetic geophysical measurements from figs. 11-14 appears to delineate specific source areas of brine in these plumes. The electromagnetic apparent conductivity is considered to be significantly high if the value is 20 mmho/m higher than the electromagnetic apparent conductivity used to delineate subarea 3. Consequently, electromagnetic apparent conductivity values for Areas 1 and 2, greater than or equal to 70 or 90 mmho/m, as shown on the following page, were used to delineate areas around or downgradient from probable sources of brine contamination.

The correlation is strong between areas of significantly high electromagnetic apparent conductivities and the location of particular brine-injection wells, oil wells, evaporation pits, pipelines, and storage-tank

MAR02-1363

Area 1	Area 2	Significantly high electromagnetic apparent conductivity (mmho/m)
10-meter, vertical-dipole orientation	20-meter, vertical-dipole orientation	≥ 70
20-meter, horizontal-dipole orientation	40-meter, horizontal-dipole orientation	≥ 90

facilities (pl. 3). On plate 3, areas of significantly high electromagnetic apparent conductivities are shaded separately from the types of plumes. Probable specific sources may be located in or hydraulically upgradient of the areas of significantly high electromagnetic apparent conductivities. However, the areas of high electromagnetic apparent conductivity may not be all-inclusive; therefore, other specific source areas may exist.

SUMMARY AND CONCLUSIONS

The sole developed source of ground water for residents in and near the East Poplar oil field is the Quaternary deposits, comprised of the Poplar River alluvium and glacial deposits. Depth to water in alluvium generally has a range of about 5-44 ft below land surface; depth to water in glacial deposits has a range of about 7-130 ft. Water in Quaternary deposits east of the Poplar River generally moves westward toward the river where it merges with southward-flowing ground water in the Poplar River valley. The Quaternary deposits are underlain by the relatively impermeable Upper Cretaceous Bearpaw Shale, which limits downward movement of ground water. Representative hydraulic-conductivity values determined from two aquifer tests were 77 ft/d for alluvium and 42 ft/d for glacial deposits; corresponding transmissivity values were 2,400 ft^2/d for alluvium and 800 ft^2/d for glacial deposits.

The quality of water in Quaternary deposits in the study area is highly variable and is dependent on location relative to sources of contamination. Dissolved-solids and chloride concentrations in water sampled during 1989-93 from wells completed in the Quaternary deposits have ranges of 427-91,100 mg/L and 7.3-58,000 mg/L, respectively. Three types of water exist in the Quaternary deposits, and a fourth type of water represents the brine. Uncontaminated water (Type 1) is principally a sodium bicarbonate and a sodium sulfate type water. Moderately contaminated water (Type 2) is a sodium chloride water, with dissolved-solids and chloride concentrations significantly larger than in uncontaminated water. Considerably contaminated water (Type 3) is principally a sodium chloride type; however, the concentrations of dissolved-solids, sodium, and chloride are significantly larger than in moderately contaminated water. Considerably contaminated water is similar to the brine (Type 4), which is produced with the oil and is injected by brine-injection wells.

Electromagnetic apparent conductivity data were collected in an area of about 21.6 mi^2. The data were contoured and interpreted in conjunction with water-quality data to delineate the lateral extent of saline-water contamination plumes in the Quaternary deposits. The extent of saline-water contamination in Quaternary deposits in the East Poplar oil field may be as much as 12.4 mi^2. Electromagnetic apparent conductivity, combined with water chemistry of samples from wells confirms the presence of 7.3 mi^2 of contamination, as much as 2.0 mi^2 of which is considerably contaminated (Type 3). Electromagnetic apparent conductivity data for unsampled areas indicate 5.1 mi^2 of possible contamination, 3.2 mi^2 of which may be considerably contaminated (Type 3).

In contaminated areas, saline water is present throughout the entire vertical extent of the saturated zone of the Quaternary deposits as evidenced by analyses of water samples from nested wells at three sites. At two of the sites, the chloride concentration and density of water in a saline-water contamination plume increases significantly with depth. At the third site, the chloride concentrations and density of water in a saline-water contamination plume did not vary significantly with depth, possibly indicating that the source may still be contributing saline water to the aquifer.

About 9-60 billion gal of water in the Quaternary deposits are possibly affected by saline-water contamination. This range is based on the estimated saturated thickness and porosity of Quaternary deposits affected by confirmed and possible saline-water contamination plumes.

Generally, the saline-water contamination appears to move laterally in the general directions of ground-water flow—laterally toward the river then

MAR02-1364

southward in the Poplar River valley. The movement of saline-water plumes is evidenced by the changes in dissolved-solids and chloride concentrations over time. Increasing concentrations over time indicate that a plume has migrated into the area; decreasing concentrations indicate a departing plume where dilution is re-establishing lower concentrations. Some movement of saline-water contamination may follow the top of the Bearpaw Shale. In one documented case, a considerably contaminated saline-water plume in the alluvium extends to both sides of the Poplar River valley; thus, the saline water may have moved beneath the river to the other side of the valley.

Saline ground water discharges to the Poplar River, as evidenced by a downstream increase in dissolved-solids and chloride concentrations, as well as a downstream change in water type from sodium bicarbonate to sodium chloride. In the northern part of the study area, a saline-water plume probably is discharging to the Poplar River. In the southern part of the study area, a larger, less contaminated saline-water plume is not significantly affecting concentrations in the Poplar River, although increasing dissolved-solids and chloride concentrations in nearby wells indicate that the plume may be approaching the river; thus, saline ground-water discharge may eventually affect this reach of the river as well.

The probable source of saline-water contamination of the Quaternary deposits is brine from the production of crude oil in the East Poplar oil field study area. Dissolved-solids and chloride concentrations of this brine have ranges of about 47,700-201,000 mg/L and 27,000-120,000 mg/L, respectively. Most brine disposal has been by injection into subsurface geologic units; smaller, unknown quantities of brine have been directed into storage and evaporation pits. Within the saline-water contamination plumes, the locations of significantly high electromagnetic apparent conductivity values generally are close to the locations of particular brine-injection wells, oil wells, pipelines, and storage-tank facilities. These areas appear to be probable specific source areas of the saline-water contamination.

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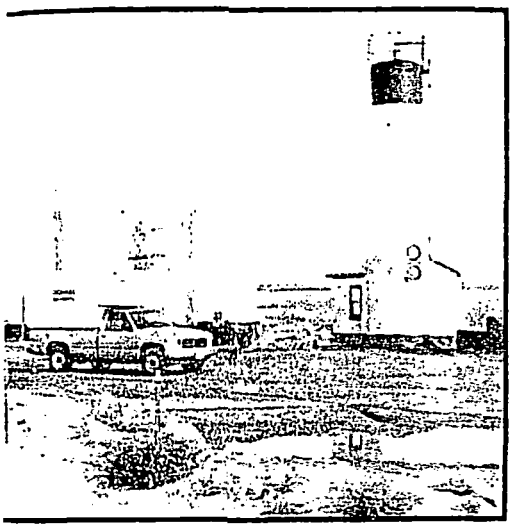
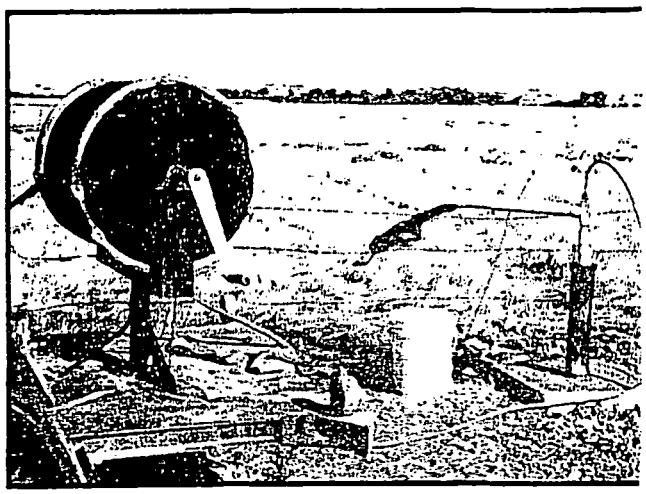
MAR02-1369

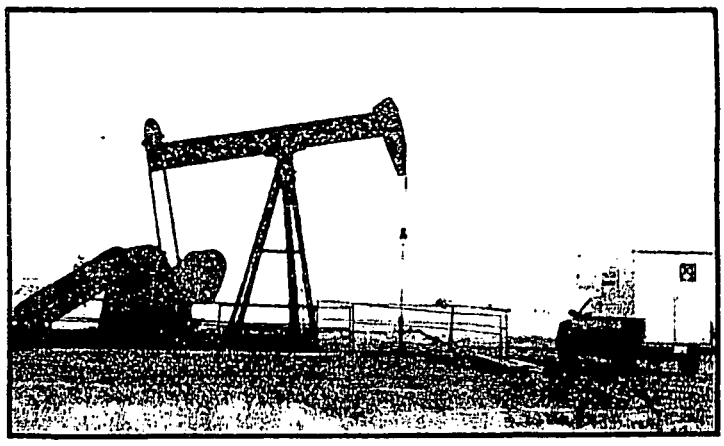
HYDROLOGIC DATA FOR THE EAST POPLAR OIL FIELD, FORT PECK INDIAN RESERVATION, NORTHEASTERN MONTANA

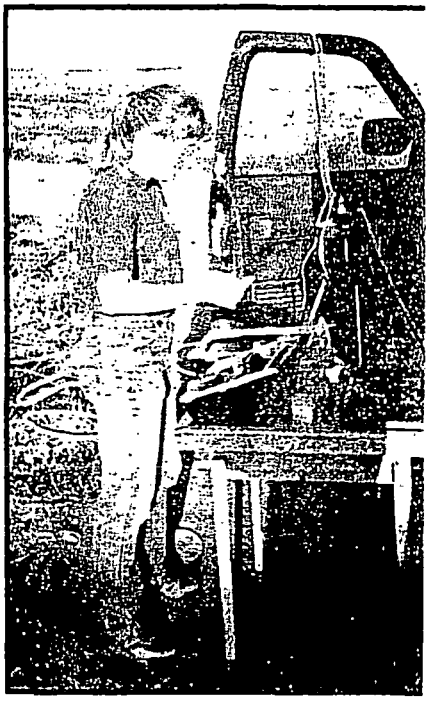
U.S. GEOLOGICAL SURVEY

Open-File Report 95-749









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MAR02-1375

Front cover--Photographs showing

Upper left:	Brine-injection well Murphy 8-D
Upper middle:	Conducting streamflow measurement on Poplar River
Upper right:	Developing monitoring well FPB92-13
Lower left:	Conducting electromagnetic geophysical survey
Lower middle:	Oil-well and pump unit near Poplar River
Lower right:	Conducting ground-water-quality sampling

HYDROLOGIC DATA FOR THE EAST POPLAR OIL FIELD, FORT PECK INDIAN RESERVATION, NORTHEASTERN MONTANA

By Joanna N. Thamke, Steven D. Craigg, and Thomas M. Mendes

U.S. GEOLOGICAL SURVEY

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Helena, Montana
January 1996

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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CONTENTS

Page

Abstract 1
Introduction 1
Purpose and scope 1
Location and general features of the area 2
Site-identification systems 2
Acknowledgments 4
Presentation of data 5
Data-collection methods 6
Existing data 6
Well inventory 8
Electromagnetic geophysics 8
Streamflow measurements 9
Monitoring-well installation 9
Aquifer testing 9
Water-quality sampling 10
Selected references 11
Data 13

ILLUSTRATIONS

Plate 1. Map showing location of privately owned wells, monitoring wells, brine-injection wells, sampled oil wells, surface-water data-collection sites, and areas of electromagnetic geophysical data collection for the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana ..... In pocket

Figure 1. Map showing location of the East Poplar oil field study area, Fort Peck Indian Reservation, northeastern Montana 3
2. Photographs showing general physiographic features of the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 4
3. Photographs showing various surface structures associated with oil production in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 5
4. Diagram showing site-numbering system 6
5. Diagram showing typical completion of monitoring wells drilled in 1992-93 in Quaternary alluvial or glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 7

TABLES

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 14
2. Records of known brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 26
3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 30
4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana 57

MAR02-1377

TABLES–Continued

	Page
Table 5. Data from aquifer test conducted in Quaternary glacial deposits on August 19, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	62
6. Physical properties and major-ion concentrations in water samples collected from privately owned wells, monitoring wells, oil wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	67
7. Trace-element and organic-carbon concentrations and stable-isotope ratios in water samples collected from privately owned wells, monitoring wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	75
8. Physical properties and major-ion concentrations in deionized-water field blanks collected during ground-water sampling in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	80
9. Trace-element and dissolved organic-carbon concentrations in deionized-water field blanks collected during ground-water sampling in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	81
10. Locations and descriptions of streamflow-measurement sites on the Poplar River in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	82
11. Streamflow and miscellaneous water-quality measurements for the Poplar River in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	83
12. Physical properties and major-ion concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	84
13. Trace-element concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana	90

SUPPLEMENTAL DATA

Floppy disk containing electromagnetic geophysical measurements in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana ..... In pocket

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	4,047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.59	square kilometer

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the equations:

$$C = 5/9\ (°F - 32)$$
$$F = 9/5\ (°C) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report:

µg/L	microgram per liter
µS/cm	microsiemen per centimeter at 25 degrees Celsius
mg/L	milligram per liter
g/mL	gram per milliliter
per mil	part per thousand

MAR02-1378

HYDROLOGIC DATA FOR THE EAST POPLAR OIL FIELD, FORT PECK INDIAN RESERVATION, NORTHEASTERN MONTANA

by Joanna N. Thamke[1], Steven D. Craigg[1], and Thomas M. Mendes[2]

Abstract

This report presents selected hydrologic data for the East Poplar oil field, located in the south-central part of the Fort Peck Indian Reservation in northeastern Montana. Data about the occurrence, quantity, and quality of ground and surface water are presented in tabular form. The tables contain records of privately owned wells (active and abandoned), monitoring wells installed by the U.S. Geological Survey and Montana Bureau of Mines and Geology, oil wells, and brine-injection wells; lithologic descriptions of drill cuttings and well-completion data from monitoring wells; data from two aquifer tests conducted in Quaternary alluvial and glacial deposits; chemical quality of ground water; and information on the quantity and chemical quality of surface water. Records of electromagnetic geophysical measurements collected throughout an area of about 20 square miles of the study area are compiled and included on a floppy disk.

Illustrations in this report contain information about study area location, site-numbering system, general physical and cultural features, and construction of monitoring wells installed by the U.S. Geological Survey. A plate-sized map presents additional information about privately owned wells, monitoring wells, oil wells, brine-injection wells, surface-water data-collection sites, and areas of electromagnetic data collection.

The data presented in this report provide a base with which to better define and interpret the occurrence, quantity, and quality of ground and surface water in the vicinity of the Poplar River Valley in the south-central part of the Fort Peck Indian Reservation. The data can be used to help delineate the occurrence of brine and saline water in Quaternary alluvial and glacial deposits in the East Poplar oil field.

INTRODUCTION

Oil production began in the East Poplar oil field in 1952 from the Mississippian Madison Group at depths between about 5,500 and 6,000 ft. Since then, large quantities of brine (water having a dissolved-solids concentration greater than 35,000 mg/L, classification of Swenson and Baldwin, 1965) have been produced with the oil. Most of this brine, which has a dissolved-solids concentration of as much as 160,000 mg/L, has been disposed of by injection into shallower formations (mainly the Upper Cretaceous Judith River Formation, and a deeper, Lower Cretaceous unit that historically has been referred to as the Dakota Sandstone by oil companies and by the Fort Peck Tribes). Some of the brine has been directed to storage and evaporation pits.

A reconnaissance investigation (Levings, 1984) determined the existence of saline-water contamination of shallow ground water in the alluvium along the Poplar River. In response to reported increased salinity of ground water used for domestic and stock supplies within and near the oil field, the U.S. Geological Survey (USGS), in cooperation with the Fort Peck Tribes, began an investigation in 1991 of shallow ground water in Quaternary alluvial and glacial deposits within the East Poplar oil field.

Purpose and Scope

This report presents hydrologic data that currently (1995) are available for the East Poplar oil field study area. Most of these data were collected onsite during summer 1991, 1992, and 1993. Some of the

[1]U.S. Geological Survey, Helena, Montana.
[2]Morrison-Maierle Environmental Corp., Helena, Montana.

MAR02-1379

data contained herein were collected during previous investigations.

Data compiled for this report include both ground-water and surface-water. Ground-water data consist of records of privately owned wells, USGS and Montana Bureau of Mines and Geology (MBMG) installed monitoring wells, oil wells, and brine-injection wells; lithologic logs of the USGS-installed monitoring wells; water-quality data from privately owned, monitoring, and brine-injection wells; and data from two aquifer tests (one conducted in alluvial deposits and one conducted in glacial deposits). Electromagnetic geophysical data also are included for two areas. Surface-water data include measurements of streamflow quantity and quality.

A description of the geology and hydrogeology of the study area is beyond the scope of this report. However, the geology of the general area has been mapped by Colton (1963a,b); the geology of the study area has been discussed by Levings (1984) and Craigg and Thamke (1992). The hydrogeology of the study area has been discussed by Levings (1984), Craigg and Thamke (1992, 1993), Mendes and others (1992), Thamke and others (1992), Thamke and Craigg (1993), and Craigg and Thamke (1995).

Location and General Features of the Area

The East Poplar oil field study area encompasses about 70 square miles northeast of Poplar in northeastern Montana, in the Fort Peck Indian Reservation, Roosevelt County (fig. 1). The study area is located primarily in Townships 28 and 29 North, and Ranges 50 and 51 East (pl. 1), in and adjacent to the Poplar River Valley. Topography of the study area generally consists of a glacial bench of relatively low relief, dissected by the Poplar River and its tributaries (fig. 2).

Dryland farming is practiced on the glacial bench and in some parts of the Poplar River Valley. Livestock ranching also is practiced locally throughout the study area. Oil wells, storage tanks, evaporation pits, pipelines, and various structures associated with oil production are present on the landscape throughout the study area (fig. 3).

Site-Identification Systems

A site number is used as the primary identification for wells. This site number is based on the rectangular system for the subdivision of public lands (fig. 4); the number consists of as many as 14 characters and is assigned according to the location of a site within a given township, range, and section. The first three characters specify the township and its position north (N) of the Montana Base Line, while the next three characters specify the range and its position east (E) of the Montana Principal Meridian. The next two characters indicate the section; the next one to four characters indicate the position of the site within the section. The first letter denotes the quarter section (160-acre tract); the second letter denotes the quarter-quarter section (40-acre tract); the third letter denotes the quarter-quarter-quarter section (10-acre tract); and the fourth letter denotes the quarter-quarter-quarter-quarter section (2.5-acre tract). These lettered subdivisions of the section are indicated as A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The last two characters form a sequence number based on the order that a site was inventoried in that tract. For example, site number 29N51E09ABBA01 represents the first well inventoried in the NE 1/4 NW 1/4 NW 1/4 NE 1/4 sec. 9, T. 29 N., R. 51 E.

Wells also are identified by an alpha-numeric well name, allowing for ease of cross reference between wells plotted on plate 1 and wells listed in relevant tables. The well name consists of as many as three alpha characters and as many as four numeric characters. The alpha character denotes the well type: (FPB)--USGS monitoring well installed during this investigation; (W)--USGS monitoring well or miscellaneous inventoried domestic well from Levings (1984); and (M)--miscellaneous privately owned well or Montana Bureau of Mines and Geology (MBMG) observation well. The numeric characters for USGS-installed monitoring wells denote the sequence that wells were drilled; for example, well FPB93-3 is the third well drilled in 1993 during this investigation. The numeric part of wells identified by "M" numbers is assigned to allow for cross reference between plate 1 and relevant tables. Brine-injection wells and sampled oil wells are identified using the name assigned by the particular oil company; for example, Murphy 1-D is a brine-injection well, and Murphy 58 is an oil well.

Streamflow measurement sites along the Poplar River are identified by an alpha-numeric system and by latitude-longitude. The alpha-numeric part of the site number follows the system used by Levings (1984) and is based on downstream order, beginning with site PR-0 and ending with site PR-9. One measurement site (PR-8) was located at a long-term USGS streamflow-gaging station (06181000), and one measurement site (PR-1) was located at a USGS miscellaneous streamflow-measurement station (06180600).

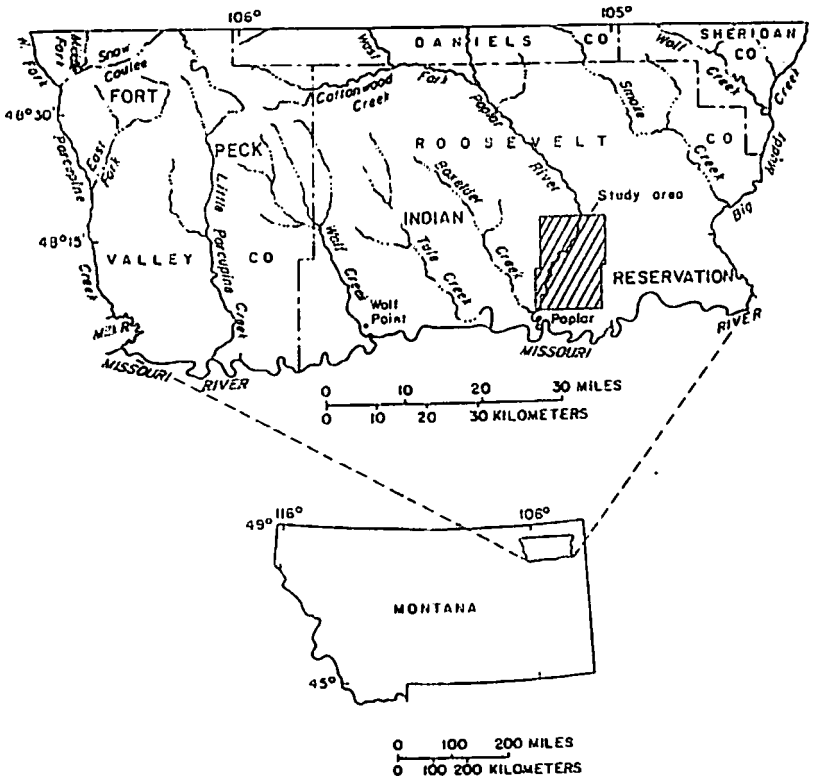


Figure 1. Location of the East Poplar oil field study area, Fort Peck Indian Reservation, northeastern Montana.

MAR02-1380

A

B

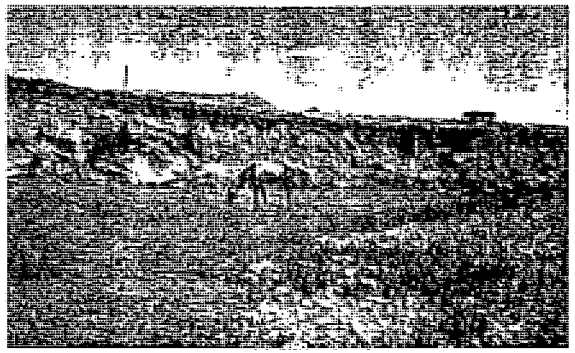
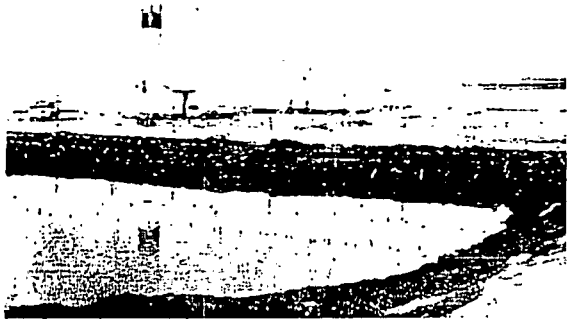


Figure 2. General physiographic features of the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana. (A) View east across the alluvium-filled Poplar River Valley, toward the glacial bench. (B) View east along Poplar River showing typical deposits consisting of a gravel bar on the near side and a river bank formed of reworked glacial deposits on the other side.

Acknowledgments

The authors would like to thank the Fort Peck Tribes for the full cooperation extended to the USGS throughout this investigation. Special appreciation is given to the Water Resources Office and the Office of Environmental Protection of the Fort Peck Tribes for supplying data about existing privately owned wells. Particular thanks for oil-well information and pipeline delineation are extended to Murphy Oil USA, Inc. We also wish to thank individual landowners in the reservation for their cooperation in allowing access to their lands during inventorying, sampling, or drilling monitoring wells, collecting electromagnetic geophysical data, and for their valuable contributions of historical information about the occurrence and use of water resources in the study area, as well as information about oil-field operations.

A



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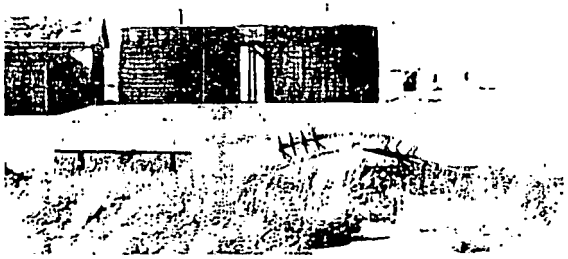

Figure 3. Various surface structures associated with oil production in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana. (A) View east (from SE 1/4 NE 1/4 NW 1/4 SE 1/4, sec. 10., T. 28 N., R. 51 E.) of a brine-injection well (Murphy 8-D; well 28N51E28DBAD01, table 2), storage tanks, and an evaporation pit. (B) View north (from SE 1/4 SE 1/4 SE 1/4, SE 1/4, sec. 30, T. 29 N., R. 51 E.) of wooden oil-storage tanks. In the background and to the right of the tanks is a brine-injection well (Murphy 1-D; well 29N51E30DDDD01, table 2).

PRESENTATION OF DATA

Ground-water data are presented for 60 privately owned wells, 34 USGS-installed monitoring wells (27 installed during this investigation and 7 from Levings, 1984), 5 MBMG-installed wells, 8 sampled oil wells (table 1) and 20 brine-injection wells (table 2). Locations of these wells are plotted on plate 1 (in pocket). Lithologic logs and completion data for the 27 monitoring wells installed during this investigation are given in table 3. Figure 5 illustrates the typical completion of a monitoring well. Data from two aquifer tests (one conducted in alluvial deposits along the Poplar River and one conducted in glacial deposits east of the river) are reported in tables 4 and 5, respectively. The location of the monitoring wells used for the aquifer tests are plotted on plate 1. Results of chemical analyses of samples from privately owned wells, monitoring wells, oil wells, and brine-injection wells are listed in tables 6 and 7. Tables 8 and 9 contain results of chemical anal-

MAR02-1381

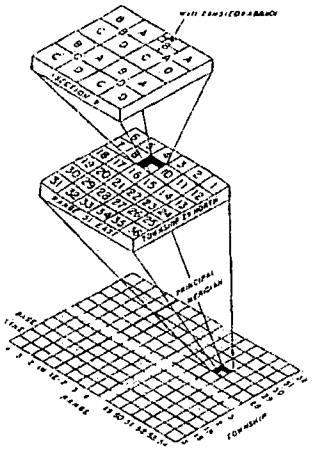

Figure 4. Site-numbering system.

yses of deionized-water field blanks processed through ground-water sampling equipment. Tables 1-9 are located at the back of the report.

Surface-water data are presented for 13 sites along the Poplar River (tables 10 and 11). Table 10 contains the site numbers and locations, along with physical descriptions of the sites; table 11 presents streamflow measurements, specific-conductance values, temperatures, and chloride concentrations of surface water at these sites. The locations of surface-water sites are plotted on plate 1. Results of water-quality analyses at two of the 13 sites (site PR-1, which was measured periodically during this investigation, and site PR-8, which is a long-term USGS gaging station) are presented in tables 12 and 13. Tables 10-13 are located at the back of the report.

Electromagnetic geophysical data were collected within two areas encompassing approximately 20 mi^2 of the East Poplar oil field; these areas are shown on plate 1. The electromagnetic data-collection site coordinates, values of apparent conductivity, and other information are compiled and included on a floppy disk located in the pocket of this report.

DATA-COLLECTION METHODS

Existing data for privately owned wells, monitoring wells, oil wells, brine-injection wells, and ground- and surface-water quality were obtained from various sources. Field activities conducted during this investigation included inventory of existing privately owned and monitoring wells, measurement of electromagnetic geophysical properties, measurements of streamflow along the Poplar River, installation of monitoring wells and description of lithologies, aquifer testing, and water-quality sampling. Methods used to collect these data are described below.

Existing Data

Existing data were obtained from various sources. These data sources and the general types of data obtained from them are listed below.

U.S. Geological Survey, Helena, Mont.--Selected ground-water-level and ground-water-quality data from Levings (1984) and Thamke (1991), selected streamflow and surface-water-quality data from Levings (1984), and geologic information from published geologic maps.

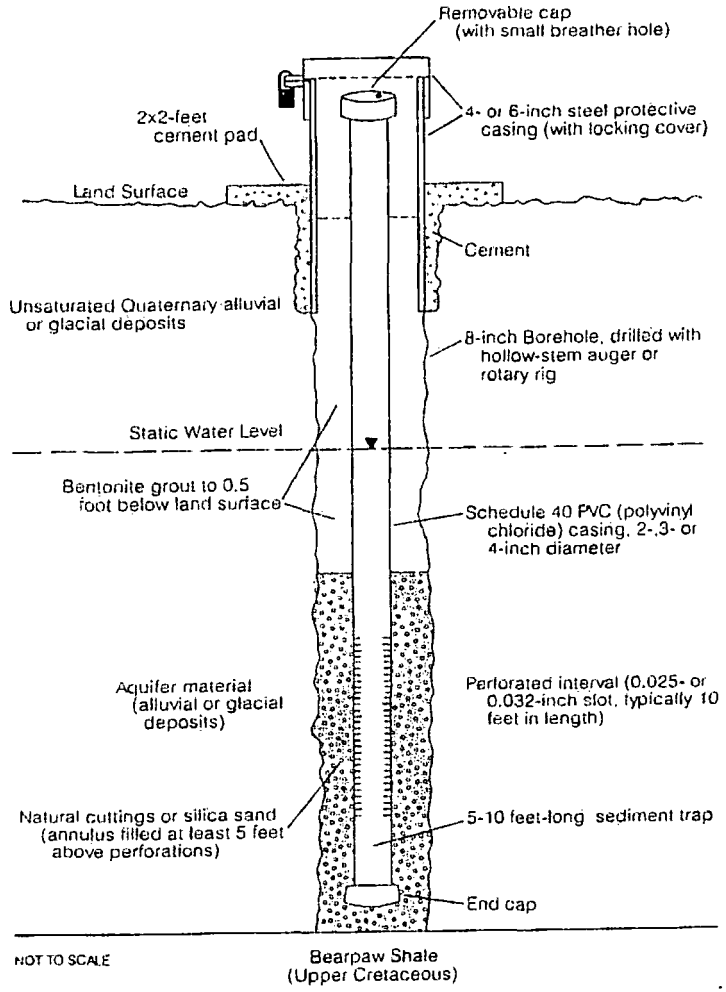

Figure 5. Typical completion of monitoring wells drilled in 1992-93 in Quaternary alluvial or glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (exact completion specifications vary somewhat, depending on site conditions).

MAR02-1382

Bureau of Land Management, Miles City, Mont.--Records of oil and gas wells, records of brine-injection wells, and locations of oil and gas and brine-injection wells.

U.S. Environmental Protection Agency, Helena, Mont.--Detailed information about brine-injection wells and water-quality analyses for water from selected brine-injection wells.

Bureau of Indian Affairs, Poplar, Mont.--Land-ownership maps.

Public Health Service/Indian Health Service-Fort Peck Service Unit, Wolf Point, Mont.--Drill logs of selected water wells and water-quality analyses for water from selected wells.

Fort Peck Tribes, Poplar, Mont.--Water Resources Office--Drill logs of selected water wells, well-ownership information, and water-quality analyses for water from selected wells

Minerals Office--Information about location and status of selected brine-injection wells and subsurface geologic information from geologic maps.

Office of Environmental Protection--Water-quality analyses for water from selected wells and information about brine-injection rates and quantities.

Murphy Oil USA, Inc., Poplar, Mont.--Locations of oil, gas, and brine-injection wells.

Montana Bureau of Mines and Geology, Butte, Mont.--Drill logs of selected water wells and water-quality analyses for water from selected wells.

Well Inventory

All privately owned water wells were inventoried to acquire data in areas not covered by the existing data sources. The well inventory included determination of well location, land-surface altitude, geologic unit, and well depth, and measurements of water level and miscellaneous onsite water quality. Land-surface altitudes were determined from 7.5-minute topographic quadrangle maps, from oil-well records, or by surveying from the nearest benchmark. Geologic units were determined from geologic maps and lithologic logs. Well depths were obtained from well-completion records or by measuring with a graduated steel tape. Water levels were measured during June and July 1990 and September 1991 in existing privately owned and monitoring wells, during August and September 1992 in existing privately owned wells and selected monitoring wells, and during August and September 1993 in the 27 monitoring wells that were drilled for this investigation to determine the potentiometric surface in Quaternary deposits. Wells inventoried during previous investigations (Levings, 1984; Thamke, 1991; Donovan and Bergantino, 1987) were revisited, and information about these wells was updated.

Electromagnetic Geophysics

During summer 1991 and summer 1992, electromagnetic geophysical techniques were used to measure the electrical conductivity of subsurface materials in selected areas (pl. 1). A variable-depth ground-conductivity meter was used. Because water in the Quaternary deposits in the study area has a specific-conductance range of 658–127,000 µS/cm, electromagnetic geophysical techniques were used to help delineate conductive plumes.

The electromagnetic geophysical survey was conducted using either a 0.1-mi grid spacing or a 0.2-mi grid spacing; a grid spacing of 0.1 mi was selected for areas having possible saline-water plumes. Grids were developed for each square mile of the selected area; county roads, fence lines, telephone lines, or power lines were used to ensure north-south and east-west orientation. The base survey line was a north-south line on the edge of the square mile, and all other survey lines emanated from the base line in an east-west direction. The transit was on a north-south line and was oriented either east or west, depending on the position of the survey crew. Distances between survey stations were determined by pacing; generally, distances determined by pacing are accurate to 3 percent or less (Lahee, 1961, p. 550). Data values were recorded on field maps; these maps are on file at the Montana District Office in Helena.

Electromagnetic geophysical measurements during the summer of 1991 were made at Area 1 (pl. 1) with 10-meter and 20-meter intercoil spacing and at Area 2 (pl. 1) with 20-meter and 40-meter intercoil spacing. Measurements during summer 1992 were made in both areas with 10-meter, 20-meter, and 40-meter intercoil spacing. At all intercoil spacings, measurements were made in both the vertical and horizontal dipole positions.

The variable-depth ground-conductivity meter was checked for gain and the receiver was compensated. The meter was nulled daily to remove any offsets in the output circuitry. Individual pacing was standardized at the beginning of each field trip and checked daily.

Streamflow Measurements

Instantaneous streamflow was measured periodically at 13 sites on the Poplar River during this investigation (table 11). In addition, more frequent measurements of instantaneous streamflow were obtained at sites PR-1 and PR-8 as a part of water-quality sampling procedures (table 12). Streamflow and/or miscellaneous water-quality measurements were made during stable streamflow conditions (discharge at site PR-8 varied 5 percent or less per day). All streamflow measurements in this report were collected using standard USGS methods (Rantz and others, 1982).

Monitoring-Well Installation

During summer 1992 and summer 1993, 27 monitoring wells were drilled and completed either in Quaternary alluvial deposits along the Poplar River or in Quaternary glacial deposits east of the river (tables 1 and 3; pl. 1). Most drill holes penetrated a few feet of the Upper Cretaceous Bearpaw Shale, allowing for the perforated interval of the well to be completed in the lowest part of the saturated Quaternary deposits. Three wells (FPB92-2B, FPB93-2, FPB93-3A; table 3; pl. 1) were completed so that the perforated interval was in the shallowest part of the saturated Quaternary deposits; these three wells were located next to wells FPB92-2A, FPB92-1, and FPB93-3, respectively (table 3; pl. 1) that are perforated just above the contact of the Quaternary deposits and the Bearpaw Shale. These three shallow wells were completed to determine vertical differences in water quality and density. Wells completed during 1992 were drilled using hollow-stem augering techniques and wells completed during 1993 were drilled using rotary techniques. Except for wells completed specifically for aquifer testing, monitoring wells were installed in areas where high apparent ground conductivity values were recorded with electromagnetic geophysical equipment.

The monitoring wells were completed with polyvinylchloride (PVC) casing; machine-slotted casing was used in the perforated interval. Wells installed during 1992 were completed with 2-in. casing using a 0.032-in. slot size for the perforated interval (one 1992 well was completed with 3-in. casing and a 0.025-in. slot size); wells installed during 1993 were completed with 4-in. casing with a 0.025-in. slot size. For each well, a sediment trap (typically 5- to 10-ft long) was installed below the perforated interval. The annulus around the perforated interval of each well was packed either with silica sand or with natural cuttings material that caved around the well casing as the auger or drill rod was withdrawn. The annulus above the pack was sealed with bentonite slurry; a cement pad was used as a surface seal. A steel protective casing with locking cover was set into the cement surface pad surrounding each well. Monitoring wells were developed by surging with compressed air until the discharge remained clear and specific conductance remained constant. General details of monitoring-well construction are shown in figure 5; additional data for each well are given in table 1; lithologic logs and completion details for each well are reported in table 3.

Aquifer Testing

Two constant-discharge aquifer tests were conducted during summer 1993, using wells installed during this investigation (tables 1, 4, 5; pl. 1). One test was conducted in alluvial deposits along the Poplar River in the NW 1/4 NE 1/4 sec. 09, T. 29 N., R. 51 E. Drawdown in three observation wells (located at distances of about 8 to 72 ft from the pumped well) was measured while discharge from the pumped well was held constant at 40 gal/min for 180 minutes. After 180 minutes, drawdown in the observation wells ranged from 0.64 to 1.41 ft. Aquifer-test data are presented in table 4.

The other test was conducted in glacial deposits east of the Poplar River in the SE 1/4 SE 1/4 sec. 33, T. 28 N., R. 51 E. Drawdown in two observation wells (located at distances of about 7 to 30 ft from the pumped well) was measured while discharge from the pumped well was held constant at 12.5 gal/min for 110 minutes. After 110 minutes, drawdown in the observation wells ranged from 0.29 to 0.48 ft. Aquifer-test data are presented in table 5.

MAR02-1383

Water-Quality Sampling

Ground-water samples were collected using a variety of samplers. Samples from privately owned wells with pumps were obtained using the existing submersible pump. Samples from monitoring wells that yielded sufficient water and privately owned wells without pumps or power were obtained using either a 2-in. or 4-in. diameter, portable stainless-steel submersible pump. Samples from monitoring wells that yielded insufficient amounts of water to pump were obtained with a PVC bailer. All wells were purged until at least three well volumes of water were removed and parameters measured onsite (pH, water temperature, and specific conductance) had stabilized. Onsite parameters were measured in a flow-through chamber for pumped wells and a clean sample container for bailed wells. Onsite values for alkalinity were determined by incremental titration of the sample with sulfuric acid.

Ground-water samples for chemical analysis were collected from a flow-through chamber for pumped wells or from a sample container for bailed wells. A peristaltic pump was used to pass sample water through a 0.45-micron pore-diameter filter for analysis of dissolved constituents. Water samples for dissolved-organic carbon analysis were collected directly into glass sample containers from a discharge point as close to the well as possible and then filtered. Sample processing, filtration, and preservation were performed in the field using methods described by Knapton (1985).

Ground-water samples (tables 6 and 7) were analyzed for dissolved major ions, trace elements, and organic carbon by the USGS's National Water Quality Laboratory (NWQL) in Arvada, Colo., using methods described by Fishman and Friedman (1989) and Fishman (1993). Ground-water samples were analyzed for oxygen-18/oxygen-16 (O-18/O-16) and deuterium/hydrogen (D/H) isotopic ratios by USGS laboratories in Reston, Va. The O-18/O-16 and D/H results are reported relative to Standard Mean Ocean Water in per mil notation which indicates enrichment (positive value) or depletion (negative value) of the heavy isotope in the sample compared to the standard.

Surface-water samples (tables 11-13) were collected using either the equal-width increment, equal-discharge increment, or dip method described in Knapton (1985). Samples collected during October 22-25, 1990 were analyzed for chloride (with a specific-ion meter) and specific conductance by the USGS District Office in Helena, Mont. Specific conductance and temperature were measured onsite during all other samplings as described by Knapton (1985). All other surface-water samples were collected using methods of Ward and Harr (1990) and were analyzed by the NWQL. Analytical methods are described by Fishman and Friedman (1989) and Fishman (1993).

Data-collection and analytical procedures used during this investigation incorporated practices designed to control, verify, and assess the quality of sample data. Methods and associated quality control for collection and processing of water samples are described by Ward and Harr (1990), Knapton (1985), and Knapton and Nimick (1991). Standard quality-assurance analytical procedures used by the NWQL are described by Friedman and Erdmann (1982) and Jones (1987).

Because of the large concentration of dissolved constituents in many of the ground-water samples, additional steps were taken after sample collection at each site to minimize possible cross-contamination between sites from sampling equipment. The plate-filter and flow-through chamber were disassembled and scrubbed using a low-phosphate detergent and then thoroughly rinsed with deionized water. Portable stainless-steel submersible pumps were placed in either a 4-in. PVC casing (for the 2-in. pump) or a 30-gallon plastic container (for the 4-in. pump) which were filled with tap water. The pump then was operated to flush water through the pump and hoses. A low-phosphate detergent was added to the tap water and passed through the pump and hoses. This was followed by rinsing the equipment with tap water until the detergent was no longer visually detected. The PVC bailer and sampling container were scrubbed using a low-phosphate detergent and then thoroughly rinsed with deionized water.

Quality-control data to document the reproducibility of analytical results and any sample contamination were provided by test samples that consisted of either a replicate sample (table 8) or a field-blank sample (table 9) incorporated in the sampling set. Quality-control samples comprised about 10 percent of the total number of ground-water samples submitted by the USGS for analysis.

A replicate sample is a volume of sampled water split into subsamples in such a manner that the physical and chemical characteristics of each subsample are considered to be essentially identical in composition. The percent difference of constituent concentrations between replicate ground-water samples did not exceed 10 percent.

A field-blank sample for this investigation was a volume of deionized water that was passed through either all or parts of the sampling equipment to test the adequacy of cleaning procedures to prevent cross-contamination between sites. Four field-blank samples were collected during this investigation. The field-blank sample collected after the described cleaning procedures at site 28N51E27DBBB01 on August 29, 1990 was a volume of deionized water passed through sampling hoses and the plate filter. The field-blank sample collected after the described cleaning procedures at site 28N51E16DBCB01 on July 21, 1991 was deionized water passed through the 2-in. stainless steel pump, hoses, flow-through chamber, and plate-filter. About 5 gal of deionized water passed through the system before the field-blank sample was collected in the same manner as the other environmental samples. The field-blank samples collected after the described cleaning procedures at sites 28N51E22CBCB01 on July 21, 1993 and 29N51E32ABAC01 on August 13, 1993 was deionized water passed through the 4-in. and 2-in. stainless-steel pumps, respectively, hoses, flow-through chamber, and plate filter. For both samples, about 20 gal of deionized water passed through the system before the field-blank sample was collected in the same manner as the other environmental samples.

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MAR02-1384

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DATA

MAR02-1385

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

Site number--numbering system described in text.

Well name--naming system described in text (used for cross reference to wells plotted on plate 1).

Altitude of land surface--in feet above sea level (determined from U.S. Geological Survey 7.5-minute topographic maps and reported to whole number; from individual oil-well or brine-injection-well records; or by surveying levels from the nearest benchmark and reported in tenths for selected privately owned wells and for observation wells drilled as part of this study).

Geologic unit (in which well is completed)--

- Qal - Alluvium (Quaternary)
- Qt - Glacial till (Pleistocene)
- Qgo - Glacial outwash (Pleistocene)
- Qw - Wiota Gravel (Pleistocene)
- Tf - Flaxville Formation (Pliocene and Miocene)
- Khf - Hell Creek Formation and Fox Hills Sandstone (Upper Cretaceous)
- Kb - Bearpaw Shale (Upper Cretaceous)
- Kjr - Judith River Formation (Upper Cretaceous)
- Mh - Heath Formation (Upper Mississippian)
- Mk - Kibbey Formation (Upper Mississippian)
- Mm - Madison Group (Mississippian)
  - Mc - Charles Formation of Madison Group
  - Mmc - Mission Canyon Limestone of Madison Group

Depth of well--in feet below land surface.

Primary use of site--Ab, abandoned; O, observation; P, oil or gas production; U, unused; W, withdrawal; Z, destroyed. Sites with two uses listed indicate that the primary use initially was the first use, but subsequently became the second use.

Primary use of water--H, domestic; S, livestock; U, unused; Z, other. Sites with two uses listed indicate that the primary use initially was the first use, but subsequently became the second use.

Water level--Depth, in feet below land surface. Altitude, in feet above sea level (determined as the difference between altitude of land surface and depth to water) reported to whole number or tenths, depending on accuracy of altitude of land surface.

Specific conductance--reported in microsiemens per centimeter at 25 degrees Celsius.

Symbol: --, no data.

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit	Depth of well (feet)	Primary use of site	Primary use of water	Water level: Depth to water (feet)	Water level: Date of measurement	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conductance measured
28N51E01BBBB01 M-1	2,190	Qt	153	W	H	48.50	07-19-82	2,142	2,820	07-21-82
						--	--	--	4,000	08-22-90
						--	--	--	3,930	07-20-91
28N51E04CCCD01 M-2	2,015	Qt	50	W	H	--	--	--	2,650	06-29-90
						--	--	--	2,650	08-25-90
28N51E05ADDA01 M-3	1,985.9	Qal	52	W	H	13.50	08-23-90	1,972.4	2,150	06-28-90
						13.35	09-12-91	1,972.6	[1]2,050	08-23-90
28N51E08BACC01 M-4	1,990	Qal	15	W	H	13.20	06-29-90	1,977	--	--
28N51E08BACC02 M-5	1,984.1	Qal	25	U	U	14.40	06-29-90	1,969.7	--	--
28N51E08BBDA01 M-6	1,990	Qal	19	U	U	13.06	06-29-90	1,977	--	--
28N51E08BBDD01 M-7	1,992.0	Qal	14	W	S	6.75	06-10-89	1,985.2	2,120	06-10-89
						11.04	10-25-89	1,981.0	2,900	10-25-89
						9.62	06-29-90	1,982.4	--	--
28N51E08BDBA01 M-8	1,986.1	Qal	39	U	U	14.00	06-29-90	1,972.1	--	--
28N51E08BDBA02 M-9	1,986.1	Qal	24	U	U	14.40	06-29-90	1,971.7	--	--
28N51E08CCBB01 M-10	1,976.4	Qal	22	W	H	8.67	07-01-90	1,967.7	[1]1,500	11-03-88
28N51E08CCBC01 M-11	1,980	Qal	22	W	H	14.30	07-01-90	1,966	1,460	07-01-90
28N51E08CCBC02 M-12	1,980	Qal	20	W,Z	U	13	03-03-82	1,967	--	--
28N51E03DDDB01 M-13	2,026.9	Qt	102	W	H	57.1	06-28-90	1,969.8	9,500	06-28-90
						57.25	08-25-90	1,969.6	8,120	08-25-90
						54.31	09-12-91	1,972.6	--	--
28N51E09BCBB01 M-14	2,043.7	Qt	90	U	U	71.30	06-29-90	1,972.4	2,610	07-17-91
						70.59	07-17-91	1,973.1	--	--
						71.29	09-12-91	1,972.4	--	--
28N51E09CCDD01 M-15	2,041.2	Qt	117	W	U	71.66	06-27-90	1,969.5	[1]2,910	04-07-89
						70.80	07-19-91	1,970.4	[1]3,220	03-16-89
						70.46	09-12-91	1,970.7	3,750	06-27-90
						--	--	--	[1]3,180	07-19-91
28N51E09CDBB01 FPB93-5	2,026.4	Qt	104	O	U	51.03	07-24-93	1,975.4	18,300	03-12-93
						52.77	03-12-93	1,973.6	--	--

MAR02-1386

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conduct-ance measured
28N51E09DCCC01 FPB92-15	2,039.4	Qt	93	O	U	69.70	10-21-92	1,969.7	1,400	08-13-93
						67.00	05-25-93	1,972.4	--	--
						66.63	08-12-93	1,972.8	--	--
						67.03	09-08-93	1,972.3	--	--
28N51E12CCBD01 Murphy 24	2,169	Mm	[2]5,910-5,920	P	Z	--	--	--	--	--
28N51E13CCCA01 M-16	2,075	Qt	33	U	U	14.51	07-01-90	2,060	3,600	08-22-90
						14.06	08-22-90	2,061	--	--
						15.00	09-16-91	2,060	--	--
28N51E13CCCC01 M-17	2,180	Qw	150	W	H	132.74	05-16-89	2,047	2,990	05-16-89
						129.14	07-01-90	2,051	3,150	07-01-90
						131.46	08-22-90	2,049	3,000	08-22-90
						129.13	09-16-91	2,051	--	--
28N51E16DBCB01 M-18	2,046.2	Qt	104	W,U	H,U	79.72	07-23-89	1,966.5	10,000	07-23-89
						79.60	10-25-89	1,966.6	12,700	07-21-91
						79.62	06-30-90	1,966.6	--	--
						78.91	07-21-91	1,967.3	--	--
						79.65	09-12-91	1,966.6	--	--
						81.78	08-23-92	1,964.4	--	--
28N51E17AABA01 M-19	1,990	Qt	37	U	U	25.59	06-29-90	1,964	--	--
28N51E17ABDC01 M-20	1,978.6	Qal	36	U	U	11.79	06-27-90	1,966.8	7,000	08-26-90
						11.84	08-26-90	1,966.8	--	--
						11.78	09-16-91	1,966.8	--	--
28N51E17ABDC02 M-21	1,975.9	Qal	36	U	U	9.36	08-23-92	1,966.5	--	--
28N51E17ABDD01 M-22	1,990.6	Qt	40	W	H	24.07	06-27-90	1,966.5	10,000	06-27-90
						24.10	08-26-90	1,966.5	8,600	08-26-90
						24.02	09-16-91	1,966.6	--	--
						24.15	08-23-92	1,966.4	--	--
28N51E17ABDD02 M-23	1,992.7	Qal	68	U	U	25.37	09-16-91	1,967.3	--	--
						25.45	08-23-92	1,967.2	--	--
28N51E17ADAD01 M-24	2,031.1	Qt	130	W	H	63.60	08-28-90	1,967.5	4,550	08-28-90
						62.80	07-16-91	1,968.3	5,380	07-16-91
						63.60	09-12-91	1,967.5	--	--
						63.77	08-23-92	1,967.3	--	--
28N51E17DADA01 M-25	2,030.9	Qt	102	W	H	75.99	06-30-90	1,954.9	[1]1,080	02-10-75
						66.09	08-25-90	1,964.8	5,200	07-22-89
						65.86	09-12-91	1,965.0	4,600	06-30-90
						66.06	08-23-92	1,964.8	4,400	08-25-90

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conduct-ance measured
28N51E18ABDC01 M-26	2,000	Qgo	--	W	H	--	--	--	790	07-01-90
28N51E21BDBC01 M-27	2,029.1	Qt	91	W,U	H,U	66.74	08-26-90	1,962.4	6,500	07-20-89
						66.40	09-12-91	1,962.7	5,820	08-26-90
						66.74	08-23-92	1,962.4	--	--
28N51E22BBBB01 FPB92-12	2,061.6	Qt	65	O	U	18.66	10-21-92	2,042.9	3,050	07-24-93
						16.92	05-26-93	2,044.7	--	--
						15.10	07-21-93	2,046.5	--	--
28N51E22BDCA01 Duckles A-1	2,085	Mc	5,572	P,Ab	U	--	--	--	[1]120,000	04-30-81
28N51E22CBCB01 FPB93-3	2,080.0	Qt	81	O	U	36.79	07-21-93	2,043.2	98,600	07-21-93
						35.76	09-08-93	2,044.2	--	--
28N51E22CBCB02 FPB93-3A	2,080.0	Qt	49	O	U	36.49	07-20-93	2,043.5	97,200	07-20-93
						35.34	09-08-93	2,044.7	--	--
28N51E22CDCC01 M-28	2,102.8	Qt	85	W,U	H,U	57.87	07-14-83	2,044.9	4,000	07-14-83
						59.26	07-01-90	2,043.5	[1]4,010	07-09-85
						59.25	06-23-91	2,043.6	13,000	07-20-89
						59.25	07-20-91	2,043.6	11,400	10-26-89
						59.06	09-12-91	2,043.7	26,500	07-20-91
						58.83	08-23-92	2,044.0	--	--
28N51E22CDCC02 M-29	2,102.7	Qt	85	W,U	H,U	60.20	07-20-89	2,042.5	--	--
						59.99	10-26-89	2,042.7	--	--
28N51E25ACBC01 Tenneco 1	2,178	Mh Mc	[2]5,350-5,380 [2]5,640-5,650	P,Ab	Z	-- --	-- --	-- --	73,200 160,000	01-09-67 01-09-67
28N51E27ABAA01 M-30	2,161.1	Qt	135	W	H	118.26	07-01-90	2,042.8	[1]1,310	10-11-89
						120.27	08-24-90	2,040.8	[1]1,550	11-10-89
						118.27	06-07-91	2,042.8	[1]1,760	12-15-89
						118.15	06-11-91	2,043.0	1,750	07-01-90
						118.15	09-12-91	2,043.0	1,120	08-24-90
						117.88	08-23-92	2,043.2	2,100	09-12-91
						--	--	--	1,550	04-15-92
						--	--	--	1,500	07-23-93
28N51E27ACDB01 Murphy 63	2,167	Mh	[2]4,960-4,970	P,Ab	Z	--	--	--	--	--

MAR02-1387

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit	Depth of well (feet)	Primary use of site	Primary use of water	Water level: Depth to water (feet)	Water level: Date of measurement	Water level: Altitude (feet)	Specific conductance, on site (µS/cm)	Date specific conductance measured
28N51E27BBB01 M-31	2,055.0	Qt	68	W,U	H,U	32.50	07-24-89	2,052.5	[1]3,470	05-23-83
						42.43	10-25-89	2,042.6	[1]15,400	11-21-88
						42.41	07-01-90	2,042.6	25,000	07-24-89
						42.43	08-27-90	2,042.6	22,500	10-25-89
						42.42	01-31-91	2,042.6	48,000	08-27-90
						42.32	04-05-91	2,042.7	[1]52,700	01-31-91
						42.30	05-08-91	2,042.7	51,400	05-08-91
						42.70	06-20-91	2,042.3	63,000	07-22-91
						41.53	07-22-91	2,043.5	50,000	04-15-92
						42.23	09-12-91	2,042.8	81,500	07-23-93
						42.20	04-15-92	2,042.8	--	--
						42.10	08-23-92	2,042.9	--	--
						41.52	07-23-93	2,043.5	--	--
28N51E29BACA01 M-32	1,974.6	Qal	50	W	H	18.49	05-15-93	1,956.1	2,060	03-17-93
28N51E29CACB01 M-33	1,974.9	Qal	32	W	H	27.88	06-29-90	1,947.0	670	06-29-90
						27.89	08-23-90	1,947.0	660	08-23-90
28N51E32CCCB01 M-34	2,020	Qt	120	W	H	--	--	--	1,200	06-30-90
28N51E32DCCC01 M-35	2,030	Qt	104	U	U	80.35	06-27-90	1,950	--	--
						81.10	09-16-91	1,949	--	--
28N51E33BBBB01 M-36	2,041.4	Qt	120	W	H	89.96	06-27-90	1,951.4	[1]2,630	03-17-89
						90.06	08-24-90	1,951.4	2,000	06-27-90
						89.70	09-12-91	1,951.7	2,670	08-24-90
28N51E33BBBC01 M-37	2,045	Qt	107	U	U	91.17	06-27-90	1,954	--	--
						91.95	09-12-91	1,953	--	--
28N51E33BBBC02 M-38	2,045	Qt	120	W	H	92.01	08-24-90	1,953	[1]2,150	03-16-89
						91.68	09-12-91	1,953	2,700	08-24-90
28N51E33CBAA01 M-39	2,050	Qt	130	U	U	100.78	06-27-90	1,949	--	--
28N51E33DDCC01 M-40	2,075	Qw	60	U	U	43.76	06-29-90	2,031		--
						43.09	09-16-91	2,032	--	--
28N51E33DDCC02 M-41	2,075	Qw	66	W,U	H,U	42.58	06-29-90	2,032	3,400	06-29-90
						41.44	09-16-91	2,034	--	--
						40.39	08-17-93	2,035	--	--
28N51E33DDCC03 FPB93-4A	2,070.6	Qw	65	O	U	41.46	08-16-93	2,029.3	3,820	08-17-93
						41.55	08-17-93	2,029.2	--	--
						41.09	09-08-93	2,029.7	--	--
28N51E33DDCC04 FPB93-4B	2,070.8	Qw	65	O	U	41.64	08-16-93	2,029.2	--	--
						41.71	08-17-93	2,029.1	--	--
						41.27	09-08-93	2,029.5	--	--

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit	Depth of well (feet)	Primary use of site	Primary use of water	Water level: Depth to water (feet)	Water level: Date of measurement	Water level: Altitude (feet)	Specific conductance, on site (µS/cm)	Date specific conductance measured
28N51E33DDCC05 FPB93-4C	2,070.8	Qw	66	O	U	41.81	08-16-93	2,029.0	--	--
						41.90	08-17-93	2,028.9	--	--
						41.45	09-08-93	2,029.4	--	--
28N52E18ACCA01 Murphy 2	2,135	Mnc	[2]6,020-6,050	P,Ab	Z	--	--	--	60,000	03-17-52
28N52E20BBBB01 M-42	2,125	Qw	103	O	U	[3]72.60	10-06-85	2,052	[3]1,780	10-06-85
						[3]72.18	08-15-85	2,053	--	--
						[3]72.31	10-06-85	2,053	--	--
						[3]72.16	11-04-85	2,053	--	--
						[3]73.03	12-10-85	2,052	--	--
						[3]72.38	01-14-86	2,053	--	--
						[3]74.85	02-11-86	2,050	--	--
						[3]72.53	04-04-86	2,052	--	--
						[3]72.30	05-07-86	2,052	--	--
						[3]72.43	06-10-86	2,053	--	--
						[3]72.45	07-03-86	2,053	--	--
						[3]72.20	08-06-86	2,053	--	--
						[3]72.10	09-11-86	2,053	--	--
						[3]72.58	10-03-86	2,052	--	--
						[3]71.91	11-20-86	2,053	--	--
						[3]72.27	01-09-87	2,053	--	--
						[3]72.08	02-11-87	2,053	--	--
						[3]72.22	03-10-87	2,053	--	--
						[3]71.74	04-09-87	2,053	--	--
						[3]71.63	05-12-87	2,053	--	--
						[3]71.72	06-03-87	2,053	--	--
						[3]71.78	06-30-87	2,053	--	--
						[3]71.75	07-31-87	2,053	--	--
						[3]72.35	10-09-87	2,053	--	--
						[3]70.99	03-27-88	2,054	--	--
						[3]71.49	07-15-88	2,054	--	--
						[3]70.75	12-15-88	2,054	--	--

MAR02-1388

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conduct-ance measured
28N52E20CCCC01 M-43	2,143	Qw	128	O	U	[5]96.4	07-24-85	2,047	2,240	08-21-90
						[5]96.10	08-15-85	2,047	--	--
						[5]96.38	10-05-85	2,047	--	--
						[5]96.04	11-04-85	2,047	--	--
						[5]96.90	12-10-85	2,046	--	--
						[5]96.25	01-14-86	2,047	--	--
						[5]95.70	02-11-86	2,044	--	--
						[5]96.62	03-06-86	2,046	--	--
						[5]96.32	04-04-86	2,047	--	--
						[5]96.29	05-07-86	2,047	--	--
						[5]96.74	06-10-86	2,047	--	--
						[5]96.24	07-08-86	2,047	--	--
						[5]96.03	08-06-86	2,047	--	--
						[5]95.93	09-11-86	2,047	--	--
						[5]96.40	10-08-86	2,047	--	--
						[5]95.75	11-20-86	2,047	--	--
						[5]96.16	01-09-87	2,047	--	--
						[5]95.93	02-11-87	2,047	--	--
						[5]96.07	03-10-87	2,047	--	--
						[5]95.61	04-09-87	2,047	--	--
						[5]95.52	05-12-87	2,047	--	--
						[5]95.55	06-05-87	2,047	--	--
						[5]95.65	06-30-87	2,047	--	--
						[5]95.61	07-31-87	2,047	--	--
						[5]96.23	10-09-87	2,047	--	--
						[5]94.97	03-27-88	2,048	--	--
						[5]95.47	07-15-88	2,048	--	--
						[5]94.80	12-18-88	2,048	--	--
						94.80	07-01-90	2,048	--	--
						95.06	08-21-90	2,048	--	--
28N52E30DDDD01 M-44	2,173	Qw	170	O	U	[3]140.55	03-15-55	2,032	[3]2,950	10-05-85
						[3]140.65	10-05-55	2,032	--	--
						[3]137.30	11-04-55	2,036	--	--
						[3]79.09	12-10-85	2,094	--	--
						[3]78.29	01-14-86	2,095	--	--
						[3]77.16	03-06-86	2,096	--	--
						[3]113.07	05-07-86	2,060	--	--
						[3]76.34	06-10-86	2,096	--	--
29N50E14CDAD01 M-45	2,380	Tf	44	U	U	37.60	06-29-90	2,342	--	--
29N50E14CDDD01 M-46	2,380	Tf	48	U	U	41.50	06-29-90	2,338	--	--
29N50E23BAAA01 M-47	2,380	Tf	--	U	U	8.66	06-29-90	2,371	--	--
29N51E08CCCA01 Murphy 58	2,100	Mc	5,970	P	Z	--	--	--	62,200	01-24-56

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conduct-ance measured
29N51E09ABBA01 FPB92-15	2,038.6	Qal	42	O	U	8.98	09-22-92	2,029.6	1,240	09-22-92
						8.57	05-25-93	2,030.1	--	--
						7.57	08-16-93	2,031.0	--	--
						7.76	09-09-93	2,030.8	--	--
29N51E09ABBA02 FPB92-16	2,038.5	Qal	38	O	U	8.95	09-24-92	2,029.6	1,240	09-24-92
						8.52	05-25-93	2,030.0	--	--
						7.55	08-16-93	2,031.0	--	--
29N51E09ABBA03 FPB92-17	2,035.4	Qal	42	O	U	8.79	09-22-92	2,029.6	1,240	09-22-92
						5.38	05-25-93	2,030.0	--	--
						7.26	08-16-93	2,031.1	--	--
29N51E09ABBA04 FPB93-1	2,033.5	Qal	35	O	U	7.42	08-16-93	2,031.1	1,260	08-16-93
29N51E10CDAA01 M-48	2,070	Qs	57	W	H	49.84	06-29-90	2,020	2,550	06-29-90
						49.35	09-11-91	2,021	--	--
29N51E10CDAB01 M-49	2,070	Qs	60	W	S	44.70	06-29-90	2,025	[1]1,940	05-14-85
						44.34	09-11-91	2,026	--	--
29N51E10CDBA01 M-50	2,065	Qal	90	W,U	S,U	44.44	05-05-82	2,021	1,390	05-05-82
						--	--	--	1,360	07-21-82
29N51E14BDDA01 M-51	2,190	Khf	160	U	U	--	--	--	1,550	06-28-90
29N51E15CACA01 M-52	2,055	Qal	62	W	H	--	--	--	1,850	06-28-90
						--	--	--	1,710	07-19-91
29N51E15CCBD01 M-53	2,041.7	Qal	65	W	H	29.23	06-28-90	2,012.5	--	--
29N51E16BDAA01 W-1	2,030.6	Qal	53	U	U	9.14	07-20-82	2,021.5	1,550	07-20-91
						10.32	11-03-82	2,020.3	--	--
						9.93	04-07-83	2,020.6	--	--
						10.79	11-18-83	2,019.8	--	--
						11.22	06-30-90	2,019.4	--	--
						10.49	07-18-91	2,020.1	--	--
						10.80	09-11-91	2,019.8	--	--
						11.22	08-23-92	2,019.4	--	--
29N51E16CBCC01 W-2	2,030.2	Qal	25	U	U	13.48	05-04-82	2,016.7	[1]1,610	07-23-79
						13.52	07-20-82	2,016.7	900	07-26-82
						15.22	07-22-89	2,015.0	--	--
						15.52	06-30-90	2,014.7	--	--
29N51E16CCAA01 W-3	2,027.0	Qal	23	W	Z	9.31	05-04-82	2,017.7	1,140	05-04-82
						11.90	06-11-89	2,015.1	1,140	07-20-82
						12.13	06-30-90	2,014.9	1,200	06-11-89
						10.51	07-18-91	2,016.5	1,220	07-18-91

MAR02-1389

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, on site (µS/cm)	Date specific conduct-ance measured
29N51E16DACA01 M-54	2,018.2	Qal	25	W	H	4.83	06-29-90	2,013.4	[1]1,220	03-08-90
						6.25	08-23-90	2,012.0	1,650	06-29-90
						6.00	09-11-91	2,012.2	1,520	08-23-90
29N51E17CCCC01 W-4	2,064.8	Qal or Kb	87	U	U	55.66	05-04-82	2,009.1	[1]1,070	07-23-79
						55.31	07-20-82	2,009.5	[1]11,500	07-27-82
						55.47	11-03-82	2,009.3	9,500	07-22-89
						55.48	04-07-83	2,009.3	--	--
						55.59	07-13-83	2,009.2	--	--
						55.73	11-18-83	2,009.1	-	--
						56.90	07-22-89	2,007.9	--	-
						57.08	06-30-90	2,007.7	--	--
						56.65	09-11-91	2,008.2	--	--
						56.94	08-23-92	2,007.9	--	--
29N51E19DCAC01 M-55	2,060	Kp	740	W,U	Z,U	--	--	--	17,000	07-22-82
29N51E20ABBA02 W-6	2,037	Qal	44	U	U	24.67	07-27-82	2,012	[1]7,300	07-23-79
						25.70	06-30-90	2,011	[1]7,400	07-26-82
29N51E20BCDB01 Murphy 84	2,049	Mm	5,773	P	Z	--	--	--	[1]62,500	03-01-76
29N51E20CCDB01 Murphy 21	2,027	Mm	5,750	P	Z	--	--	--	[1]62,500	03-01-76
29N51E20DABB01 FPB92-13	2,011.7	Qal	56	O	U	16.89	09-22-92	1,996.8	12,800	09-22-92
						20.39	05-25-93	1,993.3	14,200	08-15-93
						15.76	08-15-93	1,997.9	--	--
29N51E21ABCB01 W-7	2,016	Qal	197	U	U	11.37	05-04-82	2,005	-	--
						11.20	07-20-82	2,005	--	--
						11.20	11-03-82	2,005	--	--
29N51E21ABCC01 W-8	2,025.1	Qal	12	W	H	9.51	05-04-82	2,015.6	[1]1,240	07-23-79
						11.51	06-11-89	2,013.6	1,250	05-04-82
						11.37	07-15-91	2,013.8	1,200	07-20-82
						--	--	--	1,500	06-11-89
						--	--	--	1,520	07-15-91
29N51E21ABDA01 FPB92-14	2,027.9	Qal	33	O	U	12.39	09-22-92	2,015.5	1,380	09-22-92
						11.93	05-25-93	2,016.0	1,500	08-15-93
						11.42	08-15-93	2,016.5	--	--

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geo-logic unit	Depth of well (feet)	Pri-mary use of site	Pri-mary use of water	Water level: Depth to water (feet)	Water level: Date of measure-ment	Water level: Altitude (feet)	Specific conductance, on site (µS/cm)	Date specific conduct-ance measured
29N51E21BBAA01 W-9	2,025.4	Qal	17	U	U	9.40	05-04-82	2,016.0	[1]3,070	07-23-79
						9.82	07-20-82	2,015.6	3,100	07-26-82
						10.60	11-03-82	2,014.8	4,600	07-22-89
						10.53	04-07-83	2,014.9	--	--
						10.97	07-13-83	2,014.4	--	--
						11.04	11-18-83	2,014.4	--	--
						11.67	04-19-89	2,013.7	--	--
						11.85	07-22-89	2,013.6	--	--
						12.01	06-30-90	2,013.4	--	--
						11.08	09-11-91	2,014.3	--	--
						11.88	08-23-92	2,013.5	--	--
29N51E29CBB001 W-10	2,007	Qal	45	O,Z	U	11.23	08-31-82	1,996	10,000	11-03-82
						11.51	11-02-82	1,995	--	--
						11.53	04-07-83	1,995	--	
						11.97	07-13-83	1,995	--	--
						12.39	11-15-83	1,995	--	--
29N51E31AABB01 W-11	2,013.1	Qal	54	O	U	19.55	08-31-82	1,993.6	17,000	11-03-82
						19.87	11-02-82	1,993.2	12,000	04-19-89
						19.69	04-07-83	1,993.4	13,500	07-23-89
						20.12	07-13-83	1,993.0	--	--
						20.48	11-18-83	1,992.6	--	--
						20.48	04-19-89	1,992.6	--	--
						20.75	07-23-89	1,992.4	--	--
						21.06	08-27-90	1,992.0	--	--
						20.57	09-11-91	1,992.5	--	--
						19.64	09-09-93	1,993.5	--	--
29N51E31ABDD01 FPB92-6	2,006.1	Qal	43	O	U	15.59	09-23-92	1,990.5	15,100	09-23-92
						15.26	05-26-93	1,990.8	15,100	08-10-93
						14.46	08-10-93	1,991.6	--	--
						14.68	09-09-93	1,991.4	--	--
29N51E31DDBA01 FPB92-10	2,006.2	Qal	40	O	U	17.62	09-23-92	1,988.6	8,380	09-23-92
						17.31	05-26-93	1,988.9	8,900	08-10-93
						16.39	08-09-93	1,989.8	--	--
						16.82	09-09-93	1,989.4	--	--
29N51E31CAB001 FPB92-9	1,994.3	Qal	33	O	U	8.57	09-23-92	1,985.7	74,500	09-23-92
						8.27	05-26-93	1,986.0	24,500	08-11-93
						7.10	08-11-93	1,987.2	--	--
						7.90	09-10-93	1,986.4	--	--
29N51E31DBAD01 FPB92-7	1,998.5	Qal	37	O	U	10.54	09-23-92	1,988.0	31,000	09-23-92
						10.40	05-26-93	1,988.1	[1]26,300	08-11-93
						9.22	08-11-93	1,989.3	--	--
						9.65	09-10-93	1,988.8	--	--

MAR02-1390

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit	Depth of well (feet)	Primary use of site	Primary use of water	Water level: Depth to water (feet)	Water level: Date of measurement	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conductance measured
29N51E31DBDD01 FPB92-8	1,993.9	Qal	33	O	U	8.30	09-23-92	1,985.6	35,000	09-23-92
						7.81	05-26-93	1,986.1	31,500	08-12-93
						6.42	08-11-93	1,987.5	--	--
						6.79	09-10-93	1,987.1	--	--
29N51E32ABAC01 FPB92-4	2,018.7	Qal	41	O	U	29.34	10-21-92	1,989.4	75,100	10-21-92
						24.34	05-25-93	1,994.4	25,600	08-13-93
						21.88	07-26-93	1,996.8	--	--
						22.89	08-13-93	1,995.8	--	--
29N51E32ACCA01 FPB92-5	2,019.2	Qal	30	O	U	22.67	10-21-92	1,996.5	19,600	10-21-92
						22.50	05-25-93	1,996.7	18,600	08-14-93
						22.87	07-26-93	1,996.3	--	--
						22.85	08-14-93	1,996.4	--	--
29N51E32BAAD01 FPB92-3	2,002.1	Qal	39	O	U	8.95	10-20-92	1,993.2	57,100	10-20-92
						8.49	05-25-93	1,993.6	35,400	08-14-93
						7.20	08-13-93	1,994.9	--	--
						7.71	09-10-93	1,994.4	--	--
29N51E32BABB01 FPB92-2A	2,001.4	Qal	46	O	U	8.45	09-24-92	1,993.0	90,000	09-24-92
						7.97	05-25-93	1,993.4	102,000	07-26-93
						5.14	07-26-93	1,996.3	--	--
29N51E32BABB02 FPB92-2B	2,001.6	Qal	27	O,Z	U	7.74	09-24-92	1,993.9	17,600	09-24-92
						7.36	05-25-93	1,994.2	--	--
						4.46	07-26-93	1,997.1	--	--
29N51E32DBAA01 W-12	1,999	Qal	42	O,Z	U	8.37	08-31-82	1,991	70,000	11-02-82
						8.12	11-02-82	1,991	--	--
						7.67	04-07-83	1,991	--	--
						8.29	07-13-83	1,991	--	--
29N51E32BBBA01 W-13	2,003.6	Qal	31	O,Z	U	9.50	08-31-82	1,994.1	--	--
						9.88	11-02-82	1,993.7	--	--
						9.16	04-07-83	1,994.4	--	--
						9.67	07-13-83	1,993.9	--	--
						8.81	05-02-89	1,994.8	--	--
						8.83	07-21-91	1,994.8	--	--
						8.15	09-11-91	1,995.4	--	--
29N51E32BDBA02 W-14	2,000	Qal	47	O,Z	U	9.48	08-31-82	1,991	58,000	11-02-82
						9.69	11-02-82	1,990	--	--
						9.06	04-07-83	1,991	--	--
						9.77	07-13-83	1,990	--	--
						10.04	11-18-83	1,990	--	--
29N51E32DBBA03 FPB92-1	2,004.2	Qal	53	O	U	11.14	09-24-92	1,993.1	123,000	09-24-92
						12.23	05-25-93	1,992.0	127,000	07-23-93
						10.78	07-25-93	1,993.4	--	--
						10.80	09-09-93	1,993.4	--	--
29N51E32DBBA04 FPB93-2	2,004.2	Qal	27	O	U	8.59	07-25-93	1,995.6	12,300	07-25-93

Table 1. Records of privately owned wells, monitoring wells, and sampled oil wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit	Depth of well (feet)	Primary use of site	Primary use of water	Water level: Depth to water (feet)	Water level: Date of measurement	Water level: Altitude (feet)	Specific conductance, onsite (µS/cm)	Date specific conductance measured
29N51E32BBBB01 W-15	2,004.2	Qal	49	O	U	10.21	08-31-82	1,994.0	170,000	11-03-82
						10.20	11-02-82	1,994.0	30,000	04-19-89
						9.78	04-07-83	1,994.4	65,000	07-23-89
						10.24	07-13-83	1,994.0	--	--
						10.50	11-18-83	1,993.7	--	--
						10.20	04-19-89	1,994.0	--	--
						9.60	07-23-89	1,994.6	--	--
						11.94	08-27-90	1,992.3	--	--
29N51E32BCCA01 W-16	1,996	Qal	40	O,Z	U	8.84	08-31-82	1,987	70,000	11-02-82
						8.81	11-02-82	1,987	--	--
						8.16	04-07-83	1,988	--	--
						8.87	07-13-83	1,987	--	--
						8.97	11-18-83	1,987	--	--
29N51E32BCCA02 FPB92-11	2,001.1	Qal	45	O	U	10.19	09-24-92	1,990.9	36,600	09-24-92
						9.93	05-26-93	1,991.2	41,700	08-11-93
						8.76	08-10-93	1,992.3	--	--
29N51E36CBBB01 M-56	2,050	Qgo	42	O	U	[3]24.71	03-25-85	2,055	--	--
						[3]24.75	10-05-85	2,055	--	--
						[3]24.68	11-04-85	2,055	--	--
						[3]24.83	12-10-85	2,055	--	--
						[3]24.67	04-04-86	2,055	--	--
						[3]24.42	05-06-86	2,056	--	--
						[3]24.10	06-10-86	2,056	--	--
						[3]24.15	07-08-86	2,056	--	--
						[3]24.19	08-06-86	2,056	--	--
						[3]24.20	09-11-86	2,056	--	--
						[3]23.96	10-08-86	2,056	--	--
						[3]23.80	11-20-86	2,056	--	--
						[3]24.02	01-09-87	2,056	--	--
						[3]24.15	02-11-87	2,056	--	--
						[3]24.18	03-16-87	2,056	--	--
						[3]24.02	04-09-87	2,056	--	--
						[3]23.89	05-12-87	2,056	--	--
						[3]23.79	06-05-87	2,056	--	--
						[3]23.89	06-30-87	2,056	--	--
						[3]23.96	07-31-87	2,056	--	--
						[3]23.77	10-09-87	2,056	--	--
						[3]23.32	03-27-88	2,057	--	--
						[3]24.52	07-15-88	2,055	--	--
						[3]24.91	12-18-88	2,055	--	--
						25.02	07-01-90	2,055	--	--
29N51E36CCCC01 M-57	2,065	Qgo	30	O	U	[3]6.55	10-05-85	2,058	[3]658	10-05-85
						7.22	07-01-90	2,058	--	--

[1]Laboratory measurement; specific laboratory listed in table 6.
[2]Sampling depth.
[3]Montana Bureau of Mines and Geology, Butte, Mont.

MAR02-1391

Table 2. Records of known brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

Site number--numbering system described in text.

Well name--oil company name for specified well. Sites are plotted on plate 1.

Altitude of land surface--in feet above sea level, determined from USGS 7.5-minute topographic maps, or from individual brine-injection well records.

Geologic unit (unit either into which brine is injected or that is the source of the brine)--

- Kjr - Judith River Formation (Upper Cretaceous)
- Kd - Dakota Sandstone (Lower Cretaceous)
- Mh - Heath Formation (Upper Mississippian)
- Mm - Madison Group (Mississippian)
  - Mc - Charles Formation of Madison Group
  - Mmc - Mission Canyon Limestone of Madison Group
- Dn - Nisku Formation (Upper Devonian)

Drilled depth and well depth--in feet below land surface.

Site status--Ac, Active; Ab, abandoned.

Abbreviations used in remarks --

BWPD- Injection rate in barrels of water per day; PSI, injection pressure in pounds per square inch; µS/cm, specific conductance in microsiemens per centimeter at 25 degrees Celsius.

Symbol: --, no data; (?), uncertain.

Table 2. Records of known brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit into which brine is injected	Geologic unit that is source of the brine	Drilled depth (feet)	Well depth (feet)	Site status	Remarks
28N51E02ACDB01 Murphy 2-D	2,124	Kjr	Mm	834	834	Ab	Completed as water well December 1951. Converted to brine-injection well January 1962. Injection test of 2,880 BWPD into Judith River Formation November 1961. Abandonment date not known. Water-quality analysis available (table 6).
28N51E03BCAC01 Murphy 80-D	2,059	Kd	Mm,Mh	3,832	3,575	Ac	Producing oil well July 1956-April 1960. Temporarily abandoned May 1960. Converted to brine-injection well January 1964. Injection rates: average = 2,700 BWPD; maximum = 4,500 BWPD. Injection pressures: average = 400 PSI; maximum = 650 PSI. Water-quality analysis available (table 6).
28N51E04BCAC01 Murphy 59-D	1,990	Kd	Mm	3,760	3,365	Ab	Dry oil well drilled June 1955. Converted to brine-injection well June 1961. Abandoned June 1986. Injection rates: average = 4,500 BWPD; maximum = 6,500 BWPD. Injection pressures: average = 650 PSI; maximum = 800 PSI.
28N51E10ABAC01 Huber 4	2,085	Mm	Mc	6,063	6,063	Ab	Producing oil well September 1952-August 1969. Temporarily abandoned August 1969. Converted to brine-injection well October 1970. Abandonment date not known.
28N51E10ABAD01 Huber 1-W	2,090	Kjr	Mm	881	881	Ab	Completion as brine-injection well October 1961. Reported injection rate 696 BWPD. Abandonment date not known.
28N51E10DADC01 Grace 110X-D	2,094	Mmc	Mc,Dn	7,360	7,000	Ab	Producing oil well September 1969-September 1973. Converted to brine-injection well October 1973. Injection rates: average = 1,827 BWPD; maximum = 3,000 BWPD. Injection pressures: average = 430 PSI; maximum = 900 PSI. Abandoned May 1985. Water-quality analysis available (table 6).
28N51E10DBAD01 Murphy 8-D	2,087	Kjr	Mm	5,788	780(?)	Ac	Producing oil well September 1952-September 1965. Temporarily abandoned October 1965. Converted to brine-injection well in Dakota Sandstone January 1973. Recompleted as brine-injection well in Judith River Formation January 1978. Injection rates: average = 7,100 BWPD; maximum = 8,400 BWPD. Injection pressures: average = 650 PSI; maximum = 700 PSI. Water-quality analysis available (table 6).

MAR02-1392

Table 2. Records of known brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit into which brine is injected	Geologic unit that is source of the brine	Drilled depth (feet)	Well depth (feet)	Site status	Remarks
28N51E22BDBD01 TXO SWD-1	2,085	Kjr	Mm	960	850	Ab	Completed as brine-injection well May 1981. Abandoned June 1984.
28N51E22CBCB03 Mesa 1-W (Biere 1)	2,075	Kjr	Mm	998	998	Ab	Completed as brine-injection well July 1970. Abandoned September 1984.
29N50E11CDCA01 Grace SWD-1	2,246	Kd	Mm	6,124	3,825(?)	Ab	Producing oil well November 1953-November 1974. Converted to brine-injection well March 1977. Injection rate not known. Abandoned August 1990.
29N50E25DCDB01 Murphy 46	2,106	Mm	Mm	5,864	5,864	Ab	Drilled as oil-test well September 1954 and abandoned as a dry hole. Converted to brine-injection well April 1956. Reported injection rate 2,302 BWPD. Abandonment date uncertain, but possibly August 1959.
29N51E07BCDB01 Buck Elk 2	2,220	Kjr	Mc	5,964	5,933	Ab	Apparently first drilled as oil well and later converted to brine-injection well. Brine injected sporadically since December 1967. Injection rates: average = 525 BWPD; maximum = 1,500 BWPD. Injection pressures: average = 225 PSI; maximum = 400 PSI. Abandoned January 1986. Water-quality analysis available (table 6).
29N51E07BDBD01 Buck Elk 1-W	2,200	Kjr	Mm	1,207	1,207	Ab	Completed as brine-injection well February 1961. Abandoned May 1968. Reported injection rate 600 BWPD at 400 PSI. Water-quality analysis available (table 6).
29N51E08DCCA01 Murphy (Empire State) Smith 1	2,045	Mm	Mm	5,982	5,982	Ab (see remarks)	Producing oil well June 1953-November 1956. Temporarily abandoned December 1956. Converted to dual completion as brine-injection well and oil well August 1960. Well does not appear to have been plugged as of 1995. Appears not to have been used for long period of time.
29N51E16BACA01 Murphy (Empire State) Rehder 7	2,025	Mm	Mm	5,770	5,750	Ab	Producing oil well January 1955-August 1960. Converted to brine-injection well September 1960. Abandonment date not known.
29N51E16DDDB01 Murphy (Owens-Simons 1)	2,015'	Mm	Mm	5,850	5,780	Ab	Producing oil well June 1955-October 1959. Shut-in November 1959. Converted to brine-injection well October 1960. Abandonment date not known.

Table 2. Records of known brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number and well name (plate 1)	Altitude of land surface (feet)	Geologic unit into which brine is injected	Geologic unit that is source of the brine	Drilled depth (feet)	Well depth (feet)	Site status	Remarks
29N51E19DDBA01 Murphy 5-D	2,039	Kd	Mm	3,583	3,583	Ac	Completed as brine-injection well February 1976. Injection rates: average = 3,000 BWPD; maximum = 5,000 BWPD. Injection pressures: average = 300 PSI; maximum = 650 PSI. Water-quality analysis available (tables 6 and 7).
29N51E28CCAC01 Murphy 29-D	2,105	Kjr	Mm	5,875	--	Ab	Apparently first drilled as oil well September 1953. Later (possibly April 1981) converted to brine-injection well. Abandoned October 1987. Injection rates: average 3,225 BWPD; maximum = 4,725 BWPD. Injection pressures: average = 600 PSI; maximum = 650 PSI.
29N51E30DDDD01 Murphy 1-D	2,005	Kd	Mm	3,465	3,431	Ac	Completed as brine-injection well September 1957. Injection rates: average = 4,500 BWPD; maximum = 7,300 BWPD. Injection pressures: average = 650 PSI; maximum = 1,600 PSI. Water-quality analysis available (tables 6 and 7).
29N51E33BBAB01 Murphy 6-D	2,110	--	--	--	--	Ab (see remarks)	Abandonment date not known. Various surface structures still at site. Not known if well is plugged.

MAR02-1393

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Well name, a field-identification system used for cross reference to wells plotted on plate 1; site number, numbering system described in text; casing, in feet below land surface, except where + indicates feet above land surface. Abbreviations: ft, feet; in., inches; PVC, polyvinylchloride]

Description	Depth (feet)
Well name: FPB92-1	
Location number: 29N51E32BBBA03	
Geologic unit: Alluvial deposits	
Lithology:	
Silt, clayey, medium-gray	0-1
Clay, silty, medium-brownish gray	1-8
Gravel of various sizes with some cobbles, all of crystalline origin. Becomes somewhat finer and better sorted at 17 ft. Becomes more sandy and moist at 18 ft	8-18
Sand with fine gravel, water	18-30
Sand with much more gravel than in above interval	30-40
Coarse gravel, with some cobbles, sandy	40-51
Clay, light-gray (Bearpaw Shale)	51-53
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.7-38
2-in. PVC factory-slotted casing (0.032-in. slot size)	38-48
2-in. PVC casing, with end cap for sediment trap	48-53
Finish:	
Bentonite grout	0.5-31
Natural cuttings and silica sand pack	31-53
Surface completion:	
6-in. steel protective casing	+2.7-1.3
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 24, 1992. Site geologist, S.D. Craigg. Drilled as replacement well for older, abandoned USGS well W-13 (Levings, 1984) to obtain follow-up water-level and water-quality data.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-2A	
Location number: 29N51E32BABB01	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, light-brown	0-2
Gravel of various sizes, with some moist sand	2-10
Gravel, overall coarser than in above interval, with some cobbles and moist sand	10-20
Sand, wet	20-25
Sand, with various-sized gravels, becoming coarser toward bottom of interval	25-42
Clay, light-gray (Bearpaw Shale)	42-46
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+1.7-31
2-in. PVC factory-slotted casing (0.032-in. slot size)	31-41
2-in. PVC casing, with end cap for sediment trap	41-46
Finish:	
Bentonite grout	0.5-6
Natural cuttings	6-46
Surface completion:	
6-in. steel protective casing, with locking cover	+1.7-2.3
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 25, 1992. Site geologist, S.D. Craigg. The purpose of this site is to provide a deep well and a shallow well in alluvial deposits to measure vertical differences in water quality and density. This is the deeper of two wells at this site; well FPB92-2B is the shallow well.

MAR02-1394

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-2B	
Location number: 29N51E32BABB02	
Geologic unit: Alluvial deposits	
Lithology:	
No samples described. See description of well FPB92-2A for lithology of this hole.	
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.0-12
2-in. PVC factory-slotted casing (0.032-in. slot size)	12-22
2-in. PVC casing, with end cap for sediment trap	22-27
Finish:	
Bentonite grout	0.5-5
Natural cuttings	5-27
Surface completion:	
6-in. steel protective casing, with locking cover	+2.0-2.0
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 23, 1992. Site geologist, S.D. Craigg. Well FPB92-2B drilled 10 ft north of well FPB92-2A to determine vertical differences in water quality and density. Well had to be abandoned on August 8, 1993 because of extensive bulldozing for gravel deposits to within about 20 ft of the site, and also because "surge block" and extension rods (for developing monitoring wells) was stuck in the well and was impossible to remove.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-3	
Location number: 29N51E32BAAD01	
Geologic unit: Alluvial deposits	
Lithology:	
Silt and sand, brown	0-4
Gravel of various sizes	4-8
Gravel with some sand	8-14
Sand, wet, with possibly some fine gravel	14-32
Probably same as above interval, but change in drilling character	32-35
Clay, light-gray (Bearpaw Shale)	35-39
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+1.7-24
2-in. PVC factory-slotted casing (0.032-in. slot size)	24-34
2-in. PVC casing, with end cap for sediment trap	34-39
Finish:	
Bentonite grout	0.5-7
Natural cuttings	7-39
Surface completion:	
6-in. steel protective casing	+1.7-2.3
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 26, 1992. Site geologist, S.D. Craigg.

MAR02-1395

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-4	
Location number: 29N51E32ABAC01	
Geologic unit: Alluvial deposits	
Lithology:	
Silt and sand, medium-brown	0-3
Fine sand, light-brown	3-7
Fine sand, light-brown, with minor gravel	7-13
Gravel of various sizes, with some sand	13-20
Same as above, but with some cobbles, moist	20-25
Clay, silty, gray, moist, with some sand and fine gravel	25-30
Clay balls, dark-gray, moist, with some sand and fine gravel	30-35
Clay, sandy and silty, drilling very difficult (uncertain whether material is clay-rich alluvial or glacial deposits, or Bearpaw Shale)	35-45
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.0-16
2-in. PVC factory-slotted casing (0.032-in. slot size)	16-26
2-in. PVC casing, with end cap for sediment traps	26-41
Finish:	
Bentonite grout	0.5-11
Natural cuttings and silica sand pack	11-41
Surface completion:	
6-in. steel protective casing, with locking cover	+2.0-2.0
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 26, 1992. Site geologist, S.D. Craigg. Hole caved 4 ft at bottom.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-5	
Location number: 29N51E32ACCA01	
Geologic unit: Alluvial deposits	
Lithology:	
Silt and sand, medium-dark brown	0-1
Sand, fine, light-brown	1-7
Gravel of various sizes	7-8
Sand, brown, wet	8-15
Gravel with some minor cobbles and sand	15-18
Sand	18-26
Clay, light-gray (uncertain whether material is clay-rich alluvial or glacial deposits, or Bearpaw Shale)	26-30
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+1.7-15
2-in. PVC factory-slotted casing (0.032-in. slot size)	15-25
2-in. PVC casing, with end cap for sediment trap	25-30
Finish:	
Bentonite grout	0.5-11
Silica sand pack	11-25
Natural cuttings	25-30
Surface completion:	
6-in. steel protective casing, with locking cover	+1.7-2.3
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 26, 1992. Site geologist, S.D. Craigg.

MAR02-1396

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-6	
Location number: 29N51E31ABDD01	
Geologic unit: Alluvial deposits	
Lithology:	
Silt, clayey, light- to dark-brown	0-5
Clay balls, silty, medium-brown, slightly moist	5-10
Clay with very minor silt, medium-brown, barely moist	10-11
Gravels of various sizes, sandy cobbles at base of interval	11-30
Same as above interval, but no cobbles present	30-35
Sand, fine, silty	35-44
Clay, light-gray (Bearpaw Shale)	44-48
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.5-28
2-in. PVC factory-slotted casing (0.032-in. slot size)	28-38
2-in. PVC casing, with end cap for sediment trap	38-43
Finish:	
Bentonite grout	0.5-15
Silica sand pack	15-28
Natural cuttings	28-43
Surface completion:	
6-in. steel protective casing	+2.5-1.5
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 27, 1992. Site geologist, S.D. Craigg.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-7	
Location number: 29N51E31DBAD01	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, fine, silty, light-brown	0-6
Gravel of various sizes, with minor cobbles	6-20
Sand, fine-medium, very wet (like "quicksand")	20-33
Clay, light-gray (Bearpaw Shale)	33-38
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+1.9-23
2-in. PVC factory-slotted casing (0.032-in. slot size)	23-33
2-in. PVC casing, with end cap for sediment trap	33-37
Finish:	
Bentonite grout	0.5-7
Silica sand pack	7-8
Natural cuttings	8-37
Surface completion:	
6-in. steel protective casing	+1.9-2.1
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 28, 1992. Site geologist, S.D. Craigg.

MAR02-1397

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-8	
Location number: 29N51E31DBDD01	
Geologic unit: *Alluvial deposits*	
Lithology:	
Silt, light-brown	0-2
Gravel of various sizes, but mostly in the finer range	2-8
Sand, with possibly minor gravel toward base of interval	8-18
Gravel, very well sorted	18-32
Clay, light-gray (Bearpaw Shale)	32-33
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.1-19
2-in. PVC factory-slotted casing (0.032-in. slot size)	19-29
2-in. PVC casing, with end cap for sediment trap	29-33
Finish:	
Bentonite grout	0.5-12
Silica sand pack	12-13
Natural cuttings	13-33
Surface completion:	
6-in. steel protective casing, with locking cover	+2.1-1.9
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 28, 1992. Site geologist, S.D. Craigg.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-9	
Location number: 29N51E31CABB01	
Geologic unit: *Alluvial deposits*	
Lithology:	
Silt, light-brown	0-0.5
Gravel of various sizes, with minor cobbles	0.5-1
Sand, medium-brown	1-3
Sand with finer gravel, moist at approximately 8 ft	3-8
Sand, very wet (like "quicksand")	8-28
Clay, light-gray (Bearpaw Shale)	28-33
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.1-18
2-in. PVC factory-slotted casing (0.032-in. slot size)	18-28
2-in. PVC casing, with end cap for sediment trap	28-33
Finish:	
Bentonite grout	0.5-7
Silica sand pack	7-8
Natural cuttings	8-33
Surface completion:	
6-in. steel protective casing, with locking cover	+2.1-1.9
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 29, 1992. Site geologist, S.D. Craigg

MAR02-1398

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-10	
Location number: 29N51E31BDBA01	
Geologic unit: Alluvial deposits	
Lithology:	
Clay, dark-gray (bedded, clayey alluvium from upland erosion of Bearpaw Shale outcrop about 0.5 mi west of site)	0-5
Clay, brown, silty	5-8
Clay, dark-gray to brown, slightly silty; slightly moist at approximately 11 ft	8-15
Gravel of various sizes	15-21
Sand, very silty and clayey, medium- to dark-brown; very wet and sticky	21-30
Sand, fine, clayey, dark-gray, very moist	30-33
Clay, dark-gray (Bearpaw Shale)	33-40
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.2-20
2-in. PVC factory-slotted casing (0.032-in. slot size)	20-30
2-in. PVC casing, with end cap for sediment trap	30-40
Finish:	
Bentonite grout	0.5-10
Silica sand pack	10-28
Natural cuttings	28-40
Surface completion:	
6-in. steel protective casing, with locking cover	+2.2-1.8
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 30, 1992. Site geologist, S.D. Craigg.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-11	
Location number: 29N51E32BCCA02	
Geologic unit: Alluvial deposits	
Lithology:	
Silt, light-brown	0-5
Gravel of various sizes, fairly well sorted; minor cobbles	5-25
Sand, with minor finer gravel	25-41
Bearpaw Shale	41-45
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.2-30
2-in. PVC factory-slotted casing (0.032-in. slot size)	30-40
2-in. PVC casing, with end cap for sediment trap	40-45
Finish:	
Bentonite grout	0.5-4
Silica sand pack	4-10
Natural cuttings	10-45
Surface completion:	
6-in. steel protective casing, with locking cover	+2.2-1.8
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on August 30, 1992. Site geologist, S.D. Craigg.

MAR02-1399

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-12	
Location number: 28N51E22BBBB01	
Geologic unit: Glacial deposits	
Lithology:	
Silt, sandy, medium-brown	0-5
Clay, silty, medium-brown; encountered a large boulder at 33 ft; from 34-48 ft, becomes more moist; from 48-62 ft, becomes very tight and difficult to drill	5-62
Sand(?); drilling much easier and bit cuts like it is moving through sand, presumably water bearing	62-65
Drilling very difficult; decided to complete well; brought up bit for sample (sample was a gray clay); could not continue augering	65-68
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.5-33
2-in. PVC factory-slotted casing (0.032-in. slot size)	33-63
2-in. PVC casing, with end cap for sediment trap	63-68
Finish:	
Bentonite grout	0.5-12
Silica sand pack	12-68
Surface completion:	
6-in. steel protective casing, with locking cover	+2.5-1.5
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed September 1, 1992. Site geologist, S.D. Craigg. Originally called the interval beginning at 65 ft Bearpaw Shale but later decided (after coring the same material in well FPB92-18) that the material probably is tight glacial clay or, possibly, the Sprole Silt of Pleistocene age.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-13	
Location number: 29N51E20DABB01	
Geologic unit: Alluvial deposits	
Lithology:	
Clay, brown, silty, compact	0-4
Clay, light-brown in upper part, dark-brown in lower part, wet	4-12
Gravel of various sizes, with some cobbles	12-20
Sand, fine, saturated. Tried coring, no return	20-37
Sand and gravel, interbedded, with some clay layers; sand fine- to medium-grained, dark-gray. Cored from 44-47 ft with excellent return; also cored interval from 47-52 ft	37-47
Sand, well sorted, medium-grained, gray	47-51
Gravel and clay, sandy	51-52
Clay (Bearpaw Shale)	52-56
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.1-42
2-in. PVC factory-slotted casing (0.032-in. slot size)	42-52
2-in. PVC casing, with end cap for sediment trap	52-56
Finish:	
No data	
Surface completion:	
6-in. steel protective casing, with locking cover	+2.1-1.9
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 18, 1992. Site geologist, M.R. Cannon.

MAR02-1400

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-14	
Location number: 29N51E21ABDA01	
Geologic unit: Alluvial deposits	
Lithology:	
Silt, light-brown, dry	0-3
Clay and silt, brown	3-10
Gravel of various sizes, clayey, wet cobbles at 16-17 ft	10-20
Sand and gravel, clayey, gray, saturated	20-22
Clay (Bearpaw Shale), highly fractured. Cored from 28-33 ft, with full return; bentonite layer at 32 ft; a few small fossil shells in core; calcite filling in some of the larger fractures.	22-33
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.0-15
2-in. PVC factory-slotted casing (0.032-in. slot size)	15-25
2-in. PVC casing, with end cap for sediment trap	25-33
Finish:	
Bentonite grout	0.5-3
Natural cuttings and silica sand pack	3-33
Surface completion:	
6-in. steel protective casing	+2.0-2.0
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 19, 1992. Site geologist, M.R. Cannon. The shallow depth of the Bearpaw Shale at this site evidently represents an anomalous high of some type, the reason for which is uncertain.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-15	
Location number: 29N51E09ABBA01	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, very fine-grained, silty, light-brown	0-2
Gravel of various sizes, sandy, light-brown, moist below 7 ft	2-12
Gravel of various sizes, sandy, some cobbles up to 3.5 in. in diameter	12-16
Sand, fine- to medium-grained, gravelly, saturated, poor return from auger	16-38
Clay (Bearpaw Shale)	38-42
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.0-20
2-in. PVC factory-slotted casing (0.032-in. slot size)	20-35
2-in. PVC casing, with end cap for sediment trap	35-42
Finish:	
Bentonite grout	0.5-4
Natural cuttings	4-42
Surface completion:	
6-in. steel protective casing, with locking cover	+2.0-2.0
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 20, 1992. Site geologist, M.R. Cannon.

MAR02-1401

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-16	
Location number: 29N51E09ABBA02	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, very fine-grained, silty, light-brown	0-2
Gravel, sandy, coarsens downward (refer to log of well FPB92-15)	2-16
Sand, fine- to medium-grained, gravelly	16-37
Clay (Bearpaw Shale)	37-38
Completion details:	
Well completion:	
3-in. PVC casing, with breather cap	+2.2-18
3-in. PVC factory-slotted casing (0.025-in. slot size)	18-33
3-in. PVC casing, with end cap for sediment trap	33-38
Finish:	
No data	
Surface completion:	
6-in. steel protective casing, with locking cover	+2.2-1.8
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 20, 1992. Site geologist, M.R. Cannon.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-17	
Location number: 29N51E09ABBA03	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, very fine-grained, silty, light-brown	0-2
Gravel of various sizes, sandy, coarsens downward, some cobbles up to 3.5 in. in diameter	2-20
Sand, fine- to medium-grained, gray, gravelly	20-28
Clay, silty, gray; cored entire interval, full return	28-42
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+1.9-18
2-in. PVC factory-slotted casing (0.032-in. slot size)	18-28
2-in. PVC casing, with end cap for sediment trap	28-42
Finish:	
No data	
Surface completion:	
6-in. steel casing, with locking cover	+1.9-2.1
2x2-ft cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 21, 1992. Site geologist, M.R. Cannon. The clay from 28-42 ft is derived from the Bearpaw Shale, but is silty and has no structure; possibly deposited by water and ice reworking of the Bearpaw Shale.

MAR02-1402

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB92-18	
Location number: 28N51E09DCCC01	
Geologic unit: Glacial deposits	
Lithology:	
Sandy loam, brown	0-7
Glacial till (clay loam), mottled yellowish-brown from 7-8 ft, light brown below 8 ft, gray below about 36 ft. Some small pebbles and cobbles, moist. Cored from 38-41.5 ft, with full return; gray till with numerous pebbles. Drilled 58 ft on 09-21-92; harder drilling from 57-58 ft	7-58
Cored interval; excellent return. Till (dark-gray silty clay) with locally interspersed gravel particles of various sizes. Lower 6 in. of core water-yielding, very fine-grained gray	58-63
Sand, very fine-grained, gray, saturated; minor particles of transported coal fragments present	63-68
Same as interval above, only a few gravels present	68-80
Drilling characteristics indicate probable gravel bed	80-95
Gravel of various sizes coming up stuck onto sticky clay on auger sections. Drilling reached maximum limit of auger rig at 98 ft; still apparently in glacial till	95-98
Completion details	
Well completion:	
2-in. PVC casing, with breather cap	+1.9-68
2-in. PVC factory-slotted casing (0.032-in. slot size)	68-88
2-in. PVC casing, with end cap for sediment trap	88-93
Finish:	
Bentonite grout	0.5-10
Silica sand pack (natural cuttings at bottom)	10-93
Surface completion:	
6-in. steel protective casing, with locking cover	+1.9-2.1
2x2 ft-cement pad	0-0.5

Remarks: Well drilled using auger method; completed on September 22, 1992. S.D. Craigg replaced M.R. Cannon as site geologist 09-22-92. Had planned to try to get to 115 ft with this hole, but the limit of the auger rig was reached at 98 ft. Did not reach the Bearpaw Shale.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-1	
Location number: 29N51E09ABBA01	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, silty, very fine-grained, light-brown	0-2
Gravel and cobbles, coarsens downwards	2-18
Sand and gravel, interbedded	18-38
Clay/shale, gray, soft, smooth, sticky (Bearpaw Shale)	38-40
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+2.2-8
4-in. PVC factory-slotted casing (0.025-in. slot size)	8-33
4-in. PVC casing, with end cap for sediment trap	33-36
Finish:	
Bentonite grout	0.5-6
Natural gravel and silica sand pack	6-40
Surface completion:	
6-in. steel protective casing, with locking cover	+2.2-1.8
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 22, 1993. Site geologist, M.R. Cannon. Drilled as pumped well for aquifer test in alluvial deposits (observation wells were FPB92-15, 16, and 17).

MAR02-1403

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-2	
Location number: 29N51E32BBBA01	
Geologic unit: Alluvial deposits	
Lithology:	
Sand, brown	0-8
Gravel	8-10
Gravel, sandy	10-18
Gravel	18-23
Sand, dark-gray	23-30
Completion details:	
Well completion:	
2-in. PVC casing, with breather cap	+2.5-18
2-in. PVC factory-slotted casing (0.032-in. slot size; no sediment trap)	18-27
Finish:	
Natural cuttings	0.5-11
Bentonite grout	11-12
Natural cuttings	12-19
Silica sand pack	19-27
Surface completion:	
6-in. steel protective casing, with locking cover	+2.5-1.5
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 23, 1993. Site geologist, R.E. Davis.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-3	
Location number: 28N51E22CBCB01	
Geologic unit: Glacial deposits	
Lithology:	
Clay loam and gravel, caramel-brown	0-25
Clay and gravel, mostly coarse to very coarse pebble gravel, caramel-brown	25-33
Sand, fine-grained, caramel-brown	33-40
Gravel and sand, mostly fine pebble gravel, caramel-brown	40-46
Sand and cobbles	46-50
Sand and large cobbles	50-56
Shale, dark-gray, smooth, small pink calcareous pieces (Bearpaw Shale)	56-81
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+1.6-52
4-in. PVC factory-slotted casing (0.025-in. slot size)	52-57
4-in. PVC casing, with end cap for sediment trap	57-81
Finish:	
Bentonite grout	0.5-44
Natural cuttings	44-81
Surface completion:	
6-in. steel protective casing, with locking cover	+1.6-2.4
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 24, 1993. Site geologist, J.N. Thamke. The purpose of this site is to provide a deep well and a shallow well in glacial deposits to measure vertical differences in water quality and density. This well is the deeper of two wells at the site; well FPB93-3A is the shallow well.

MAR02-1404

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-3A	
Location number: 28N51E22CBCB02	
Geologic unit: Glacial deposits	
Lithology:	
Clay and gravel, medium-sized pebbles, some sand	0-12
Clay and gravel, minor amounts of iron staining on clay; gravel more abundant than in interval above	12-20
Clay and gravel, mostly fine pebble gravel	20-26
Gravel, clay, and sand, black and brown; mostly coarse pebble gravel and fine sand	26-31
Sand and gravel, caramel-brown; mostly coarse pebble gravel	31-36
Gravel, very coarse pebble gravel	36-46
Gravel and sand, mostly very coarse pebble gravel	46-51
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+1.8-41
4-in. PVC factory-slotted casing (0.025-in. slot size)	41-46
4-in. PVC casing, with end cap for sediment trap	46-49
Finish:	
Bentonite grout	0.5-37
Silica sand pack	37-51
Surface completion:	
6-in. steel protective casing, with locking cover	+1.8-2.2
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 25, 1993. Site geologist, J. N. Thamke. The purpose of this site is to provide a deep well and a shallow well in glacial deposits to measure vertical differences in water quality and density. This well is the shallower of two wells at the site; well FPB93-3 is the deep well.

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-4A	
Location number: 28N51E33DDCC03	
Geologic unit: Wiota Gravel	
Lithology:	
Topsoil	0-2
Gravel, medium-pebble size; some thin, sandy seams	2-4
Clay and gravel, silty, dark-brown; mostly fine to medium pebble gravel	4-29
Gravel and clay	29-35
Clay, plastic; some granular iron concretions	35-39
Sand and clay, dark-brown	39-41
Gravel and sand, dark-brown, mostly fine pebble gravel, well rounded (Wiota Gravel)	41-61
Shale, steel-blue, hard, consolidated (Bearpaw Shale)	61-70
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+1.7-40
4-in. PVC factory-slotted casing (0.025-in. slot size)	40-60
4-in. PVC casing, with end cap for sediment trap	60-65
Finish:	
Bentonite grout	0.5-31
Silica sand pack	31-54
Natural cuttings, gravel	54-70
Surface completion:	
6-in. steel protective casing, with locking cover	+1.7-2.3
2x2-ft cement pad	0-0.5

Remarks: Well completed using mud rotary method; completed on June 26, 1993. Site geologist, J.N. Thamke. Well drilled as an observation well for aquifer test in glacial deposits (the other observation well was FPB93-4C; the pumped well was FPB93-4B).

MAR02-1405

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-4B	
Location number: 28N51E33DDCC04	
Geologic unit: Wiota Gravel	
Lithology:	
Topsoil	0-2
Gravel	2-6
Clay, moist; small iron concretions	6-10
Clay and gravel, gray, hard; mostly fine pebble gravel	10-20
Clay and gravel, silty; some small iron concretions	20-40
Silt, sandy	40-42
Gravel, mostly fine pebble gravel, well rounded (Wiota Gravel)	42-62
Bearpaw Shale	62-70
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+1.9-40
4-in. PVC factory-slotted casing (0.025-in. slot size; no sediment trap)	40-65
Finish:	
Bentonite grout	0.5-33
Silica sand pack	33-70
Surface completion:	
6-in. steel protective casing, with locking cover	+1.9-2.1
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 27, 1993. Site geologist, J.N. Thamke. Well drilled as the pumped well for aquifer test in glacial deposits (the observation wells were FPB93-4A and 4C).

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-4C	
Location number: 28N51E33DDCC05	
Geologic unit: Wiota Gravel	
Lithology:	
Clay and gravel, gray, hard; mostly fine pebble gravel	0-37
Clay and gravel, some iron concretions	37-39
Silt, sandy, brown; some iron color; thin, interbedded gravel layer at 43 ft	39-47
Gravel; thin, interbedded sand seams	47-48
Wiota Gravel	48-61
Bearpaw Shale	61-67
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+1.7-41
4-in. PVC factory-slotted casing (0.025-in. slot size)	41-61
4-in. PVC casing, with end cap for sediment trap	61-66
Finish:	
Bentonite grout	0.5-37
Silica sand pack	37-67
Surface completion:	
6-in. steel protective casing, with locking cover	+1.7-2.3
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 27, 1993. Site geologist, J.N. Thamke. Well drilled as an observation well for aquifer test in glacial deposits (the other observation well was FPB93-4A; the pumped well was FPB93-4B).

MAR02-1406

Table 3. Lithologic logs and completion details for monitoring wells drilled in 1992-93 in Quaternary alluvial and glacial deposits in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Description	Depth (feet)
Well name: FPB93-5	
Location number: 28N51E09CDBB01	
Geologic unit: Glacial deposits	
Lithology:	
Clay and sand, light-brown	0-5
Clay and sand, light-brown; small rock fragments	5-12
Cobble, black, large; granitic origin; contains garnet crystals	12-13
Clay and sand; minor amounts of fine pebble gravel	13-20
Clay, brown, sticky; minor amounts of well-rounded, fine pebble gravel	20-35
Clay, gray, hard, plastic; minor amounts of gravel with occasional cobbles	35-61
Gravel, dark-red and brown, well-rounded, coarse pebble gravel; contains coal fragments	61-80
Gravel; coal fragments becoming more abundant; thin, sandy seam at 86 ft	80-99
Shale, steel-gray, shiny, hard, slippery (Bearpaw Shale)	99-106
Completion details:	
Well completion:	
4-in. PVC casing, with breather cap	+2.1-81
4-in. PVC factory-slotted casing (0.025-in. slot size)	81-101
4-in. PVC casing, with end cap for sediment trap	101-104
Finish:	
Bentonite grout	0.5-12
Natural cuttings and silica sand pack	12-104
Surface completion:	
6-in. steel protective casing, with locking cover	+2.1-1.9
2x2-ft cement pad	0-0.5

Remarks: Well drilled using mud rotary method; completed on June 28, 1993. Site geologist, J.N. Thamke. The purpose of this well is to help delineate extent of saline-water plume in glacial deposits.

Table 4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[--, no data or not applicable]

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB92-15	0.00	9.65	0.00	--	Water-level measurements by S.D. Craigg (initial and final two measurements with steel tape; others with electric line and steel tape attached). Pumped well FPB93-1. Pump on at 0850 hours. Discharge held constant at 40 gallons per minute for 180 minutes. Well located 10.2 ft north of pumped well FPB93-1.
	.25	10.15	.50	--	
	.50	10.27	.62	--	
	.75	10.34	.69	--	
	1.00	10.43	.78	--	
	1.25	10.48	.83	--	
	1.50	10.52	.87	--	
	1.75	10.54	.89	--	
	2.00	10.56	.91	--	
	2.25	10.59	.94	--	
	2.50	10.63	.98	--	
	2.75	10.63	.98	--	
	3.00	10.63	.98	--	
	3.50	10.64	.99	--	
	4.00	10.66	1.01	--	
	4.50	10.65	1.03	--	
	5.00	10.65	1.03	--	
	6.00	10.70	1.06	--	
	7.00	10.71	1.06	--	
	8.00	10.72	1.07	--	
	9.00	10.73	1.08	--	
	10	10.73	1.08	--	
	12	10.73	1.08	--	
	14	10.73	1.08	--	
	16	10.73	1.08	--	
	18	10.73	1.08	--	
	20	10.73	1.08	--	
	25	10.74	1.09	--	
	30	10.74	1.09	--	
	35	10.74	1.09	--	
	40	10.74	1.09	--	
	45	10.74	1.09	--	
	50	10.74	1.09	--	
	60	10.74	1.09	--	
	70	10.74	1.09	--	
	80	10.74	1.09	--	
	90	10.74	1.09	--	
	100	10.74	1.09	--	
	120	10.75	1.10	--	
	140	10.75	1.10	--	
	160	10.76	1.11	--	
	180	10.76	1.11	--	Pump off at 1150 hours.
	180.25	10.53	--	0.88	Residual drawdown values measured during recovery.
	180.50	10.50	--	.65	
	180.75	10.15	--	.50	
	181.00	10.04	--	.39	
	181.25	9.94	--	.29	
	181.50	9.92	--	.27	
	181.75	9.89	--	.24	
	182.00	9.85	--	.21	
	182.25	9.84	--	.19	

MAR02-1407

Table 4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB92-15 (Continued)	182.50	9.83	--	.18	
	182.75	9.81	--	.16	
	183.00	9.79	--	.14	
	183.50	9.77	--	.12	
	184.00	9.76	--	.11	
	184.50	9.74	--	.09	
	185	9.74	--	.09	
	186	9.73	--	.08	
	187	9.72	--	.07	
	188	9.70	--	.05	
	189	9.70	--	.05	
	190	9.70	--	.05	
	192	9.69	--	.04	
	194	9.68	--	.03	
	196	9.68	--	.03	
	198	9.68	--	.03	
	200	9.68	--	.03	
	205	9.68	--	.03	
	210	9.68	--	.03	
	215	9.67	--	.02	
	220	9.67	--	.02	
	225	9.67	--	.02	
	230	9.67	--	.02	
	240	9.66	--	.01	
	250	9.66	--	.01	
	260	9.65	--	.00	Ended test at 1310 hours on 08-18-93. Final measurement made at approximately 1400 hours on August 19, 1993.
	1,750	9.65	--	.00	
Observation well FPB92-16	.00	9.80	.00	--	Water-level measurements by Eloise Kendy for first 30 minutes, and by D.W. Briar and S.D. Craigg thereafter (initial and final two measurements with steel tape; others with electric line and steel tape attached). Pumped well FPB93-1. Pump on at 0850 hours. Discharge held constant at 40 gallons per minute for 180 minutes. Well located 8.1 ft north of pumped well FPB93-1.
	.20	10.25	.45	--	
	.45	10.51	.71	--	
	.60	10.62	.82	--	
	.78	10.71	.91	--	
	1.20	10.79	.99	--	
	1.28	10.86	1.06	--	
	1.50	10.90	1.10	--	
	1.73	10.94	1.14	--	
	1.95	10.98	1.18	--	
	2.15	10.99	1.19	--	
	2.43	11.01	1.21	--	
	2.67	11.02	1.22	--	
	2.88	11.03	1.23	--	
	3.05	11.04	1.24	--	
	3.40	11.06	1.26	--	
	3.58	11.07	1.27	--	
	3.90	11.07	1.27	--	
	4.13	11.07	1.27	--	
	4.53	11.09	1.29	--	
	4.87	11.10	1.30	--	
	5.20	11.11	1.31	--	
	5.38	11.11	1.31	--	
	5.82	11.11	1.31	--	
	6.28	11.11	1.31	--	
	6.83	11.13	1.33	--	
	7.20	11.13	1.33	--	

Table 4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB92-16 (Continued)	7.78	11.13	1.33	--	
	8.90	11.13	1.33	--	
	9.30	11.14	1.34	--	
	10.92	11.15	1.35	--	
	11.90	11.15	1.35	--	
	13	11.15	1.35	--	
	14	11.15	1.35	--	
	15	11.15	1.35	--	
	16	11.15	1.35	--	
	17	11.15	1.35	--	
	18	11.16	1.36	--	
	19	11.16	1.36	--	
	20	11.16	1.36	--	
	23	11.16	1.36	--	
	25	11.16	1.36	--	
	30	11.15	1.35	--	
	35	11.16	1.36	--	
	40	11.16	1.36	--	
	45	11.17	1.37	--	
	50	11.18	1.38	--	
	60	11.18	1.38	--	
	70	11.18	1.38	--	
	80	11.19	1.39	--	
	90	11.19	1.39	--	
	100	11.19	1.39	--	
	120	11.19	1.39	--	
	140	11.19	1.39	--	
	160	11.20	1.40	--	
	180	11.21	1.41	--	Pump off at 1150 hours.
	197	9.85	--	.05	Residual drawdown values measured during recovery.
	201	9.85	--	.05	
	206	9.84	--	.04	
	211	9.84	--	.04	
	250	9.83	--	.03	
	260	9.80	--	.00	Ended test at 1310 hours on August 18, 1993. Final measurement made at approximately 1400 hours on August 19, 1993.
	1,750	9.81	--	.01	
Observation well FPB92-17	.00	9.21	.00	--	Water-level measurements by J.N. Thamke for first 30 minutes, and by D.W. Briar and S.D. Craigg thereafter (initial and final two measurements with steel tape; others with electric line and steel tape attached). Pumped well FPB93-1. Pump on at 0850 hours. Discharge held constant at 40 gallons per minute for 180 minutes. Well located 72 ft north of pumped well FPB93-1.
	.25	9.30	.09	--	
	.50	9.41	.20	--	
	.75	9.45	.27	--	
	1.00	9.53	.32	--	
	1.25	9.55	.37	--	
	1.50	9.60	.39	--	
	1.75	9.63	.42	--	
	2.00	9.65	.44	--	
	2.25	9.68	.47	--	
	2.50	9.70	.49	--	
	3.00	9.71	.50	--	
	3.50	9.73	.52	--	
	4.00	9.75	.54	--	
	4.50	9.76	.55	--	

MAR02-1408

Table 4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB92-17 (Continued)	5.00	9.76	.55	--	
	6.00	9.77	.56	--	
	7.00	9.78	.57	--	
	8.00	9.79	.58	--	
	9.00	9.80	.59	--	
	10	9.80	.59	--	
	12	9.81	.60	--	
	14	9.81	.60	--	
	16	9.81	.60	--	
	18	9.81	.60	--	
	20	9.82	.61	--	
	25	9.82	.61	--	
	30	9.82	.61	--	
	36	9.82	.61	--	
	40	9.82	.61	--	
	47	9.83	.62	--	
	50	9.83	.62	--	
	60	9.84	.63	--	
	70	9.84	.63	--	
	80	9.84	.63	--	
	90	9.84	.63	--	
	100	9.84	.63	--	
	118	9.84	.63	--	
	140	9.85	.64	--	
	160	9.85	.64	--	
	180	9.85	64	--	Pump off at 1150 hours.
	180.25	9.79	--	.58	Residual drawdown values measured during recovery.
	180.50	9.70	--	.49	
	180.75	9.61	--	.40	
	181.00	9.54	--	.33	
	181.25	9.50	--	.29	
	181.50	9.47	--	.26	
	181.75	9.43	--	.22	
	182.00	9.41	--	.20	
	182.25	9.39	--	.18	
	182.50	9.37	--	.16	
	182.75	9.36	--	.15	
	183.00	9.35	--	.14	
	183.50	9.34	--	.13	
	184.00	9.33	--	.12	
	184.50	9.32	--	.11	
	185	9.31	--	.11	
	186	9.29	--	.08	
	187	9.28	--	.07	
	188	9.28	--	.07	
	189	9.28	--	.07	
	190	9.28	--	.07	
	192	9.27	--	.06	
	194	9.26	--	.05	
	196	9.26	--	.05	
	198	9.26	--	.05	
	200	9.26	--	.05	
	205	9.26	--	.05	

Table 4. Data from aquifer test conducted in Quaternary alluvial deposits on August 18, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB92-17 (Continued)	210	9.25	--	.04	
	215	9.25	--	.04	
	235	9.24	--	.03	
	250	9.24	--	.03	
	260	9.23	--	.02	Ended test at 1310 hours on August 18, 1993. Final measurement made at approximately 1400 hours on August 19, 1993.
	1,750	9.23	--	.02	

MAR02-1409

Table 5. Data from aquifer test conducted in Quaternary glacial deposits on August 19, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[--, no data or not applicable]

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB93-4A	0.00	43.51	0.00	--	Water-level measurements by S.D. Craigg (initial and final six measurements with steel tape; others with electric line and steel tape attached). Pump on at 0830 hours. Discharge held constant at 12.5 gallons per minute for 110 minutes. Well located 7.1 ft south of pumped well FPB93-4B.
	.25	43.51	.00	--	
	.50	43.51	.00	--	
	.75	43.51	.00	--	
	1.00	43.51	.00	--	
	1.25	43.57	.06	--	
	1.50	43.61	.10	--	
	1.75	43.65	.14	--	
	2.00	43.69	.18	--	
	2.25	43.72	.21	--	
	2.50	43.75	.24	--	
	2.75	43.75	.24	--	
	3.00	43.76	.25	--	
	3.50	43.77	.26	--	
	4.00	43.79	.28	--	
	4.50	43.80	.29	--	
	5.00	43.81	.30	--	
	6.00	43.81	.30	--	
	7.00	43.82	.31	--	
	8.00	43.83	.32	--	
	9.00	43.84	.33	--	
	10	43.85	.34	--	
	12	43.85	.34	--	
	14	43.86	.35	--	
	16	43.87	.36	--	
	18	43.87	.36	--	
	20	43.88	.37	--	
	25	43.89	.38	--	
	30	43.90	.39	--	
	35	43.91	.40	--	
	40	43.91	.40	--	
	45	43.92	.41	--	
	50	43.93	.42	--	
	60	43.94	.43	--	
	70	43.95	.44	--	
	80	43.97	.46	--	
	90	43.98	.47	--	
	100	43.99	.48	--	
	110	43.99	.48	--	
	110.25	43.96	--	0.45	Residual drawdown values measured during recovery.
	110.50	43.91	--	.40	
	110.75	43.85	--	.34	
	111.00	43.80	--	.29	
	111.25	43.75	--	.24	
	111.50	43.72	--	.21	
	111.75	43.71	--	.20	
	112.25	43.71	--	.20	
	112.50	43.70	--	.19	
	112.75	43.69	--	.18	
	113.00	43.69	--	.18	

Table 5. Data from aquifer test conducted in Quaternary glacial deposits on August 19, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB93-4A (Continued)	113.50	43.69	--	.18	
	114.00	43.68	--	.17	
	114.50	43.67	--	.16	
	115.00	43.67	--	.16	
	116	43.66	--	.15	
	117	43.65	--	.14	
	118	43.65	--	.14	
	119	43.64	--	.13	
	120	43.63	--	.12	
	122	43.63	--	.12	
	124	43.63	--	.12	
	126	43.62	--	.11	
	128	43.62	--	.11	
	130	43.62	--	.11	
	135	43.61	--	.10	
	140	43.61	--	.10	
	145	43.60	--	.09	
	150	43.59	--	.08	
	155	43.59	--	.08	
	160	43.56	--	.05	
	170	43.56	--	.05	
	180	43.52	--	.01	
	190	43.52	--	.01	
	200	43.52	--	.01	
	210	43.52	--	.01	Ended test at 1200 hours on August 19, 1993. Final measurement made at approximately 0600 hours on August 20, 1993. Final measurement 0.01 is above initial static water level.
	1,290	43.50	--	+.01	
Pumped well FPB93-4B	.00	43.88	.00	--	Water-level measurements by D.W. Briar (initial and final three measurements with steel tape; others with electric line and steel tape attached). Pump on at 0830 hours. Discharge held constant at 12.5 gallons per minute for 110 minutes.
	2.45	50.62	6.74	--	
	4.00	51.16	7.28	--	
	5.00	51.33	7.45	--	
	6.00	51.38	7.50	--	
	7.00	51.41	7.53	--	
	8.00	51.50	7.62	--	
	9.00	51.56	7.68	--	
	10	51.56	7.68	--	
	12	51.60	7.72	--	
	14	51.66	7.78	--	
	16	51.71	7.83	--	
	18	51.75	7.87	--	
	20	51.77	7.89	--	
	25	51.90	8.02	--	
	30	51.98	8.10	--	
	40	52.06	8.18	--	
	46	52.06	8.18	--	
	52	52.15	8.27	--	
	61	52.22	8.34	--	
	70	52.19	8.31	--	
	81	52.28	8.40	--	
	90	52.26	8.38	--	
	100	52.29	8.41	--	
	110	52.28	8.40	--	Pump off at 1020 hours.

MAR02-1410

Table 5. Data from aquifer test conducted in Quaternary glacial deposits on August 19, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Pumped well FPB93-4B (Continued)	121	45.04	--	1.16	Begin water-level measurements by S.D. Craigg. Ended test at 1200 hours on August 19, 1993. Final measurement made at approximately 0600 hours on August 20, 1993. Final measurement 0.02 ft above initial static water level.
	140	43.92	--	.04	
	165	43.88	--	.00	
	1,290	43.86	--	+.02	
Observation well FPB93-4C	00	43.87	.00	--	Water-level measurements by F.A. Bailey (initial and final two measurements with steel tape; others with electric line and steel tape attached). Pump on at 0330 hours. Discharge held constant at 12.5 gallons per minute for 110 minutes. Well located 29.5 ft north of pumped well FPB93-4B.
	.25	--	--	--	
	.50	--	--	--	
	.75	--	--	--	
	1.00	--	--	--	
	1.25	--	--	--	
	1.50	--	--	--	
	1.75	43.89	.02	--	
	2.00	43.90	.03	--	
	2.25	43.92	.05	--	
	2.50	43.93	.06	--	
	2.75	43.94	.07	--	
	3.00	43.95	.08	--	
	3.50	43.96	.09	--	
	4.00	43.97	.10	--	
	4.50	43.98	.11	--	
	5.00	43.99	.12	--	
	6.00	44.00	.13	--	
	7.00	44.01	.14	--	
	8.00	44.02	.15	--	
	9.00	44.03	.16	--	
	10	44.03	.16	--	
	12	44.04	.17	--	
	14	44.05	.18	--	
	16	44.05	.18	--	
	18	44.06	.19	--	
	20	44.06	.19	--	
	25	44.07	.20	--	
	30	44.08	.21	--	
	35	44.09	.22	--	
	40	44.10	.23	--	
	45	44.10	.23	--	
	51	44.11	.24	--	
	60	44.12	.25	--	
	70	44.13	.26	--	
	80	44.14	.27	--	
	90	44.15	.28	--	
	100	44.16	.29	--	
	110	44.16	.29	--	
	110.25	44.16	--	.29	Residual drawdown values measured during recovery.
	110.50	44.16	--	.29	
	110.75	44.15	--	.28	
	111.00	44.15	--	.28	
	111.25	44.13	--	.26	
	111.50	44.12	--	.25	
	111.75	44.11	--	.24	
	112.00	44.08	--	.21	

Table 5. Data from aquifer test conducted in Quaternary glacial deposits on August 19, 1993 in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Well	Time after start of test (minutes)	Depth to water below measuring point (feet)	Draw-down (feet)	Residual drawdown (feet)	Remarks
Observation well FPB93-4C (Continued)	112.25	44.08	--	.21	
	112.50	44.07	--	.20	
	112.75	44.06	--	.19	
	113.00	44.05	--	.18	
	113.50	44.05	--	.18	
	114.00	44.04	--	.17	
	114.50	44.03	--	.16	
	115	44.03	--	.16	
	116	44.02	--	.15	
	117	44.01	--	.14	
	118	44.01	--	.14	
	119	44.01	--	.14	
	120	44.00	--	.13	
	122	44.00	--	.13	
	124	43.99	--	.12	
	126	43.99	--	.12	
	128	43.99	--	.12	
	130	43.98	--	.11	
	135	43.97	--	.10	
	140	43.97	--	.10	Begin water-level measurements by S.D. Craigg.
	145	43.96	--	.09	
	150	43.95	--	.08	
	155	43.95	--	.08	
	160	43.95	--	.08	
	170	43.93	--	.06	
	180	43.93	--	.06	
	190	43.94	--	.05	
	200	43.94	--	.05	
	210	43.89	--	.02	Ended test at 1200 hours on August 19, 1993. Final measurement made at approximately 0600 hours on August 20, 1993. Final measurement 0.02 ft above initial static water level.
	1,290	43.85	--	+.02	

MAR02-1411

Table 6. Physical properties and major-ion concentrations in water samples collected from privately owned wells, monitoring wells, oil wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

Site number--numbering system described in text.

Geologic unit (in which well is completed; for brine-injection wells, indicates unit that is the source of the brine)--

- Qal - Alluvium (Quaternary)
- Qt - Glacial till (Pleistocene)
- Qgo - Glacial outwash (Pleistocene)
- Qw - Wiota Gravel (Pleistocene)
- Kb - Bearpaw Shale (Upper Cretaceous)
- Kjr - Judith River Formation (Upper Cretaceous)
- Mh - Heath Formation (Upper Mississippian)
- Mk - Kibbey Formation (Upper Mississippian)
- Mm - Madison Group (Mississippian)
  - Mc - Charles Formation of Madison Group
  - Mmc - Mission Canyon Limestone of Madison Group
- Dn - Nisku Formation (Upper Devonian)

Depth of well--in feet below land surface.

Constituents are dissolved, except as indicated.

Collecting agency and analyzing laboratory:

ASCHM, Asto-Chem Service Laboratory.
CHNO, Chen-Northern, Inc.,
ELAB, Energy Laboratories, Inc..
IHS, Public Health Service/Indian Health Service-Fort Peck Service Unit.
MBMG, Montana Bureau of Mines and Geology.
MDHES, Montana Department of Health and Environmental Sciences, Water Quality Bureau.
NALCO, Nalco Chemical Company.
PETRO, Petrolite Oil Field Chemicals Group.
USGS, U.S. Geological Survey.
YSB, Yapuncich, Sanderson, and Brown Laboratories, currently Energy Laboratories, Inc.

Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; g/mL, grams per milliliter; mg/L, milligrams per liter. Symbols: <, less than; --, no data.

MAR02-1412

Table 6. Physical properties and major-ion concentrations in water samples collected from privately owned wells, monitoring wells, oil wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number	Geologic unit	Depth of well (feet)	Collecting agency	Analyzing agency	Date sample collected	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Density (g/mL at 20°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
28N51E01BBBB01	Qt	153	USGS	USGS	07-21-82	2,820	7.2	12.0	–	1,100	110
			USGS	USGS	07-20-91	3,930	6.7	12.0	–	1,700	170
28N51E02ACDB01[7]	Mm	834	--	–	09-14-64	173,000	8.1	–	–	2,900	970
28N51E03BCAC01	Mb,Mm	3,575	--	NALCO	[5]09-22-89	--	[5]5.9	–	–	–	920
28N51E04CCCD01	Qt	50	USGS	USGS	08-25-90	2,650	7.6	10.0	–	410	69
28N51E08ADDA01	Qal	52	USGS	USGS	08-23-90	[1]2,050	7.7	11.0	–	230	45
28N51E03CCBB01	Qal	22	--	CHNO	11-08-88	[1]1,503	[1]7.6	--	–	440	99
28N51E03DDDB01	Qt	102	USGS	USGS	08-25-90	8,120	7.1	10.0	–	2,200	400
28N51E09BCBB01	Qt	90	USGS	USGS	07-17-91	2,610	7.5	18.0	–	350	61
28N51E09CCDD01	Qt	117	--	CHNO	04-07-89	[1]2,910	[1]7.3	--	–	340	100
			--	CHNO	08-16-89	[1]3,220	[1]7.2	--	–	570	100
			USGS	USGS	07-19-91	[1]3,180	7.3	11.5	–	650	120
28N51E09CDBB01	Qt	104	USGS	USGS	[4]08-12-93	18,300	6.9	11.0	1.005	4,600	870
			USGS	USGS	[4]08-12-93	18,300	6.9	11.0	1.005	4,700	890
28N51E09DCCC01	Qt	93	USGS	USGS	08-13-93	1,400	7.4	10.0	–	350	120
28N51E10DADC01	Mc,Dn	7,000	--	NALCO	08-24-84	--	[5]5.8	–	–	–	1,600
28N51E10DBAD01	Mm	780 (?)	USGS	USGS	07-24-89	[1]124,000	6.4	80.0	–	3,000	950
			--	NALCO	[5]12-11-89	--	[5]5.8	--	–	--	1,000
			USGS	USGS	08-29-90	117,000	[1]7.0	61.5	–	2,300	760
28N51E12CCBD01	Mm	[5]5,910-5,920	USGS	USGS	12-09-54	--	--	--	–	3,200	1,000
28N51E13CCCA01	Qt	33	USGS	USGS	08-22-90	3,600	7.4	11.0	–	1,700	240
28N51E13CCCC01	Qt	150	USGS	USGS	08-22-90	3,000	7.3	12.0	–	810	110
28N51E16DBCB01	Qt	104	USGS	USGS	07-23-89	10,000	7.3	10.0	–	2,900	580
			USGS	USGS	07-21-91	12,700	7.3	13.5	–	3,600	700
28N51E17ABDC01	Qal	36	USGS	USGS	08-26-90	7,000	7.3	11.0	–	1,900	350
28N51E17ABDD01	Qt	40	USGS	USGS	[4]08-26-90	8,600	7.2	10.0	–	2,500	480
			USGS	USGS	[4]08-26-90	8,600	7.2	10.0	–	2,500	480
28N51E17ADAD01	Qt	130	USGS	USGS	07-16-91	5,380	7.2	10.5	–	1,200	240
28N51E17DADA01	Qt	102	--	YSB	02-10-75	[1]1,080	[1]7.2	–	–	180	34
			USGS	USGS	08-25-90	4,400	7.4	10.5	–	900	160
28N51E21BDBC01	Qt	91	USGS	USGS	08-26-90	5,820	7.4	10.0	–	1,700	330
28N51E22BBBB01	Qt	68	USGS	USGS	07-24-93	3,050	7.3	11.0	1.001	1,500	250
28N51E22BDCA01	Mc	5,872	--	ASCHM	[6]04-30-81	[1]120,000	[1]7.3	--	–	--	4,000
28N51E22CBCB01	Qt	51	USGS	USGS	07-21-93	98,600	6.6	18.0	1.046	4,400	1,200
28N51E22CBCB02	Qt	49	USGS	USGS	07-20-93	97,200	6.5	19.0	1.045	4,500	1,300
28N51E22CDCC01	Qt	85	--	ELAB	07-09-85	[1]4,010	[1]7.1	–	–	1,900	360
			USGS	USGS	07-20-89	13,000	6.8	11.0	–	3,600	920
			USGS	USGS	07-20-91	26,500	6.3	12.5	–	9,800	1,600
28N51E25ACBC01	Mk	[5]3,350-3,380	USGS	USGS	01-09-67	73,200	7.1	–	–	2,400	810
	Mc	[5]5,640-5,660	USGS	USGS	01-09-67	160,000	6.8	–	–	3,200	1,000
28N51E27ABAA01	Qt	135	--	ASCHM	[3]10-11-89	[1]1,310	[1]8.2	–	–	280	44
			--	ASCHM	[3]11-09-89	[1]1,550	[1]7.6	–	–	570	95
			--	ELAB	12-13-89	[1]1,760	[1]7.5	–	–	300	32
			USGS	USGS	[4]08-24-90	1,120	7.2	17.5	–	400	71
			USGS	USGS	[4]08-24-90	1,120	7.2	17.5	–	410	72
			USGS	USGS	09-16-91	--	–	–	–	--	--
			USGS	USGS	04-15-92	1,550	7.2	7.0	.997	530	59
28N51E27ACDB01	Mh	[5]4,960-4,970	USGS	USGS	01-24-56	--	6.6	–	1.044	4,300	1,400
28N51E27BDDD01	Qt	68	--	ELAB	05-23-85	[1]3,470	[1]7.6	–	–	1,600	250
			--	CHNO	11-21-88	[1]15,400	[1]6.7	–	–	7,600	1,230

Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Iodide, dissolved (mg/L as I)	Dissolved solids, computed (mg/L)	Site number
200	310	4	4.1	[1]886	590	29	0.4	--	--	1,900	28N51E01BBBB01
320	350	4	4.6	893	1,100	36	.4	0.34	0.034	2,540	
120	73,000	590	500	170	2,200	110,000	--	–	--	190,000	28N51E02ACDB01
170	56,000	81	--	[1]360	510	88,000	--	--	--	146,000	28N51E03BCAC01
58	410	9	8.1	434	230	420	.2	.27	.023	1,480	28N51E04CCCD01
38	360	9	6.1	436	230	260	.2	.16	.020	1,220	28N51E08ADDA01
46	170	3	8	[1]395	390	32	.3	--	--	1,370	28N51E03CCBB01
280	980	9	15	286	260	2,800	.2	1.4	.200	4,950	28N51E03DDDB01
55	400	9	7.2	461	300	430	.4	.25	.031	1,550	28N51E09BCBB01
69	450	8	9	[1]366	210	670	.2	--	--	1,770	28N51E09CCDD01
75	460	8	9	[1]359	190	660	.2	--	--	1,740	
84	500	9	7.6	373	210	780	.3	.30	.029	1,950	
590	2,000	13	20	269	340	6,300	.2	.67	.360	10,300	28N51E09CDBB01
600	2,000	13	19	269	300	6,100	.2	.60	.380	10,100	
61	65	1	1.4	[1]367	340	25	.4	--	--	856	28N51E09DCCC01
150	49,000	43	--	[1]210	1,600	78,000	--	--	--	130,000	28N51E10DADC01
140	39,000	310	500	[1]183	1,800	60,000	5.6	12	.880	100,000	28N51E10DBAD01
360	43,000	47	--	[1]360	840	69,000	--	--	--	114,000	
130	36,000	330	470	[1]204	1,900	60,000	13	16	1.1	99,500	
140	[6]77,000	--	--	[7]196	2,600	120,000	--	--	--	201,000	28N51E12CCBD01
270	110	1	18	610	210	200	.8	.45	.012	2,420	28N51E13CCCA01
130	440	7	8.1	1,040	820	20	.4	.13	.057	2,190	28N51E13CCCC01
360	940	8	16	307	490	3,100	.1	.77	.049	5,810	28N51E16DBCB01
440	1,200	9	18	309	580	3,700	.4	1.0	.061	7,070	
240	750	8	14	304	230	2,300	<.1	.67	.130	4,100	28N51E17ABDC01
320	1,000	9	17	282	250	3,000	<.4	1.6	.190	5,280	28N51E17ABDD01
320	990	9	17	282	250	3,100	<.1	1.7	.210	5,370	
170	620	7	9.9	320	390	1,400	.5	.59	.076	3,050	28N51E17ADAD01
22	220	7	--	[1]350	180	64	.4	--	--	757	28N51E17DADA01
120	530	8	8.7	342	150	1,100	.2	.37	.068	2,300	
200	590	6	12	314	330	1,700	.2	.46	.048	3,390	28N51E21BDBC01
270	160	1	13	445	1,500	15	.6	.19	.007	2,470	28N51E22BBBB01
970	26,000	97	--	--	2,300	50,000	--	--	--	83,400	28N51E22BDCA01
320	20,000	130	290	539	1,500	35,000	--	6.0	.440	58,700	28N51E22CBCB01
290	22,000	140	280	571	1,200	38,000	--	5.9	.440	63,500	28N51E22CBCB02
270	410	--	5	[1]952	1,700	66	--	--	--	3,370	28N51E22CDCC01
790	870	5	15	713	1,400	4,100	.2	3.5	.560	8,640	
1,400	2,200	10	20	708	1,600	7,900	.5	4.8	.510	15,200	
85	22,000	200	650	[7]367	1,800	35,000	--	--	--	60,800	28N51E25ACBC01
150	63,000	480	500	[7]310	1,500	98,000	--	--	--	164,000	
41	220	6	8	[1]395	150	160	--	--	--	856	28N51E27ABAA01
80	335	6	8	[1]886	380	24	--	--	--	1,445	
54	320	0	11	[1]788	230	11	.5	--	--	1,110	
54	100	2	4.9	530	81	11	.4	.04	.006	671	
55	110	2	4.6	530	80	11	.5	.04	.007	684	
--	200	--	--	–	--	27	--	--	--	--	
74	200	4	6.1	[1]750	220	22	.4	0.10	.016	1,100	
230	[6]22,000	--	--	[7]390	1,400	36,000	--	--	--	61,400	28N51E27ACDB01
240	370	--	6	[1]753	1,500	85	--	--	--	2,930	28N51E27BDBB01
1,100	970	5	20	[1]499	1,300	5,200	.3	--	--	10,100	

MAR02-1413

Table 6. Physical properties and major-ion concentrations in water samples collected from privately owned wells, monitoring wells, oil wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number	Geologic unit	Depth of well (feet)	Collecting agency	Analyzing agency	Date sample collected	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Density (g/mL at 20°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
28N51E27BBBB01 (Continued)			--	ASCHM	03-10-89	--	--	--	--	--	1,500
			USGS	USGS	07-24-89	25,000	6.8	10.5	--	11,000	1,800
			USGS	USGS	08-27-90	48,000	6.5	11.5	--	16,000	2,800
			USGS	USGS	01-31-91	[1]52,700	5.8	7.0	--	16,000	2,900
			USGS	USGS	05-08-91	51,400	[1]6.7	11.5	--	16,000	2,900
			USGS	USGS	[4]07-22-91	63,000	6.3	10.0	--	16,000	2,900
			USGS	USGS	[4]07-22-91	63,000	6.3	10.0	--	16,000	3,000
			USGS	USGS	04-15-92	50,000	6.5	11.0	1.033	14,000	2,800
			USGS	USGS	07-23-93	81,500	6.6	10.5	1.038	12,000	2,800
28N51E29BACA01	Qal	50	USGS	USGS	08-17-93	2,090	7.5	10.5	.998	460	88
28N51E29CACB01	Qal	32	USGS	USGS	08-23-90	690	7.8	11.5	--	260	46
28N51E33DBBB01	Qt	120	--	CHNO	03-17-89	[2]2,630	[1]7.4	--	--	660	120
			USGS	USGS	08-24-90	2,670	7.1	11.0	--	760	140
28N51E33BBBC02	Qt	120	BIS	CHNO	03-16-89	[3]2,480	[1]7.4	--	--	570	100
28N51E33DDCC03	Qw	65	USGS	USGS	08-17-93	3,820	7.4	10.0	1.000	990	180
28N52E18ACCA01	Mmc	[5]6,020-6,050	USGS	USGS	05-17-52	60,000	7.4	--	1.043	2,800	890
28N52E20BBBB01	Qw	100	MBMG	MBMG	10-06-85	1,780	[1]7.3	10.0	--	390	74
28N52E20CCCC01	Qw	128	USGS	USGS	08-21-90	2,240	7.8	13.0	--	150	25
28N52E30DDDD01	Qw	170	MBMG	MBMG	10-05-85	2,950	8.0	10.0	--	120	25
29N51E07BCDB01	Mc	5,933	--	NALCO	07-06-79	--	[1]7.0	--	--	--	4,400
29N51E07BDBD01	Mm	1,207	--	NALCO	02-03-82	--	[1]6.4	--	--	--	4,800
29N51E08CCCA01	Mc	5,970	--	--	01-24-56	62,200	6.5	--	1.039	4,100	1,200
29N51E09ABBA04	Qal	36	USGS	USGS	08-16-93	1,260	7.7	9.0	.997	160	33
29N51E10CDAB01	Qt	60	BIS	ELAB	05-14-85	[1]1,940	[1]7.6	--	--	380	93
29N51E10CDBA01	Qt	90	USGS	USGS	07-21-82	1,360	7.4	9.0	--	340	87
29N51E13CACA01	Qal	62	USGS	USGS	07-19-91	1,710	7.3	11.5	--	430	85
29N51E15BDAA01	Qal	53	USGS	USGS	07-20-91	1,550	8.1	10.5	--	27	6.1
29N51E16CBCC01	Qal	25	MDHES	MDHES	07-23-79	[1]1,610	[1]8.0	--	--	260	47
			USGS	USGS	07-26-82	900	7.9	9.0	--	150	30
29N51E16CCAA01	Qal	23	USGS	USGS	07-20-82	1,140	7.7	9.5	--	160	27
			USGS	USGS	[4]07-18-91	1,220	7.6	11.5	--	160	27
			USGS	USGS	[4]07-18-91	1,220	7.6	11.5	--	160	27
29N51E16DACA01	Qal	25	--	ASCHM	[3]03-05-90	[1]1,220	[1]7.7	--	--	350	80
			USGS	USGS	08-23-90	1,520	7.5	16.5	--	330	72
29N51E17CCCC01	Qal or Kb	87	MDHES	MDHES	07-23-79	[1]1,070	[1]7.5	--	--	170	40
			USGS	USGS	07-27-82	[1]11,500	7.4	9.5	--	3,100	700
			USGS	USGS	07-22-89	9,500	7.4	10.5	--	2,600	600
29N51E19DCAC01	Kp	740	USGS	USGS	07-22-82	17,000	7.6	--	--	300	91
[6]29N51E19DDBA01	Mm	3,553	USGS	USGS	07-22-82	130,000	6.4	--	--	4,600	1,500
			--	NALCO	12-11-89	--	[1]5.8	--	--	--	2,000
29N51E20ABBA02	Qal	44	MDHES	MDHES	07-23-79	[1]7,300	[1]7.4	--	--	1,800	340
			USGS	USGS	07-26-82	[1]7,430	7.5	--	--	1,600	290
29N51E20BCDB01	Mm	5,773	--	YSB	[3]03-01-76	[1]62,500	[1]7.9	--	--	--	800
29N51E20CCDB01	Mm	5,750	--	YSB	[3]03-01-76	[1]62,500	[1]7.7	--	--	--	840
29N51E20DABB01	Qal	56	USGS	USGS	08-15-93	14,200	7.5	--	1.003	2,900	500
29N51E21ABCC01	Qal	12	MDHES	MDHES	07-23-79	[1]1,240	[1]8.0	--	--	190	38
			USGS	USGS	07-20-82	1,200	7.6	9.5	--	180	36
			USGS	USGS	07-18-91	1,520	7.4	10.5	--	240	47
29N51E21ABDA01	Qal	33	USGS	USGS	08-15-93	1,500	7.5	10.5	.998	170	28
29N51E21BBAA01	Qal	17	MDHES	MDHES	07-23-79	[1]3,070	7.8	--	--	230	39

Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Iodide, dissolved (mg/L as I)	Dissolved solids, computed (mg/L)	Site number
1,300	1,200	--	19	[1]526	950	6,700	--	--	--	12,300	28N51E27BBBB01 (Continued))
1,600	1,700	7	26	510	1,200	9,700	<.1	5.8	.066	16,400	
2,200	5,400	19	41	404	1,000	21,000	<.1	8.7	.150	32,800	
2,100	6,900	24	44	[1]419	1,200	22,000	5.1	9.6	<.110	35,500	
2,200	8,200	28	50	[1]446	1,400	23,000	8.2	9.2	.092	40,100	
2,000	9,000	31	52	466	1,200	23,000	1.9	8.1	.072	38,500	
2,100	9,200	32	49	466	1,300	23,000	1.9	9.0	.074	41,000	
1,500	11,000	40	61	[1]416	1,800	29,000	3.2	9.6	.087	46,800	
1,300	14,000	55	57	511	1,300	32,000	--	7.4	.110	51,900	
57	290	6	5.4	339	180	330	4	.13	.016	1,170	28N51E29BACA01
36	47	1	5.2	254	47	7.3	.4	.040	.002	427	28N51E29CACB01
57	380	6	8	[1]604	810	47	.3	--	--	1,810	28N51E33DBBB01
100	400	6	6.4	660	1,000	40	3	1.6	.190	2,120	
73	340	7	8	[1]558	770	34	.2	--	--	1,760	28N51E33BBBC02
130	610	8	6.4	775	1,200	62	.5	.18	.058	2,680	28N51E33DDCC03
130	[6]18,000	--	--	[7]215	2,400	28,000	--	--	--	50,000	28N52E18ACCA01
50	330	7	7	[1]738	360	15	.2	--	--	1,330	28N52E20BBBB01
20	570	19	4.3	810	440	20	.5	.060	.029	1,560	28N52E20CCCC01
15	800	31	1	[1]1,205	580	34	.7	--	--	2,200	28N52E30DDDD01
1,500	28,000	92	--	[1]152	810	54,000	--	--	--	88,500	29N51E07BCDB01
1,400	22,000	72	--	[1]360	700	46,000	--	--	--	75,700	29N51E07BDBD01
300	[6]20,000	--	--	119	120	33,000	--	--	--	54,300	29N51E08CCCA01
15	230	8	3.3	343	210	8.7	.4	.050	.007	787	29N51E09ABBA04
36	338	--	3	--	590	11	--	--	--	1,070	29N51E10CDAB01
30	180	4	3.6	[1]338	280	9.4	.3	--	--	809	29N51E10CDBA01
52	210	4	3.7	288	610	8.8	.4	.070	.014	1,160	29N51E13CACA01
2.8	330	28	1.9	581	97	110	.7	.48	.470	906	29N51E15BDAA01
35	230	6	--	[1]319	120	230	--	--	--	550	29N51E16CBCC01
18	130	5	3.8	[1]250	93	34	.5	--	--	438	
22	220	8	4.1	[1]473	160	18	.4	--	--	752	29N51E16CCAA01
22	210	7	4.3	461	200	13	.4	.070	.005	772	
22	200	7	4.1	461	190	13	.4	.090	.005	750	
36	215	5	4.0	[1]381	140	16	--	--	--	1,250	29N51E16DACA01
37	220	5	4.0	354	430	13	.3	.090	.008	1,020	
17	130	4	--	--	64	240	--	--	--	530	29N51E17CCCC01
320	1,400	11	12	[1]234	1,300	3,300	.1	--	--	7,210	
270	1,300	11	12	348	1,400	3,000	.1	3.3	.048	7,750	
18	3,900	98	10	[1]198	<5.0	6,500	.6	--	--	10,600	29N51E19DCAC01
200	33,000	212	550	[1]76	1,500	61,000	4.4	--	--	97,900	29N51E19DDBA01
390	42,000	220	--	[1]440	740	68,000	--	--	--	113,000	
240	790	8	--	[1]254	230	2,200	--	--	--	3,950	29N51E20ABBA02
220	890	10	11	[1]213	260	2,300	.2	--	--	4,120	
160	17,000	148	--	--	1,600	27,000	--	--	--	47,700	29N51E20BCDB01
170	19,000	30	--	--	1,500	30,000	--	--	--	52,300	29N51E20CCDB01
410	2,000	16	35	[1]337	170	4,600	.4	3.6	.300	7,960	29N51E20DABB01
24	220	7	--	[1]454	150	34	--	--	--	734	29N51E21ABCC01
22	220	7	4.1	[1]474	160	30	.4	--	--	773	
29	240	7	5.0	554	250	32	.4	.12	.003	952	
24	290	10	5.1	568	190	15	.5	.030	.013	916	29N51E21ABDA01
32	530	15	--	[1]312	180	630	--	--	--	1,600	29N51E21BBAA01

MAR02-1414

Table 6. Physical properties and major-ion concentrations in water samples collected from privately owned wells, monitoring wells, oil wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number	Geologic unit	Depth of well (feet)	Collecting agency	Analyzing agency	Date sample collected	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Density (g/mL at 20°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
29N51E21BBAA01			USGS	USGS	07-26-82	3,100	7.5	--	--	220	39
(Continued)			USGS	USGS	07-22-89	4,600	7.7	8.5	--	300	55
29N51E29CBBB01	Qal	45	USGS	USGS	11-03-82	10,000	6.9	10.0	--	3,500	750
[4]29N51E30DDDD01	Mm	3,431	USGS	MDHES	07-23-79	[1]100,000	--	--	--	4,300	1,500
			USGS	USGS	07-22-82	170,000	6.6	--	--	6,000	2,000
			--	PETRO	11-29-89	--	[1]6.7	--	--	8,800	3,300
29N51E31AABB01	Qal	54	USGS	USGS	11-03-82	17,000	7.1	10.0	--	2,500	670
			USGS	USGS	07-23-89	13,500	8.1	10.0	--	3,400	790
29N51E31ABDD01	Qal	43	USGS	USGS	08-10-93	15,100	7.0	13.5	1.004	3,000	700
29N51E31BDBA01	Qal	40	USGS	USGS	08-10-93	8,900	6.9	16.5	1.002	2,200	520
29N51E31CABB01	Qal	33	USGS	USGS	08-11-93	24,500	6.9	13.0	1.008	3,500	910
29N51E31DBAD01	Qal	37	USGS	USGS	08-11-93	[1]26,300	7.1	11.0	1.009	1,300	320
29N51E31DBDD01	Qal	33	USGS	USGS	08-12-93	31,500	7.2	9.5	1.010	2,000	450
29N51E32ABAC01	Qal	41	USGS	USGS	08-13-93	25,600	7.0	10.5	--	3,300	620
29N51E32ACCA01	Qal	30	USGS	USGS	08-14-93	18,600	7.5	24.0	1.004	650	160
29N51E32BAAD01	Qal	39	USGS	USGS	08-14-93	35,400	7.3	12.0	1.012	2,000	380
29N51E32BABB01	Qal	46	USGS	USGS	07-26-93	102,000	6.9	17.0	1.051	15,000	1,100
29N51E32BBAA01	Qal	42	USGS	USGS	11-02-82	70,000	6.8	12.0	--	4,700	1,300
29N51E32BBBA02	Qal	47	USGS	USGS	11-02-82	58,000	6.7	10.5	--	4,700	1,400
29N51E32BBDA03	Qal	53	USGS	USGS	07-25-93	127,000	6.7	11.0	1.060	11,000	3,300
29N51E32BBBA04	Qal	27	USGS	USGS	[4]07-25-93	12,300	7.5	12.0	1.004	670	170
			USGS	USGS	[4]07-25-93	12,300	7.5	12.0	1.003	630	160
29N51E32BBBB01	Qal	49	USGS	USGS	11-03-82	120,000	6.6	25.0	--	7,800	2,300
			USGS	USGS	07-23-89	65,000	6.7	16.0	--	5,000	1,500
29N51E32BCCA01	Qal	40	USGS	USGS	11-02-82	70,000	6.8	10.0	--	16,000	4,100
29N51E32BCCA02	Qal	45	USGS	USGS	08-11-93	41,700	7.3	12.0	1.015	4,200	1,000
29N51E36CCCC01	Qgo	30	MBMG	MBMG	10-05-85	658	[1]7.5	10.0	--	270	40

[1] Laboratory measurement.
[2] Brine-injection well completed in Judith River Formation.
[3] Date analyzed.
[4] Replicate analyses.
[5] Depth of sample interval; well depth unavailable.
[6] Sodium plus potassium.
[7] Onsite fixed-endpoint titration.
[8] Brine-injection well completed in Dakota Sandstone.

Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Iodide, dissolved (mg/L as I)	Dissolved solids, computed (mg/L)	Site number
30	510	15	6.1	[1]323	190	620	.4	--	--	1,610	29N51E21BBAA01
40	820	21	9.3	432	170	1,100	.3	1.2	.110	2,630	(Continued)
400	870	6	12	[1]246	630	3,400	.1	--	--	6,250	29N51E29CBBB01
140	70,000	457	--	[1]140	1,700	110,000	--	--	--	--	29N51E30DDDD01
250	56,000	314	910	[1]153	1,200	100,000	4.6	--	--	161,000	
110	37,000	170	--	[1]150	1,400	62,000	--	--	--	103,000	
210	4,100	35	20	[1]395	1,000	7,500	.2	--	--	13,800	29N51E31AABB01
350	1,800	13	15	334	740	4,800	.1	3.7	.150	8,860	
300	1,900	15	18	308	640	4,600	.5	1.6	.180	8,400	29N51E31ABDD01
220	950	9	12	263	980	2,100	.3	1.0	.024	4,960	29N51E31BDBA01
290	3,900	29	19	330	650	7,700	.6	0.66	.150	13,700	29N51E31CBAB01
110	5,900	73	34	338	560	9,100	.7	1.3	.430	16,300	29N51E31DBAD01
200	6,300	62	29	396	490	10,000	.7	0.74	.350	18,000	29N51E31DBDD01
420	3,900	30	42	[1]212	320	8,500	.5	--	--	13,900	29N51E32ABAC01
61	3,800	65	32	428	290	5,800	1.6	1.1	.130	10,400	29N51E32ACCA01
260	7,100	69	57	453	710	12,000	8	1.4	.270	20,800	29N51E32BAAD01
2,900	5,200	19	340	279	1,300	35,000	--	8.7	.690	46,100	29N51E32BABB01
350	25,000	160	250	[1]255	340	42,000	<.1	--	--	69,900	29N51E32BBAA01
300	19,600	120	59	[1]301	800	34,000	<.1	--	--	55,800	29N51E32BBBA02
750	28,600	110	1.6	217	720	58,000	--	4.5	1.5	91,100	29N51E32BBDA03
55	2,200	37	15	349	510	3,200	.7	1.7	.210	6,450	29N51E32BBBA04
54	2,200	38	13	449	500	3,100	.5	1.8	.210	6,310	
380	43,000	210	150	[1]172	1,100	67,000	<.1	--	--	114,000	29N51E32BBBB01
290	17,600	110	83	323	770	30,000	.1	9.2	1.1	50,000	
1,300	23,000	50	97	[1]126	440	46,000	<.1	--	--	75,100	29N51E32BCCA01
400	8,600	54	37	407	530	14,000	.8	1.4	.270	24,300	29N51E32BCCA02
40	60	2	4.5	[1]296	85	1.5	.6	--	--	435	29N51E36CCCC01

MAR02-1415

Table 7. Trace-element and organic-carbon concentrations and stable-isotope ratios in water samples collected from privately owned wells, monitoring wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

Site number--numbering system described in text.

Geologic unit (in which well is completed; for brine-injection wells, indicates unit that is the source of the brine)--

- Qal - Alluvium (Quaternary)
- Qt - Glacial till (Pleistocene)
- Qgo - Glacial outwash (Pleistocene)
- Qw - Wiota Gravel (Pleistocene)
- Kb - Bearpaw Shale (Upper Cretaceous)
- Kjr - Judith River Formation (Upper Cretaceous)
- Mm - Madison Group (Mississippian)

Depth of well--in feet below land surface.

Constituents are dissolved, except as indicated.

Collecting agency and analyzing laboratory:

- ASCHM, Astro-Chem Service Laboratory.
- CHNO, Chen-Northern, Inc..
- ELAB, Energy Laboratories, Inc..
- MBMG, Montana Bureau of Mines and Geology.
- USGS, U.S. Geological Survey.
- YSB, Yapuncich, Sanderson, and Brown Laboratories, currently Energy Laboratories, Inc.

Abbreviations: µg/L, micrograms per liter; mg/L, milligrams per liter; per mil, parts per thousand. D/H, deuterium/hydrogen; O-18/O-16, oxygen 18/oxygen 16. Symbols: <, less than; --, no data.

MAR02-1416

Table 7. Trace-element and organic-carbon concentrations and stable-isotope ratios in water samples collected from privately owned wells, monitoring wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number	Geologic unit	Depth of well (feet)	Collecting agency	Analyzing agency	Date sample collected	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)	Carbon, organic, dissolved (mg/L as C)	D/H stable-isotope ratio (per mil)	O-18/O-16 stable-isotope ratio (per mil)	Site number
28N51E01BBBB01	Qt	153	USGS	USGS	07-21-82	--	--	40	--	430	--	--	--	--	28N51E01BBBB01
			USGS	USGS	07-20-91	<100	760	20	270	520	3,400	2.9	-143.0	-18.65	
28N51E04CCCD01	Qt	50	USGS	USGS	08-25-90	<100	870	390	120	670	910	3.8	--	--	28N51E04CCCD01
28N51E08ADDA01	Qal	52	USGS	USGS	08-23-90	<100	800	2,800	110	160	550	3.5	-125.0	-15.05	28N51E08ADDA01
28N51E08CCBB01	Qal	22	--	CHNO	11-08-88	--	--	7,400	--	790	--	--	--	--	28N51E08CCBB01
28N51E08DDDB01	Qt	102	USGS	USGS	08-25-90	200	810	18,000	250	930	4,500	3.9	--	--	28N51E08DDDB01
28N51E09BCBB01	Qt	90	USGS	USGS	07-17-91	<100	790	2,200	130	190	850	2.2	--	--	28N51E09BCBB01
28N51E09CCDD01	Qt	117	--	CHNO	04-07-89	--	--	7,300	--	490	--	--	--	--	28N51E09CCDD01
			--	CHNO	08-16-89	--	--	6,500	--	360	--	--	--	--	
			USGS	USGS	07-19-91	<100	640	6,100	150	260	1,500	2.4	-127.0	-15.70	
28N51E09CDBB01	Qt	104	USGS	USGS	[1]08-12-93	300	640	3,500	300	1,100	9,300	--	--	--	28N51E09CDBB01
			USGS	USGS	[1]08-12-93	300	680	--	290	970	9,100	--	--	--	
29N51E09DCCC01	Qt	93	USGS	USGS	05-13-93	--	740	16	--	--	--	--	--	--	29N51E09DCCC01
28N51E10DDAD01	Mm	--	USGS	USGS	07-24-89	590	20,000	690	5,200	240	54,000	7.0	-138.5	-16.25	28N51E10DDAD01
			USGS	USGS	08-29-90	1,000	22,000	1,300	160	270	47,000	5.5	-133.0	-16.20	
28N51E13CCCA01	Qt	33	USGS	USGS	08-22-90	300	630	30	230	130	1,800	--	--	--	28N51E13CCCA01
28N51E13CCCC01	Qw	150	USGS	USGS	08-22-90	<100	810	7,800	150	60	2,100	6.3	--	--	28N51E13CCCC01
28N51E16DBCB01	Qt	104	USGS	USGS	07-23-89	140	680	24,000	320	3,300	5,500	1.4	-139.5	-17.40	28N51E16DBCB01
			USGS	USGS	07-21-91	<100	680	28,000	300	3,600	7,400	4.6	-137.0	-17.50	
28N51E17ABDC01	Qal	36	USGS	USGS	08-26-90	300	800	18,000	230	1,300	3,300	--	-132.0	-16.45	28N51E17ABDC01
28N51E17ABDD01	Qt	40	USGS	USGS	[1]08-26-90	<100	800	24,000	260	1,300	5,100	--	-131.0	-16.50	28N51E17ABDD01
			USGS	USGS	[1]08-26-90	<100	800	25,000	260	1,300	4,900	4.2	--	--	
28N51E17ADAD01	Qt	130	USGS	USGS	07-16-91	<100	630	9,500	210	290	2,600	1.2	--	--	28N51E17ADAD01
28N51E17DADA01	Qt	102	--	YSB	02-10-75	--	--	2,500	--	--	--	--	--	--	28N51E17DADA01
			USGS	USGS	08-25-90	100	670	7,500	160	360	1,900	3.9	-128.0	-15.65	
28N51E21BDBC01	Qt	91	USGS	USGS	08-26-90	100	720	14,000	220	2,100	3,100	--	-138.0	-17.65	28N51E21BDBC01
28N51E22BBBB01	Qt	68	USGS	USGS	07-24-93	<100	220	<10	230	20	2,000	--	--	--	28N51E22BBBB01
28N51E22CBCB01	Qt	81	USGS	USGS	07-21-93	200	15,000	50	3,500	310	45,000	--	--	--	28N51E22CBCB01
28N51E22CBCB02	Qt	49	USGS	USGS	07-20-93	200	14,000	50	3,300	310	44,000	--	--	--	28N51E22CBCB02
28N51E22CDCC01	Qt	85	--	ELAB	07-09-85	--	--	460	--	--	--	--	--	--	28N51E22CDCC01
			USGS	USGS	07-20-89	52	660	430	560	6,600	13,000	5.5	-141.5	-18.35	
			USGS	USGS	07-20-91	<100	710	5,900	530	5,000	28,000	18	--	--	
28N51E27ABAA01	Qt	133	--	ASCHM	[2]10-11-59	--	--	100	--	--	--	--	--	--	28N51E27ABAA01
			-	ASCHM	[2]11-09-59	--	--	200	--	--	--	--	--	--	
			--	ELAB	12-15-69	--	--	70	--	160	--	--	--	--	
			USGS	USGS	[1]08-24-90	41	570	17	32	97	1,000	7.6	-131.0	-19.75	
			USGS	USGS	[1]08-24-90	42	560	22	53	97	1,000	7.6	-153.0	-19.60	
			USGS	USGS	04-15-92	43	610	17	92	67	1,400	--	--	--	
28N51E27BBBB01	Qt	68	-	ELAB	05-23-85	--	--	<30	--	--	--	--	--	--	28N51E27BBBB01
			--	CHNO	11-21-88	--	--	700	--	1,100	--	--	--	--	
			-	ASCHM	03-10-59	--	--	100	--	--	--	--	--	--	
			USGS	USGS	07-24-89	78	670	1,100	880	940	29,000	6.5	-135.0	-17.70	
			USGS	USGS	05-27-90	<100	760	4,000	1,200	1,600	41,000	--	-133.0	-17.40	
			USGS	USGS	01-31-91	200	770	3,500	680	1,600	44,000	--	--	--	
			USGS	USGS	05-08-91	300	620	7,700	720	1,800	--	--	--	--	
			USGS	USGS	[1]07-22-91	<100	680	2,400	760	1,700	47,000	2.7	--	--	
			USGS	USGS	[1]07-22-91	200	--	2,400	270	1,700	52,000	1.2	--	--	
			USGS	USGS	04-15-92	200	670	17,000	870	1,900	42,000	--	--	--	
			USGS	USGS	07-23-93	200	540	3,100	2,300	1,400	49,000	--	--	--	
28N51E29BACA01	Qal	50	USGS	USGS	03-17-93	<100	630	800	110	250	670	--	--	--	28N51E29BACA01
28N51E29CACB01	Qal	32	USGS	USGS	08-23-90	86	180	6	24	<1	290	1.7	--	--	28N51E29CACB01
28N51E33BBBB01	Qt	120	--	CHNO	03-17-89	--	--	1,400	--	220	--	--	--	--	28N51E33BBBB01
			USGS	USGS	03-24-90	<100	730	11,000	220	510	1,700	3.7	-144.0	-18.95	

MAR02-1417

Table 7. Trace-element and organic-carbon concentrations and stable-isotope ratios in water samples collected from privately owned wells, monitoring wells, and brine-injection wells in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number	Geologic unit	Depth of well (feet)	Collecting agency	Analyzing agency	Date sample collected	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)	Carbon, organic, dissolved (mg/L as C)	D/H stable-isotope ratio (per mil)	O-18/O-16 stable-isotope ratio (per mil)	Site number
28N51E33BBBC02	Qt	102	--	CHNO	03-16-89	--	--	1,400	--	220	--	--	--	--	28N51E33BBBC02
28N51E33DDCC03	Qw	65	USGS	USGS	08-17-93	<100	590	<10	220	860	2,300	--	--	--	28N51E33DDCC03
28N52E20BBBB01	Qw	100	MBMG	MBMG	10-06-85	-	--	2,300	--	64	--	--	--	--	28N52E20BBBB01
28N52E20CCCC01	Qw	128	USGS	USGS	08-21-90	<100	960	1,100	110	60	460	--	--	--	28N52E20CCCC01
28N52E30DDDD01	Qw	170	MBMG	MBMG	10-05-85	--	--	1,200	--	23	--	--	--	--	28N52E30DDDD01
29N51E09ABBA04	Qal	36	USGS	USGS	08-16-93	45	670	1,500	100	92	360	--	--	--	29N51E09ABBA04
29N51E10CDBA01	Qt	90	USGS	USGS	07-21-82	--	--	1,600	--	190	--	--	--	--	29N51E10CDBA01
29N51E15CACA01	Qal	62	USGS	USGS	07-19-91	24	400	<3	170	13	750	--	--	--	29N51E15CACA01
29N51E16BDAA01	Qal	53	USGS	USGS	07-20-91	74	1,900	18	78	23	150	--	--	--	29N51E16BDAA01
29N51E16CBCC01	Qal	25	USGS	USGS	07-26-82	--	--	27	--	27	--	--	--	--	29N51E16CBCC01
29N51E16CCAA01	Qal	23	USGS	USGS	07-20-82	--	--	470	--	170	--	--	--	--	29N51E16CCAA01
			USGS	USGS	[1]07-15-91	43	670	1,500	66	160	360	3.5	-133.0	-16.75	
			USGS	USGS	[1]07-18-91	43	650	1,500	65	160	360	3.6	--	--	
29N51E16DACA01	Qal	25	USGS	USGS	08-23-90	25	510	170	92	100	620	8.0	-130.0	-16.75	29N51E16DACA01
29N51E17CCCC01	Qal or Kb	87	USGS	USGS	07-27-82	--	--	17,000	--	1,800	--	--	--	--	29N51E17CCCC01
			USGS	USGS	07-22-89	15	500	26,000	480	1,500	5,500	4.5	-135.5	-17.00	
29N51E19DCAC01	Kjr	740	USGS	USGS	07-22-82	--	--	30	--	80	--	--	--	--	29N51E19DCAC01
29N51E19DDBA01[3]	Mm	3,593	USGS	USGS	07-22-82	--	--	730	--	160	--	--	--	--	29N51E19DDBA01
29N51E20ABBA02	Qal	44	USGS	USGS	07-26-82	--	--	270	--	1,200	--	--	--	--	29N51E20ABBA02
29N51E20DABB01	Qal	36	USGS	USGS	08-15-93	300	690	16,000	230	1,500	5,500	--	--	--	29N51E20DABB01
29N51E21ABCC01	Qal	12	USGS	USGS	07-20-82	--	660	5	--	3	--	--	--	--	29N51E21ABCC01
			USGS	USGS	07-15-91	53	760	33	77	1	520	3.5	--	--	
29N51E21ABDA01	Qal	33	USGS	USGS	05-15-93	64	1,100	1,700	83	680	390	--	--	--	29N51E21ABDA01
29N51E21BBAA01	Qal	17	USGS	USGS	07-26-82	--	--	2,800	--	460	--	--	--	--	29N51E21BBAA01
			USGS	USGS	07-22-89	89	1,600	5,400	190	230	710	3.0	-138.5	-17.05	
29N51E29CBBB01	Qal	45	USGS	USGS	11-03-82	--	--	22,000	--	1,800	--	--	--	--	29N51E29CBBB01
29N51E30DDDD01[3]	Mm	3,431	USGS	USGS	07-22-82	--	--	1,400	--	300	--	--	--	--	29N51E30DDDD01
29N51E31AABB01	Qal	54	USGS	USGS	11-03-82	--	--	9,500	--	1,500	--	--	--	--	29N51E31AABB01
			USGS	USGS	07-23-89	67	730	27,000	550	2,000	12,000	5.0	-134.0	-16.80	
29N51E31ABDD01	Qal	43	USGS	USGS	05-10-93	<100	1,900	19,000	450	1,400	13,000	--	--	--	29N51E31ABDD01
29N51E31BDBA01	Qal	40	USGS	USGS	05-10-93	<100	490	20	390	320	4,600	--	--	--	29N51E31BDBA01
29N51E31CABB01	Qal	33	USGS	USGS	05-11-93	<100	510	16,000	460	2,400	11,000	--	--	--	29N51E31CABB01
29N51E31DBAD01	Qal	37	USGS	USGS	05-11-93	<100	5,900	15,000	600	710	7,500	--	--	--	29N51E31DBAD01
29N51E31DBDD01	Qal	33	USGS	USGS	05-12-93	200	1,200	13,000	530	760	9,500	--	--	--	29N51E31DBDD01
29N51E32ABAC01	Qal	41	USGS	USGS	05-13-93	--	1,100	60	--	--	--	--	--	--	29N51E32ABAC01
29N51E32ACCA01	Qal	30	USGS	USGS	08-14-93	200	3,300	20	350	620	2,300	--	--	--	29N51E32ACCA01
29N51E32BAAD01	Qal	39	USGS	USGS	08-14-93	200	1,400	13,000	840	980	6,200	--	--	--	29N51E32BAAD01
29N51E32BABB01	Qal	46	USGS	USGS	07-26-93	300	13,000	35,000	3,200	2,500	49,000	--	--	--	29N51E32BABB01
29N51E32BBAA01	Qal	42	USGS	USGS	11-02-82	--	--	49,000	--	3,300	--	--	--	--	29N51E32BBAA01
29N51E32BBBA02	Qal	47	USGS	USGS	11-02-82	--	--	21,000	--	3,200	--	--	--	--	29N51E32BBBA02
29N51E32BBBA03	Qal	53	USGS	USGS	07-25-93	200	2,900	71,000	2,600	6,600	110,000	--	--	--	29N51E32BBBA03
29N51E32BBBA04	Qal	27	USGS	USGS	[1]07-25-93	<100	2,000	2,100	350	420	4,900	--	--	--	29N51E32BBBA04
			USGS	USGS	[1]07-25-93	<100	2,000	2,200	350	420	5,000	--	--	--	
29N51E32BBBB01	Qal	49	USGS	USGS	11-03-82	--	--	33,000	--	6,900	--	--	--	--	29N51E32BBBB01
			USGS	USGS	07-23-89	150	5,500	21,000	2,300	6,400	52,000	7.0	-122.0	-16.15	
29N51E32BCCA01	Qal	40	USGS	USGS	11-02-82	--	--	55,000	--	14,000	--	--	--	--	29N51E32BCCA01
29N51E32BCCA02	Qal	45	USGS	USGS	08-11-93	300	860	17,000	610	3,000	23,000	--	--	--	29N51E32BCCA02
29N51E36CCCC01	Qgo	30	MBMG	MBMG	10-05-85	--	--	36	--	--	--	--	--	--	29N51E36CCCC01

[1]Replicate analyses.
[2]Date of analysis.
[3]Brine-injection well completed in Dakota Sandstone.

MAR02-1418

Table 8. Physical properties and major-ion concentrations in deionized-water field blanks collected during ground-water sampling in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Site number indicates site where sampling equipment was used prior to collecting field blank. Constituents are dissolved, except as indicated. Laboratory analyses by the U.S. Geological Survey. Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; g/mL, grams per milliliter; mg/L, milligrams per liter. Symbols: <, less than; --, no data]

Site number of previous site	Date sample collected	Specific conductance, laboratory (µS/cm)	pH, laboratory (standard units)	Water temperature, onsite (°C)	Density (g/mL at 20 °C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
28N51E27BBBB01	08-29-90	6	6.2	--	--	1	0.39	0.05	0.80
28N51E16DBCB01	07-21-91	734	7.6	--	--	15	3.6	1.5	11
28N51E22CBCB01	07-21-93	39	6.9	24.0	--	4	.99	.29	5.4
29N51E32ABAC01	08-13-93	26	5.6	23.5	0.997	4	1.1	.17	<.20

Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, laboratory (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Iodide, dissolved (mg/L as I)	Dissolved solids, computed (mg/L)	Site number of previous site
0.3	0.10	3.0	<1.0	0.40	<0.10	<0.010	<0.001	--	28N51E27BBBB01
1	.20	194	46	15	.10	.040	.002	196	28N51E16DBCB01
1	.10	3.2	2.0	7.7	<.10	.010	<.001	45	28N51E22CBCB01
--	<.10	8.6	1.5	.30	<.10	<.010	<.001	--	29N51E32ABAC01

Table 9. Trace-element and dissolved organic-carbon concentrations in deionized-water field blanks collected during ground-water sampling in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Site number indicates site where sample was collected prior to collecting field blank. Constituents are dissolved, except as indicated. Laboratory analyses by the U.S. Geological Survey. Abbreviations: µg/L, micrograms per liter; mg/L, milligrams per liter. Symbols: <, less than; --, no data]

Site number of previous site	Date sample collected	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)	Carbon, organic, dissolved (mg/L as C)
28N51E27BBBB01	08-29-90	<2	<10	6	<4	2	20	0.6
28N51E16DBCB01	07-21-91	<2	30	12	<4	2	20	.6
28N51E22CBCB01	07-21-93	<2	20	6	<4	1	17	--
29N51E32ABAC01	08-13-93	3	20	41	6	11	6	--

MAR02-1419

Table 10. Locations and descriptions of streamflow-measurement sites on the Poplar River in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

Site number (described in text)	Latitude	Longitude	Physical description of site
PR-0	481655	1050512	Poplar River above Empire Bridge, near Poplar, Mont. Located about 13 mi northeast of Poplar, 3.5 mi southwest of Geddart Lake, 0.5 mi upstream from Empire Bridge; in SW 1/4, SE 1/4, NE 1/4, sec. 09, T. 29 N., R. 51 E.
PR-1	481625	1050517	U.S. Geological Survey miscellaneous streamflow-measurement station 06180600 (Poplar River above Slims Coulee, near Poplar, Mont.). Located about 12 mi northeast of Poplar, 0.4 mi west of Route 251, 1.5 mi above Slims Coulee; in NW 1/4, NE 1/4, NE 1/4, sec. 16, T. 29 N., R. 51 E.
PR-2	481515	1050516	Poplar River above Slims Coulee, near Poplar, Mont. Located about 11 mi northeast of Poplar, 3.0 mi southwest of Geddart lake, 1.5 mi south of Empire Bridge; in SW 1/4, SE 1/4, NE 1/4, sec. 21, T. 29 N., R. 51 E.
PR-2A	481458	1050459	Poplar River below Slims Coulee, near Poplar, Mont. Located about 10 mi northeast of Poplar, 0.75 mi southwest of Slims Coulee, 0.75 mi northeast of concrete culvert bridge; in SE 1/4, SW 1/4, SW 1/4, sec. 21, T. 29 N., R. 51 E.
PR-3	481413	1050641	Poplar River below Slims Coulee, near Poplar, Mont. Located about 9 mi northeast of Poplar, 1.6 mi southwest of Slims Coulee, at concrete culvert bridge; in NE 1/4, NW 1/4, SE 1/4, sec. 29, T. 29 N., R. 51 E.
PR-3A	481318	1050719	Poplar River above Culbertson Creek, near Poplar, Mont. Located about 8 mi northeast of Poplar, 0.75 mi upstream from Culbertson Creek, in NE 1/4, NW 1/4, SW 1/4, sec. 32, T. 29 N., R. 51 E.
PR-3B	481330	1050803	Poplar River above Culbertson Creek, near Poplar, Mont. Located about 8 mi northeast of Poplar, 500 ft upstream from Culbertson Creek; in NE 1/4, SW 1/4, NE 1/4, sec. 31, T. 29 N., R. 51 E.
PR-4	481327	1050817	Poplar River below Culbertson Creek, near Poplar, Mont. Located about 8 mi northeast of Poplar, 0.25 mi downstream from Culbertson Creek; in SE 1/4, SW 1/4, NW 1/4, sec. 31, T. 29 N., R. 51 E.
PR-5	481249	1050831	Poplar River below Culbertson Creek, near Poplar, Mont. Located about 7 mi northeast of Poplar, 1 mi downstream from Culbertson Creek; in SE 1/4, NE 1/4, NW 1/4, sec. 04, T. 28 N., R. 51 E.
PR-6	481151	1050907	Poplar River below Flea Creek, near Poplar, Mont. Located about 6 mi northeast of Poplar, 0.5 mi downstream from Flea Creek, at a culvert bridge; in SE 1/4, NE 1/4, NE 1/4, sec. 08, T. 28 N., R. 51 E.
PR-7	481108	1050956	Poplar River below Badger Creek, near Poplar, Mont. Located about 5 mi northeast of Poplar, 0.75 mi downstream from Badger Creek at ford 1 mi downstream from a culvert bridge; in NW 1/4, NE 1/4, NW 1/4, sec. 17, T. 28 N., R. 51 E.
PR-8	481015	1051042	U.S. Geological Survey streamflow-gaging station 06181000 (Poplar River near Poplar, Mont.). Located on right bank, about 4 mi north of Poplar, at river mi 11; in SW 1/4, NE 1/4, NE 1/4, sec. 19, T. 28 N., R. 51 E.
PR-9	480904	1051008	Poplar River below gage, near Poplar, Mont. Located about 3 mi northeast of Poplar, at ford 1.25 mi downstream from streamflow-gaging station 06181000; in SE 1/4, SW 1/4, NW 1/4, sec. 29, T. 28 N., R. 51 E.

Table 11. Streamflow and miscellaneous water-quality measurements for the Poplar River in the East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Abbreviations: ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter. Symbol: --, no data]

Date	Site number (described in text)	Streamflow, instantaneous (ft^3/s)	Specific conductance, onsite (µS/cm)	Temperature, water (°C)	Chloride, dissolved (mg/L as Cl)
09-09-81	PR-1	1.7	1,560	20.0	20
	PR-2	--	1,590	--	18
	PR-3	1.1	3,090	23.0	600
	PR-4	--	3,620	--	540
	PR-5	.7	3,790	25.0	880
10-22-90	PR-0	--	1,480	--	12
	PR-1	--	1,490	--	15
10-24-90	PR-2	--	1,480	--	16
	PR-2A	--	1,500	--	17
	PR-3	--	1,580	--	42
	PR-3A	--	1,610	--	56
	PR-4	--	1,940	--	210
	PR-5	--	1,730	--	110
10-25-90	PR-6	--	1,970	--	200
	PR-7	--	1,970	--	210
	PR-8	--	2,020	--	240
	PR-9	--	2,030	--	240
04-03-91	PR-0	82	946	10.5	11
	PR-1	86	922	11.0	9.6
	PR-2	83	949	11.0	8.9
	PR-2A	94	946	11.5	10
	PR-3	91	953	12.0	8.1
	PR-3A	76	956	12.5	11
	PR-3B	87	956	13.0	13
	PR-4	84	976	13.0	13
	PR-5	79	998	13.0	21
	PR-6	85	1,000	13.0	23
	PR-7	82	1,000	13.0	24
	PR-8	88	996	13.0	25
	PR-9	85	1,000	12.5	29
07-23-91	PR-0	47	1,270	19.5	10
	PR-1	49	1,260	20.0	9.5
	PR-2	46	1,280	20.0	9.9
	PR-3	46	1,300	22.0	22
	PR-4	49	1,340	23.0	35
	PR-6	52	1,410	24.0	51
	PR-8	44	--	--	61
09-12-91	PR-1	7.9	--	--	17
	PR-2	11	--	--	15
	PR-3	11	--	--	41
	PR-3B	--	--	--	47
	PR-4	11	--	--	47
	PR-5	10	--	--	160
	PR-6	11	--	--	170
	PR-8	11	--	--	160

MAR02-1420

Table 12. Physical properties and major-ion concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Samples collected and analyzed by the U.S. Geological Survey. Abbreviations: ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees C; °C, degrees Celsius; mg/L, milligrams per liter. Symbols: <, less than; --, no data]

Site number (described in text)	Date	Streamflow, instantaneous, (ft^3/s)	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Dissolved solids, computed (mg/L)
PR-1	10-25-79	22	1,380	8.8	7.0	190	24	31	280	9	7.4	300	250	12	0.40	917
	09-09-81	1.7	1,560	9.0	20.0	140	12	27	320	12	8.5	560	240	20	.50	967
	02-21-91	2.0	1,380	[1]8.1	0.0	160	23	24	270	9	6.0	--	230	14	.40	912
	04-03-91	86	922	--	11.0	--	--	--	--	--	--	--	--	9.6	--	--
	04-24-91	36	1,180	[1]8.6	16.0	160	24	24	240	8	5.7	--	220	8.8	.40	827
	07-23-91	49	1,260	--	20.0	--	--	--	--	--	--	--	--	9.5	--	--
	07-24-91	38	1,280	[1]8.6	22.0	160	22	26	230	8	7.9	--	180	10	.40	802
	09-12-91	7.9	--	--	--	--	--	--	--	--	--	--	--	17	--	--
	09-23-91	13	1,430	[1]8.7	9.5	150	18	25	280	10	6.2	--	220	17	.50	897
	10-28-91	9.8	1,550	[1]8.6	.5	170	21	29	320	11	6.0	--	270	15	.60	1,030
	04-21-92	51	1,120	[1]8.4	4.5	160	29	21	210	7	6.5	--	180	13	.40	721
	06-23-92	17	1,470	[1]8.8	19.0	150	17	25	290	10	6.1	--	240	21	.40	935
	08-05-92	12	[1]1,430	[1]8.9	21.0	140	15	26	280	10	6.4	--	200	16	.30	880
	10-16-92	8.9	1,530	[1]8.7	1.0	150	19	26	320	11	5.6	--	250	12	.60	976
	04-07-93	102	900	[1]8.5	6.0	130	22	19	150	6	6.5	--	130	7.3	.30	553
	06-17-93	29	1,330	[1]8.8	15.5	140	17	23	270	10	6.0	--	210	10	.50	828
	08-12-93	118	1,210	[1]8.5	17.0	200	33	28	210	6	8.4	--	180	9.9	.40	778
PR-8	08-13-75	37	1,650	8.9	21.5	230	23	41	320	9	14	539	300	46	.40	1,070
	09-15-75	35	1,670	8.8	19.5	220	27	37	330	10	12	549	290	92	.50	1,120
	12-23-75	10	2,150	8.3	0.0	320	53	45	370	9	7.9	633	290	120	.50	1,280
	03-16-76	37	930	8.0	0.0	180	35	23	160	5	10	360	130	35	.40	619
	04-07-76	443	593	8.2	11.0	130	26	16	79	3	8.2	222	73	11	.30	356
	06-22-76	221	1,050	8.3	20.5	200	31	29	170	5	10	379	170	15	.30	662
	07-09-76	471	920	8.8	25.0	150	29	26	150	5	11	363	140	9.6	.30	593
	08-06-76	63	1,390	8.8	20.0	200	26	34	260	8	12	449	260	38	.40	904
	09-10-76	21	1,550	8.7	14.5	210	26	33	290	9	10	476	250	77	.40	981
	10-01-76	21	1,550	9.3	13.0	210	26	36	280	8	9.2	468	240	84	.40	962
	11-11-76	28	1,520	8.7	.5	230	31	36	280	8	7.4	506	250	48	.40	965
	12-10-76	26	1,890	8.1	0.0	330	45	53	340	8	8.1	661	310	70	.50	1,230
	01-28-77	7.0	2,530	7.8	0.0	420	74	56	380	8	7.6	582	290	290	.50	1,460
	02-11-77	19	2,050	7.9	0.0	370	65	50	420	10	7.8	633	280	280	.40	1,490
	03-31-77	164	1,330	8.5	4.0	150	27	21	240	8	5.4	330	140	150	.40	787
	04-26-77	44	1,420	8.5	19.0	190	30	28	270	9	6.9	450	210	81	.40	901
	05-09-77	79	1,560	8.5	21.0	200	28	32	300	9	7.7	460	240	110	.50	999
	06-06-77	57	1,550	8.5	22.5	230	30	38	290	8	9.7	480	260	87	.50	1,010
	07-19-77	7.4	2,140	8.6	26.0	220	25	38	420	12	9.9	510	270	270	.50	1,350
	08-22-77	6.6	3,180	8.6	18.5	260	28	45	600	16	13	500	290	590	.40	1,870
	09-15-77	15	2,590	8.5	17.5	210	27	35	480	14	10	500	240	380	.60	1,480
	10-28-77	29	1,930	8.5	8.0	230	31	36	380	11	7.6	510	260	190	.60	1,220
	11-15-77	30	1,690	8.3	2.0	210	29	34	310	9	6.7	510	240	96	.50	1,030

MAR02-1421

Table 12. Physical properties and major-ion concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number (described in text)	Date	Streamflow, instantaneous, (ft^3/s)	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Dissolved solids, computed (mg/L)
PR-8 (Continued)	12-21-77	9.0	2,530	7.7	0.0	340	54	51	460	11	9.5	660	330	240	.50	1,510
	01-09-78	7.0	2,560	7.9	0.0	410	66	60	470	10	8.6	690	340	250	.60	1,620
	02-13-78	1.0	2,510	7.9	0.0	450	83	65	430	9	7.5	540	310	380	.40	1,610
	03-24-78	3,500	271	7.4	1.0	68	15	7.5	26	1	5.7	110	34	4.1	.10	167
	04-18-78	237	882	8.4	7.0	180	34	24	140	4	7.0	330	140	24	.30	576
	05-11-78	184	1,180	8.6	14.5	210	32	31	200	6	7.6	430	180	22	.40	737
	06-12-78	77	1,390	8.7	19.3	230	29	38	260	7	9.4	530	200	49	.40	909
	07-21-78	63	1,180	8.5	21.5	200	31	30	210	6	8.9	410	170	51	.40	760
	08-15-78	17	1,680	8.6	22.0	210	26	36	300	9	9.2	440	210	150	.50	1,000
	09-18-78	139	1,180	8.8	12.5	120	18	19	230	9	6.2	420	170	20	.40	727
	10-26-78	40	1,410	8.7	6.0	200	30	31	260	8	7.1	470	220	68	.40	906
	11-17-78	36	1,610	8.6	.5	270	38	42	300	8	7.1	550	270	60	.40	1,060
	12-11-78	18	2,060	8.1	.5	390	62	57	360	5	10	680	320	130	.50	1,360
	01-15-79	4.1	3,400	7.7	0.0	580	100	79	550	10	11	530	280	540	.40	1,890
	02-20-79	2.5	2,530	7.8	0.0	500	99	61	420	8	8.5	430	280	460	.30	1,600
	03-30-79	945	493	8.0	1.0	120	25	15	61	2	12	170	93	4.9	.10	324
	04-19-79	5,500	310	8.0	4.0	83	17	11	33	2	7.4	110	40	2.7	.20	189
	05-15-79	375	1,180	8.5	15.0	250	45	33	150	5	7.7	400	260	24	.30	739
	06-18-79	75	1,420	8.7	19.0	270	38	42	240	6	8.6	430	220	82	.40	895
	07-17-79	31	1,250	8.4	21.0	190	30	28	220	7	8.0	380	190	80	.40	796
	08-13-79	23	1,660	8.4	20.5	230	31	38	300	9	8.2	430	240	180	.40	1,060
	09-17-79	13	1,870	8.6	18.5	260	32	43	390	11	9.1	430	260	260	.40	1,260
	10-16-79	16	2,010	8.5	10.0	260	36	42	340	9	9.2	450	250	230	.40	1,190
	11-26-79	46	1,780	8.8	.5	260	38	40	320	9	9.1	530	270	93	.40	1,100
	12-11-79	24	1,750	8.6	.5	260	38	39	310	5	7.7	550	280	64	.50	1,100
	01-08-80	17	2,000	8.1	0.0	320	51	47	370	9	8.2	610	320	100	.70	1,270
	03-28-80	96	1,040	8.1	.5	150	22	24	150	6	6.5	330	180	13	.30	631
	04-17-80	128	841	8.6	12.5	160	26	22	130	5	7.1	250	130	19	.30	515
	05-01-80	52	1,270	8.7	17.5	200	32	30	220	7	7.3	420	190	47	.70	796
	06-24-80	10	1,600	8.7	21.0	180	19	32	300	10	8.6	490	270	71	.50	1,000
	07-31-80	1.0	2,300	9.0	26.0	260	24	48	420	11	11	410	300	300	.60	1,370
	08-21-80	12	1,780	8.6	19.0	200	21	35	350	11	8.1	430	250	160	.50	1,090
	09-18-80	7.3	1,980	8.6	13.5	230	26	39	350	10	7.9	430	260	240	.50	1,190
	10-23-80	29	1,660	8.8	4.0	200	27	32	310	10	8.1	410	250	130	.50	1,010
	11-13-80	30	1,540	8.6	3.0	210	29	34	290	9	7.9	490	240	59	.40	962
	01-21-81	24	1,650	8.1	.5	270	43	40	310	8	6.8	550	290	35	60	1,060
	03-24-81	69	1,120	8.5	7.0	180	29	23	190	6	5.5	320	170	32	.30	650
	04-27-81	34	1,420	8.6	14.5	210	30	32	270	5	6.4	420	240	55	.40	892
	07-02-81	24	1,480	8.7	21.0	190	19	34	280	9	6.6	510	260	61	.40	973
	07-29-81	5.3	1,710	8.7	25.0	190	20	35	310	10	6.9	420	240	170	.40	1,040
	08-25-81	.85	2,150	8.7	24.0	240	22	44	390	11	8.2	430	280	280	.50	1,280
	09-09-81	.14	2,100	8.9	24.5	240	23	44	380	11	11	450	260	260	.40	1,250
	09-23-81	.12	1,940	8.7	13.5	230	25	41	380	11	7.7	460	310	220	.40	1,260
	11-18-86	27	1,860	8.6	0.0	290	42	44	350	9	7.1	632	310	66	.50	1,210
	01-14-87	15	1,710	8.3	0.0	280	43	39	300	8	5.6	592	260	61	.50	1,080

MAR02-1422

Table 12. Physical properties and major-ion concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number (described in text)	Date	Streamflow, instantaneous, (ft^3/s)	Specific conductance, onsite (µS/cm)	pH, onsite (standard units)	Water temperature, onsite (°C)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, onsite (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Dissolved solids, computed (mg/L)
PR-8 (Continued)	03-25-87	118	894	8.2	.5	160	29	22	150	5	4.6	311	130	33	.30	564
	05-29-87	60	1,470	8.5	16.5	190	26	31	260	8	6.6	427	200	83	.40	868
	07-09-87	5.6	2,150	8.6	23.0	220	22	41	380	11	8.2	440	270	270	.40	1,260
	09-21-87	12	1,840	8.5	15.0	210	26	35	340	10	7.4	455	230	170	.40	1,090
	11-09-87	25	1,840	8.5	2.0	210	29	33	300	9	6.0	511	250	71	.50	1,010
	01-27-88	1.6	3,730	7.7	0.0	630	120	79	550	10	9.7	683	410	590	.50	2,190
	03-24-88	90	540	8.2	.5	130	20	20	150	6	4.3	305	140	13	.30	541
	05-26-88	15	[1]1,770	8.5	21.0	190	21	31	340	11	6.6	511	270	120	.50	1,110
	07-07-88	25	1,250	8.4	20.0	130	18	21	240	9	6.9	363	170	68	.40	732
	09-23-88	.02	1,730	8.6	10.0	200	22	36	310	9	6.9	424	250	150	.30	1,030
	10-26-88	5.4	2,210	8.5	4.0	290	37	48	450	11	7.5	465	270	320	.40	1,410
	12-12-88	7.0	2,260	8.2	0.0	310	46	48	470	12	6.5	669	340	210	.50	1,540
	03-25-89	729	460	8.0	0.0	81	17	9.4	57	3	5.9	122	70	5.4	.10	244
	05-04-89	62	1,370	8.3	11.5	200	32	30	260	7	6.1	422	220	49	.40	840
	07-13-89	7.4	1,820	8.5	19.0	200	22	34	360	11	8.5	415	220	250	.40	1,160
	09-20-89	4.8	2,550	8.6	12.5	250	26	44	510	14	11	474	250	410	.50	1,580
	10-26-89	5.0	2,200	8.5	7.5	240	31	39	430	12	8.0	495	250	300	.50	1,390
	12-06-89	19	[1]1,950	8.5	0.0	240	34	38	380	11	6.1	567	300	110	.40	1,240
	02-22-90	4.2	[1]2,600	8.1	0.0	320	53	45	450	12	8.2	638	330	260	.40	1,590
	04-04-90	124	1,040	8.7	8.0	150	24	22	190	7	5.3	337	170	22	.20	675
	06-26-90	6.4	1,860	8.5	22.5	200	19	36	370	12	7.4	476	270	200	<.10	1,200
	08-14-90	15	1,270	8.3	21.0	190	31	25	230	7	10	377	160	95	.40	798
	10-17-90	5.7	2,300	8.7	4.0	250	31	42	430	12	8.2	447	230	300	.20	1,320
	12-03-90	7.6	2,330	8.4	0.0	310	45	47	440	11	7.7	718	--	180	.60	--
	02-20-91	1.7	1,560	8.1	0.0	210	34	31	330	10	8.4	--	250	92	.40	1,090
	04-24-91	33	1,320	8.5	13.5	180	29	25	240	8	5.7	469	200	52	.50	846
	07-24-91	44	1,390	8.4	22.0	190	27	29	260	8	9.0	499	160	58	.40	865
	09-23-91	14	1,550	8.6	10.5	210	27	34	340	10	7.0	494	240	170	.60	1,130
	10-28-91	16	1,840	8.7	.5	220	30	34	360	11	6.6	543	240	120	60	1,130
	12-04-91	11	2,240	8.4	0.0	330	51	45	420	10	7.0	665	330	140	.80	1,410
	02-04-92	19	1,710	8.1	0.0	240	39	35	320	9	6.2	572	240	72	.60	1,080
	04-21-92	57	1,240	8.4	5.5	140	26	19	230	8	5.1	404	180	40	.50	755
	06-18-92	31	1,490	8.4	20.0	150	22	23	290	10	6.0	427	230	57	.40	898
	08-05-92	12	1,790	9.0	19.5	190	20	33	330	11	6.4	492	230	140	.50	1,060
	10-09-92	7.7	2,100	8.8	8.0	220	26	35	400	12	7.0	--	270	200	.50	1,260
	12-01-92	--	1,840	8.6	0.0	240	34	38	330	9	6.6	--	250	63	.10	1,130
	02-04-93	--	2,440	7.8	0.0	420	77	54	360	8	6.9	--	250	350	.30	1,430
	04-07-93	103	914	8.7	6.0	130	22	19	150	6	6.8	--	120	22	.30	547
	06-17-93	20	1,660	8.8	13.5	170	21	28	300	10	6.4	--	230	110	.50	983
	08-12-93	143	1,330	8.6	17.0	230	41	31	220	6	8.7	--	190	41	.40	834
	10-14-93	45	1,630	8.8	5.0	220	30	35	290	9	6.0	--	250	78	.40	1,020
	12-03-93	35	1,820	8.3	0.0	270	39	42	320	8	6.2	--	280	70	.50	1,130
	03-18-94	1,880	394	8.1	.5	85	16	11	56	3	9.2	--	72	4.7	.10	263

[1]Laboratory measurement.

MAR02-1423

Table 13. Trace-element concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana

[Samples collected and analyzed by the U.S. Geological Survey. Abbreviations: ft^3/s, cubic feet per second; µg/L, micrograms per liter. Symbols: <, less than; --, no data]

Site number (described in text)	Date	Streamflow, instantaneous (ft^3/s)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)
PR-1	10-25-79	22	--	960	10	--	--	--
	09-09-81	1.7	--	1,200	21	--	--	--
	02-21-91	2.0	--	790	74	--	--	--
	04-24-91	36	--	760	46	--	6	--
	07-24-91	38	--	1,000	35	--	--	--
	09-23-91	13	--	1,600	15	--	--	--
	10-28-91	9.8	--	1,100	22	--	--	--
	04-21-92	51	--	640	3,400	--	190	--
	06-23-92	17	--	1,100	62	--	--	--
	08-05-92	12	--	1,100	58	--	--	--
	10-16-92	8.9	--	1,100	15	--	--	--
	04-07-93	102	--	540	190	--	5	--
	06-17-93	29	--	950	41	--	--	--
	08-12-93	118	--	1,000	35	--	--	--
PR-6	03-13-75	37	--	1,600	60	--	<10	--
	09-15-75	35	--	1,200	60	--	<10	--
	12-23-75	10	--	1,600	<10	--	60	--
	05-16-76	37	--	500	130	--	30	--
	04-07-76	434	--	290	120	--	20	--
	06-22-76	221	--	800	60	--	4	--
	07-09-76	471	--	870	110	--	--	--
	08-06-76	60	--	1,300	20	--	--	--
	09-10-76	21	--	1,200	<10	110	<10	--
	10-01-76	21	--	1,100	20	--	--	--
	11-11-76	23	--	990	20	--	--	--
	12-10-76	26	--	1,100	<10	130	30	--
	01-28-77	7.0	--	870	20	--	--	--
	02-11-77	19	--	890	30	--	--	--
	03-31-77	168	--	520	90	70	20	--
	04-26-77	44	--	790	30	--	--	--
	05-09-77	29	--	880	20	--	--	--
	06-06-77	52	--	1,200	20	90	<10	--
	07-19-77	7.4	--	1,200	20	--	--	--
	08-22-77	6.6	--	810	<10	150	<10	--
	09-15-77	15	--	1,200	20	--	--	--
	10-28-77	29	--	1,100	30	--	--	--
	11-15-77	30	--	--	30	--	--	--
	12-21-77	9.0	--	1,200	30	140	40	--
	01-09-78	7.0	--	1,100	40	--	--	--
	02-13-78	1.0	--	840	<10	--	--	--
	03-24-78	3,500	--	150	160	<10	30	--
	04-18-78	237	--	460	80	--	--	--
	05-11-78	134	--	670	50	--	--	--
	06-12-78	77	--	910	<10	110	<10	--

Table 13. Trace-element concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number (described in text)	Date	Streamflow, instantaneous (ft^3/s)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)
PR-6 (Continued)	07-21-78	63	--	920	130	--	--	--
	08-15-78	17	--	1,100	<10	--	--	--
	09-18-78	139	--	880	40	90	<10	--
	10-26-78	40	--	940	<10	--	<10	--
	11-17-78	36	--	1,100	<10	--	--	--
	12-11-78	15	--	1,200	30	--	70	--
	01-15-79	4.1	--	990	<10	--	--	--
	02-20-79	2.5	--	720	50	--	--	--
	03-30-79	945	--	300	150	--	<10	--
	04-19-79	3,500	--	200	50	--	20	--
	05-15-79	375	--	630	50	--	--	--
	06-18-79	75	--	1,100	<10	--	<10	--
	07-17-79	31	--	760	30	--	--	--
	08-13-79	23	--	660	<10	--	--	--
	09-17-79	13	--	1,000	<10	--	20	--
	10-16-79	16	--	990	<10	--	--	--
	12-11-79	24	--	1,100	--	--	20	--
	01-08-80	17	--	930	20	--	--	--
	03-28-80	96	--	650	40	--	10	--
	04-17-80	128	--	640	40	--	5	--
	05-01-80	52	--	760	10	--	--	--
	06-24-80	10	--	1,200	20	--	8	--
	07-31-80	1.0	--	1,200	20	--	0	--
	08-21-80	12	--	1,100	20	--	--	--
	09-18-80	7.3	--	1,000	<10	--	10	--
	10-23-80	29	--	800	10	--	--	--
	11-13-80	30	--	830	20	--	--	--
	01-21-81	24	--	1,100	10	--	--	--
	03-24-81	69	--	570	40	--	10	--
	04-27-81	34	--	760	20	--	--	--
	07-02-81	24	--	1,100	<10	--	3	--
	07-29-81	5.3	--	940	10	--	--	--
	08-25-81	.85	--	1,000	80	--	10	--
	09-09-81	.14	--	1,000	30	--	--	--
	09-23-81	.12	--	1,000	19	--	13	--
	11-18-86	27	76	--	17	120	22	610
	03-25-87	118	55	--	95	52	17	350
	07-09-87	5.6	57	--	17	110	6	430
	09-21-87	12	63	--	8	90	5	450
	11-09-87	25	52	--	7	91	5	460
	03-24-88	90	35	--	45	44	7	290
	07-07-88	25	49	--	150	68	3	300
	09-23-88	.02	52	--	11	95	2	410
	10-26-88	5.4	60	--	19	120	9	660
	03-23-89	729	45	--	300	18	7	170

MAR02-1424

Table 13. Trace-element concentrations in water samples collected from the Poplar River, East Poplar oil field, Fort Peck Indian Reservation, northeastern Montana (Continued)

Site number (described in text)	Date	Streamflow, instantaneous (ft^3/s)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Strontium, dissolved (µg/L as Sr)
PR-8 (Continued)	07-18-89	7.4	55	--	7	100	5	500
	09-10-89	4.8	55	--	7	140	6	650
	10-26-89	8.0	50	--	21	120	6	630
	02-22-90	4.2	72	--	21	130	45	830
	06-26-90	6.4	53	--	5	110	5	450
	08-14-90	15	89	--	18	68	2	460
	10-17-90	5.7	57	--	9	130	11	610
	02-20-91	1.7	51	--	73	95	62	450
	07-24-91	44	89	--	35	100	3	460
	09-23-91	14	63	--	19	110	8	470
	10-25-91	16	56	--	7	110	13	450
	02-04-92	19	55	--	18	110	37	530
	06-18-92	31	57	--	57	89	<1	400
	08-05-92	12	50	--	13	110	3	420
	10-09-92	7.7	52	--	21	130	6	520
	02-04-93	--	69	--	15	120	260	900
	06-17-93	20	50	--	40	95	2	420
	08-12-93	143	59	--	24	81	5	520
	10-14-93	45	57	--	11	97	18	490
	03-18-94	1,880	39	--	160	19	22	170

MAR02-1425

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RECONNAISSANCE EVALUATION OF CONTAMINATION IN THE ALLUVIAL AQUIFER IN THE EAST POPLAR OIL FIELD, ROOSEVELT COUNTY, MONTANA

by Gary W. Levings

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4174

Prepared in cooperation with the

U.S. BUREAU OF LAND MANAGEMENT and the

FORT PECK ASSINIBOINE AND SIOUX TRIBES

Helena, Montana
September 1984

MAR02-1426

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

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MAR02-1427

CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and scope	2
Location of the area	2
Well-numbering system	2
Data collection	5
Well inventory	5
Test drilling	5
Geology	5
Hydrology	8
Ground water	8
Surface water	10
Contamination of the alluvial aquifer	15
Indication of contamination	15
Possible sources of contamination	16
Need for additional study	18
Summary and conclusions	18
Selected references	19
Supplemental data	21

ILLUSTRATIONS

Figure 1.	Map showing location of study area	3
2.	Diagram showing numbering system for wells	4
3.	Map showing generalized geology, location of wells, and altitude of water levels in the alluvial aquifer	6
4.	Chemical-constituent diagrams for water sampled from wells in 1982	9
5-8.	Maps showing:	
	5. Sodium concentration of water from wells	11
	6. Chloride concentration of water from wells	12
	7. Sulfate concentration of water from wells	13
	8. Discharge and chloride concentration at sites along the Poplar River, September 1981	14
9.	Chemical-constituent diagrams for water from the Poplar River, September 1981	15
10.	Map showing iron and manganese concentrations of water from wells	17

TABLES

Table 1.	Records of water-supply, unused, test, and brine-disposal wells	22
2.	Chemical-quality data for water from wells and for injection brines	23
3.	Drillers' logs of test wells	27
4.	Chemical quality of water in the Poplar River	29

MAR02-1428

CONVERSION FACTORS

The following factors can be used to convert inch-pound units in this report to the International System of Units (SI).

Multiply inch-pound unit	By	To obtain SI unit
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
inch	25.40	millimeter
micromho per centimeter at 25° Celsius (micromho)	100	microsiemens per meter at 25° Celsius
mile	1.609	kilometer
pound per square inch	6895	pascal

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

MAR02-1429

RECONNAISSANCE EVALUATION OF CONTAMINATION IN THE ALLUVIAL AQUIFER IN THE EAST POPLAR OIL FIELD, ROOSEVELT COUNTY, MONTANA

by

Gary W. Levings

ABSTRACT

The alluvial aquifer in the East Poplar oil field was studied to determine the occurrence, movement, and chemical quality of ground water and to evaluate contamination in the alluvial aquifer. In the oil field area, shallow water occurs in alluvium beneath the Poplar River valley floor. The general direction in flow of water in the alluvium is from north to south down the Poplar River valley. Localized areas may have directional components of flow toward the river.

Four distinct types of ground water were identified in the study area. Type 1 is sodium bicarbonate water with a range of dissolved-solids concentration of about 490 to 770 milligrams per liter. Type 2 is sodium chloride water with varying quantities of calcium and magnesium and dissolved-solids concentration ranging from about 1,600 to 7,200 milligrams per liter. Type 3 water contains sodium and chloride in significantly larger concentrations than Type 2 water, and dissolved-solids concentrations range from 13,800 to 114,000 milligrams per liter. Type 3 water is from test wells drilled near a brine-disposal well and is similar to Type 4 water, which is the brine being injected. The dissolved-solids concentrations of the brine being injected are 97,900 and 161,000 milligrams per liter.

Contamination of the alluvial aquifer by brine is indicated by a brine/fresh-water interface in the alluvium, and a downstream increase in chloride concentration (20 to 880 milligrams per liter) and change in water type (from sodium bicarbonate to sodium chloride) of the Poplar River. Contamination also may be indicated by the distribution of iron and manganese concentrations in water from wells near a brine-disposal well.

Possible sources of sodium chloride contamination in the alluvium are brine-disposal wells, pipelines, and storage or evaporation pits. The contamination can occur from leaks in the casing of brine-disposal wells or in pipelines caused by the corrosive nature of the brine or from storage or evaporation pits that have been improperly sealed or have sustained tears in the sealing material.

INTRODUCTION

Oil production began in 1952 in the East Poplar oil field, which is located entirely within the Fort Peck Indian Reservation. Since then, brine produced with the oil has been injected into subsurface geologic units by means of brine-disposal

MAR02-1430

wells or has been directed to storage and evaporation pits. In response to reported increased salinity of ground water used for domestic and stock supply in and near the oil field, the Oil and Gas Branch of the Conservation Division of the U.S. Geological Survey in 1981 requested that a reconnaisance study of the contamination be made. In 1982 the branch function became part of the U.S. Minerals Management Service and in 1983 became part of the U.S. Bureau of Land Management. Additional cooperation was provided by the Office of Environmental Protection of the Fort Peck Assiniboine and Sioux Tribes.

Purpose and scope

The purpose of this report is to describe the results of the reconnaissance study of contamination of the alluvial aquifer in the East Poplar oil field, Roosevelt County, Montana. Specifically, the purpose includes: (1) Description of the occurrence, movement, and chemical quality of water in the alluvial aquifer and (2) evaluation of the contamination of the alluvial aquifer.

Existing wells in the study area were inventoried, water levels measured, and water samples collected. In addition, seven test wells were drilled and cased near a brine-disposal well. Water levels were measured and water samples were collected from the wells. Water samples were collected from the Poplar River and stream discharge was measured along the reach within the study area to give an indication of movement of contaminated ground water to the stream.

Location of the area

The East Poplar oil field is located in northeastern Montana, about 8 miles north-northeast of Poplar (fig. 1). The study area is located in Tps. 28 and 29 N., R. 51 E., along the Poplar River, a tributary of the Missouri River.

Well-numbering system

The local system of numbering wells is based on the rectangular system for the subdivision of public lands (fig. 2). A well number consists of 14 characters and is assigned according to its location within a given township, range, and section. The first three characters consist of the township number and the letter N designating position north of the Montana Base Line. The next three characters consist of the range number and the letter E designating position east of the Montana Principal Meridian. The next two characters indicate the section. The letters following the section number indicate the position of the well within the section. The first letter denotes the quarter section (160-acre tract); the second, the quarter-quarter section (40-acre tract); the third, the quarter-quarter-quarter section (10-acre tract); and the fourth, the quarter-quarter-quarter-quarter section (2.5-acre tract). The subdivisions of the sections are lettered A, B, C, and D in a counterclockwise direction beginning in the northeast quadrant. The next two characters are a sequence number indicating the order of inventory in that tract. For example, well 29N51E32BBBA02 is the second well inventoried in the NE1/4 NW1/4 NW1/4 NW1/4 sec. 32, T. 29 N., R. 51 E.

MAR02-1431

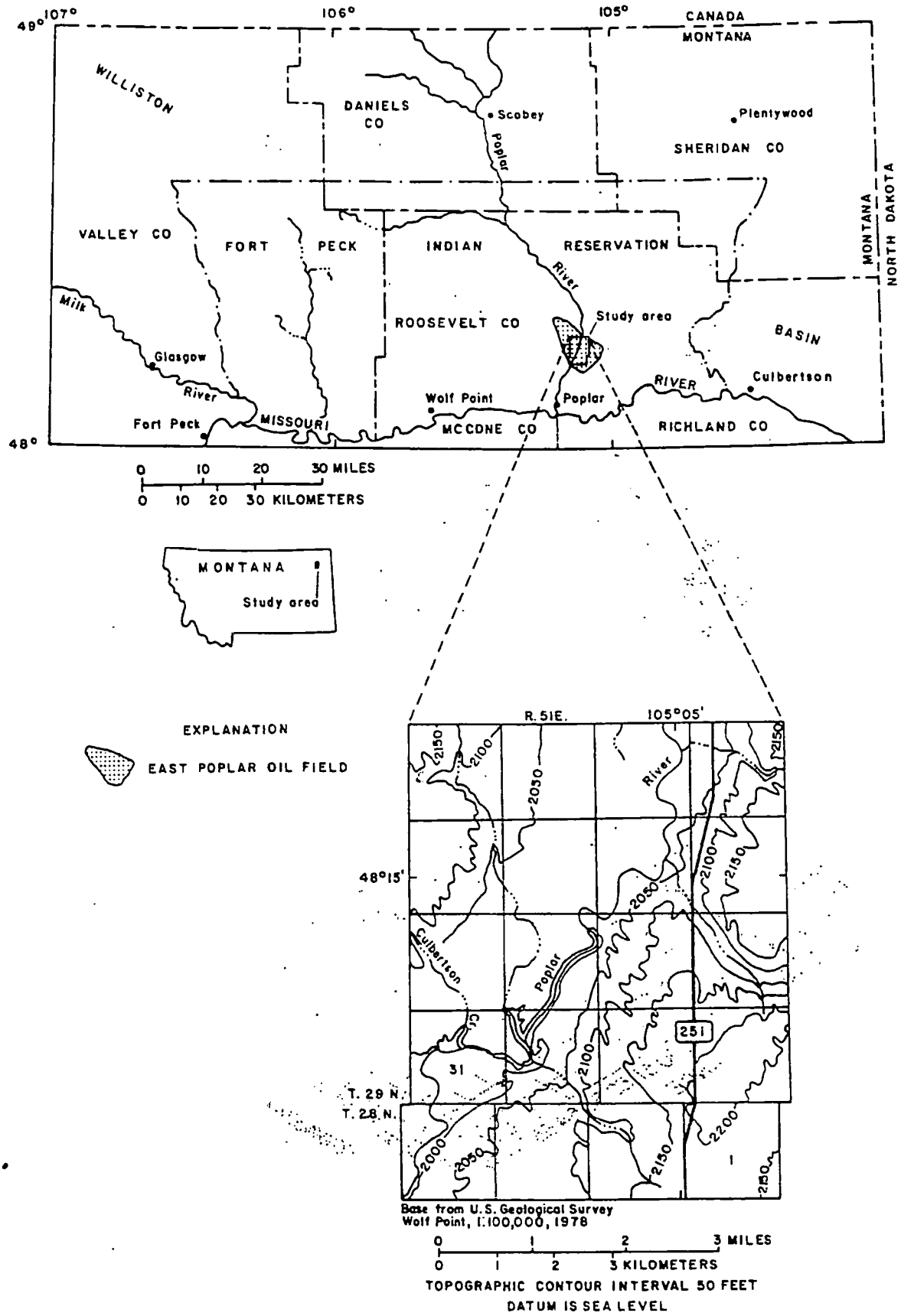


Figure 1.--Location of study area.

MAR02-1432

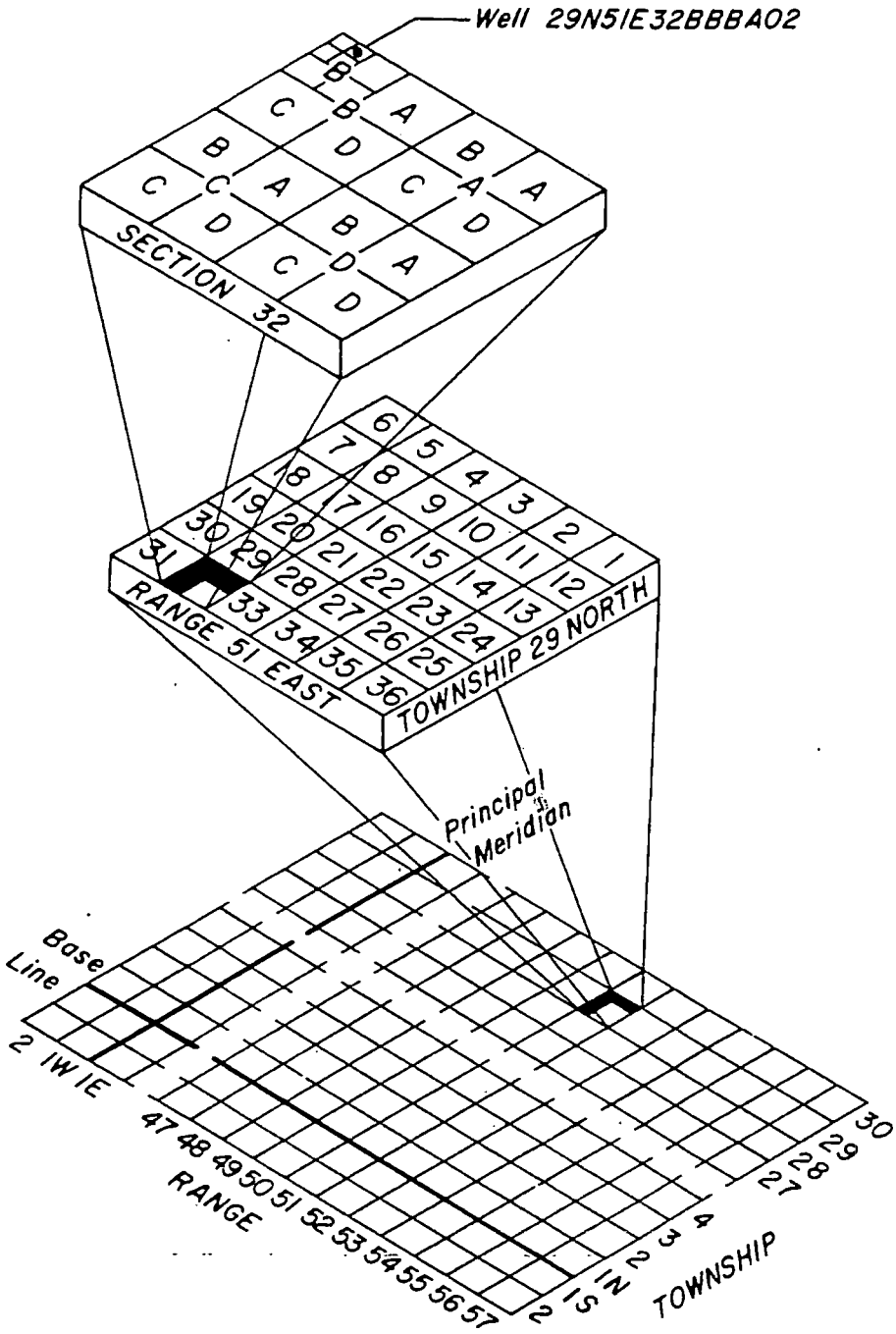


Figure 2.--Numbering system for wells.

DATA COLLECTION

Well inventory

During May and July 1982, wells in the study area were inventoried; where possible the data collected included date completed, depth of hole, depth of well, depth to first opening, and static water level. Data collected during the inventory are listed in table 1 (Supplemental Data at back of report) and the location of all wells inventoried is shown in figure 3. During July 1982, water samples for chemical analysis were collected from six water-supply and unused wells and two brine-disposal wells, SWD-1 and SWD-5. All available water-quality data for wells are presented in table 2 (Supplemental Data at back of report).

Test drilling

Seven test wells, W-10 to W-16, were installed during August 1982 in the area around brine-disposal well SWD-1 (fig. 3). The test wells were augered through the alluvium and into bedrock at each site. The wells were completed with perforated 2-inch plastic casing. Each hole was to be cased to total depth; however, problems in withdrawing the hollow-stem auger flites from the hole without bringing out the casing at the same time generally resulted in the collapse of a few feet of augered hole. The total depth of the hole and the cased depth are included in table 1. The loss of 17 feet of hole in test well W-13 required the drilling of test well W-14, 5.5 feet to the west. This hole was successfully cased to within 0.5 foot of bedrock. The drillers' log for each test well is given in table 3 (Supplemental Data at back of report).

After the casing was installed, each test well was pumped for several hours to prevent clay and silt from plugging the perforations and to develop the well. In November 1982, each test well, except W-13, was pumped for about 2 hours prior to collecting a water sample for chemical analysis (table 2).

GEOLOGY

The East Poplar oil field is located astride the Poplar anticline, which is on the west flank of the Williston Basin of northeastern Montana and North Dakota. The discovery well was completed in 1952 at a depth of about 5,800 feet, with oil production from limestones in the Charles Formation of the Madison Group of Mississippian age. The Charles Formation is at a depth of about 5,300 feet below land surface in the study area.

The oldest formation cropping out in the study area is the Upper Cretaceous Bearpaw Shale. Glaciation and subsequent erosion by the Poplar River have resulted in deposits of Pleistocene till, fan alluvium and colluvium, and dune sand, as well as Holocene alluvium. The sequence and thickness of Pleistocene and Holocene deposits differ throughout the area.

Descriptions of these formations are in reports by Colton (1963a,b) and Howard (1960). The geologic map (fig. 3) shows the areal distribution of the geologic units.

MAR02-1434

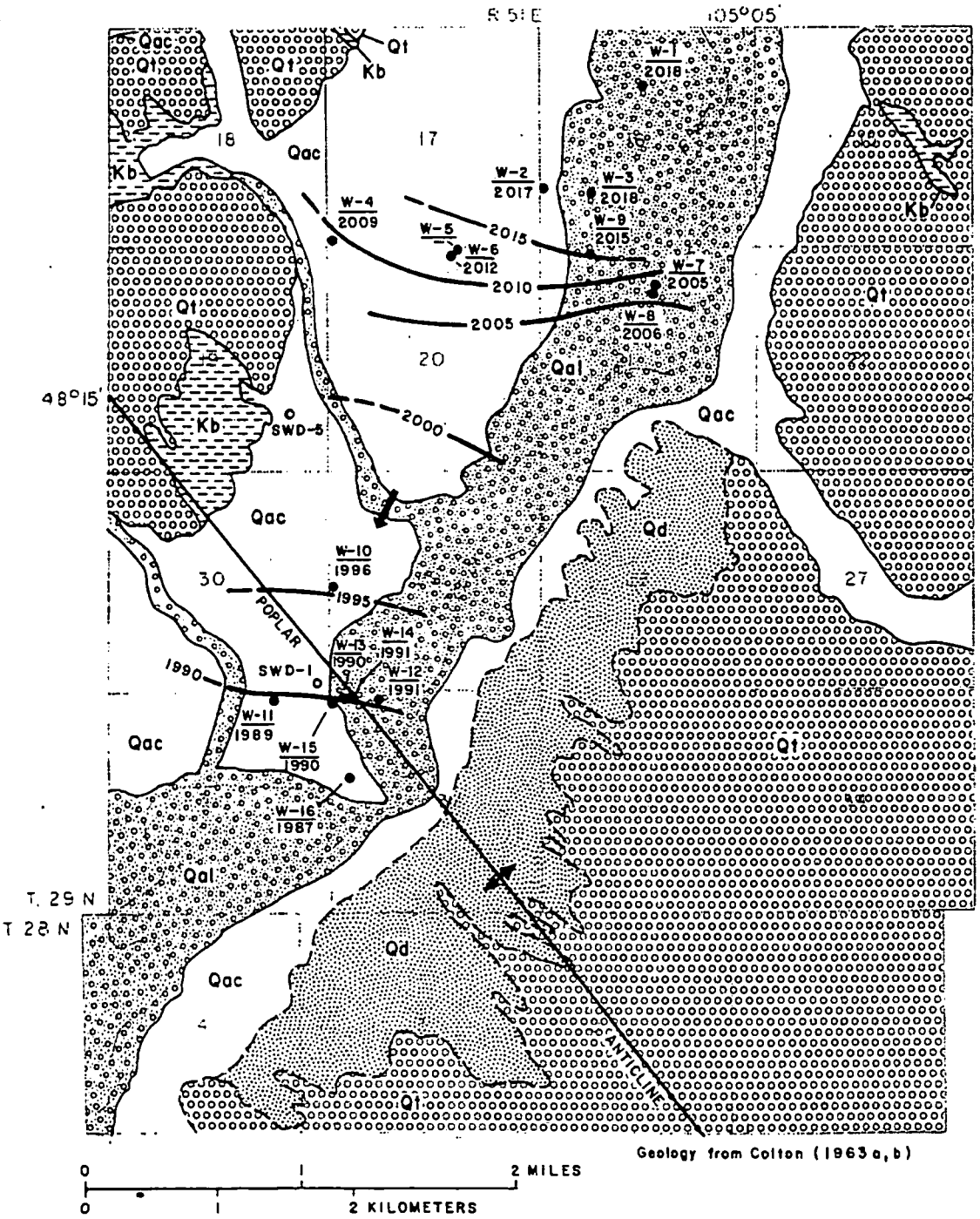
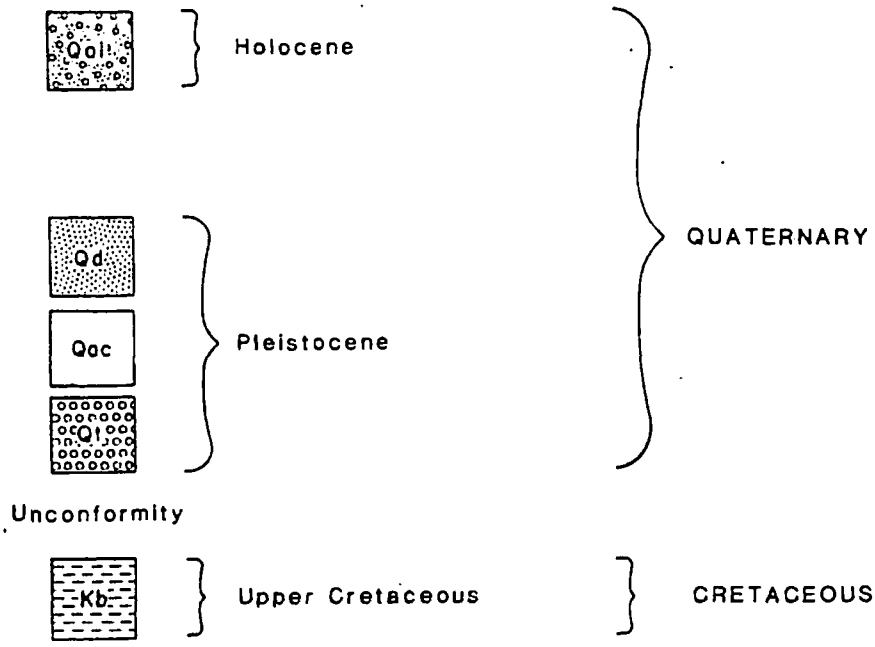
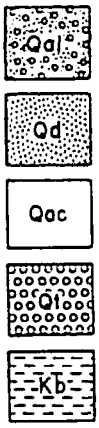


Figure 3.--Generalized geology, location of wells, and altitude of water levels in the alluvial aquifer.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS



ALLUVIUM

DUNE SAND

FAN ALLUVIUM AND COLLUVIUM

TILL

BEARPAW SHALE

——— — — CONTACT--Dashed where approximately located

—2000— — POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells, 1982. Dashed where approximately located. Contour interval 5 feet. Datum is sea level

➡ GENERAL DIRECTION OF GROUND-WATER FLOW

DATA SITE

W-8/2006 ● Water-supply, unused, or test well--Upper number is well number; lower number, where shown, is altitude of static water level, in feet above sea level

SWD-1 ○ Brine-disposal well and number

MAR02-1436

HYDROLOGY

Ground water

The alluvium is the source of most of the water from wells W-1 through W-16. Although several wells penetrate a limited thickness of saturated fan alluvium and colluvium, this limited thickness is not sufficient to yield much, if any, water to wells. The underlying Bearpaw Shale is a relatively impermeable bedrock unit that is a barrier to downward movement of water from the overlying units. As a result, all water in the alluvium eventually moves laterally downvalley.

The altitude of static water levels in wells and the generalized direction of ground-water flow are shown in figure 3. The altitude of static water levels indicates that the overall ground-water movement is from north to south down the Poplar River valley. Localized areas may have directional components of flow toward the river.

Based on chemical analyses of water samples collected from wells (table 2), the quality of ground water in the study area is extremely variable. Sodium, bicarbonate, and chloride are the dominant ions in water from most wells.

Dissolved solids, reported in milligrams per liter, is the sum of all dissolved constituents in the water and in reality is the total of the major ions in solution. Dissolved-solids concentrations of ground water sampled in the study area range from 488 to 114,000 mg/L (milligrams per liter).

In analyzing chemical-quality data, graphical methods are used to identify water types by a determination of the ionic compositions. The water type can be identified by use of chemical-constituent diagrams modified from Stiff (1951). These diagrams represent unit concentrations, in milliequivalents per liter, of the major constituents of each analysis plotted to scale. The diagram provides a visual comparison of the ionic content of each analysis.

The range in unit concentration of the major ions in water from the wells in the study area is too large to use the same scale for all diagrams. Chemical-constituent diagrams, at three different scales, for samples collected in 1982, are shown in figure 4. Visual inspection of the diagrams indicates that the water can be separated into four principal types representing different dominant ions and concentrations of dissolved solids.

Type 1 water contains sodium as the dominant cation and bicarbonate as the dominant anion. The dissolved-solids concentration ranges from 488 to 774 mg/L.

Type 2 water differs from Type 1 in that chloride has replaced bicarbonate as the dominant anion; sodium remains the dominant cation. However, the concentrations of calcium and magnesium vary considerably at each of the wells. The dissolved-solids concentration ranges from 1,610 to 7,210 mg/L. Wells W-4, W-6, and W-9 are located in a straight line (fig. 3) about three-quarters of a mile apart. The chemical composition of the water changes from significant quantities of calcium and magnesium in well W-4 to insignificant quantities in well W-9, and the total concentration of all constituents decreases. The unit concentrations of calcium and magnesium in water from well W-10 are almost the same as for sodium.

MAR02-1437

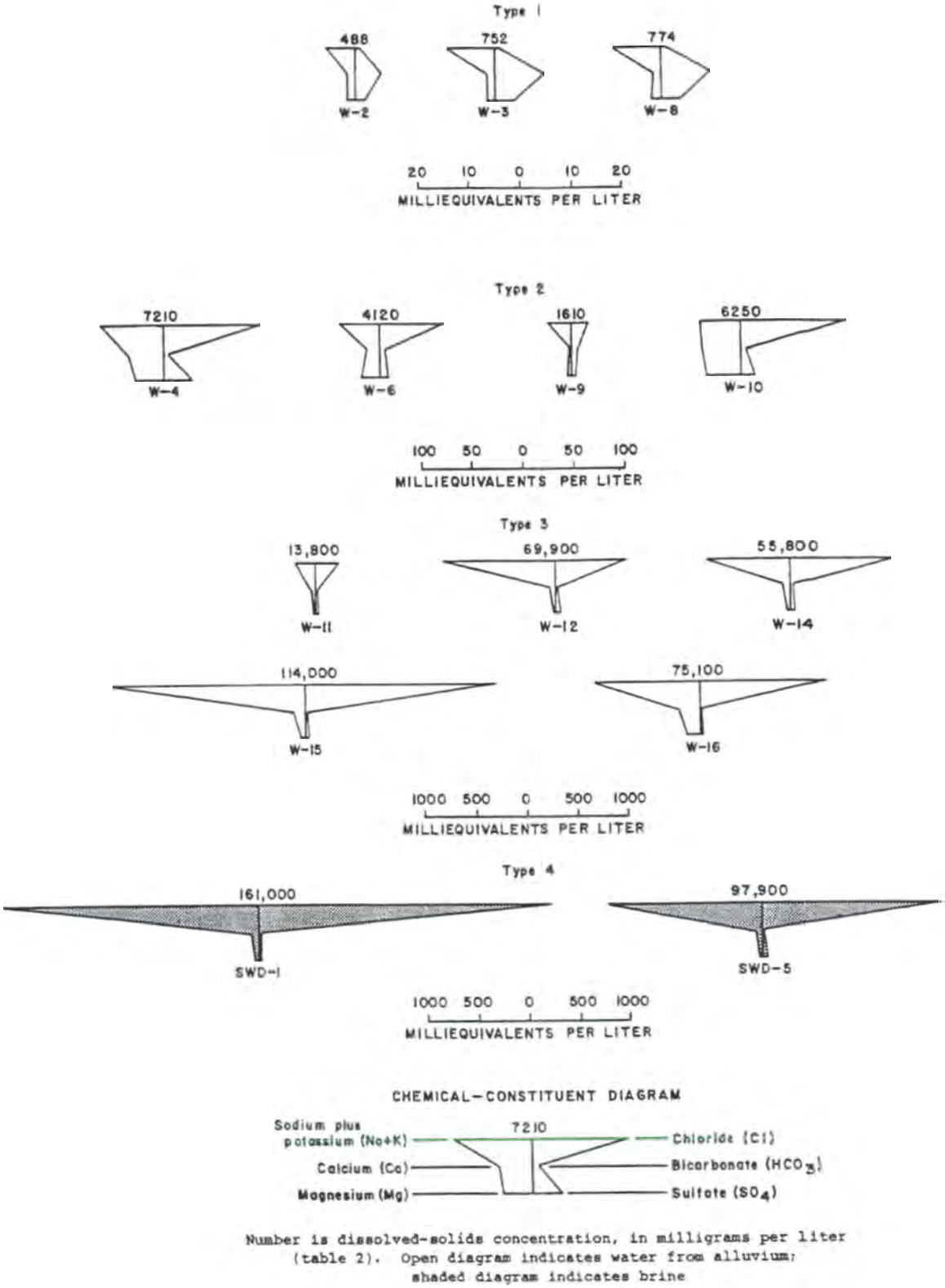


Figure 4.--Chemical-constituent diagrams for water sampled from wells in 1982.

MAR02-1438

Type 3 water also contains chloride and sodium as the dominant ions; however, the total concentration of constituents is larger than Type 2 water. The dissolved-solids concentration ranges from 13,800 to 114,000 mg/L. These waters are very similar to those of Type 4, which represents the brine being injected into brine-disposal wells SWD-1 and SWD-5. The dissolved-solids concentrations of the brine are 97,900 and 161,000 mg/L. The brine is a mixture of brines from oil-production wells.

The areal distribution of concentrations of sodium, chloride, and sulfate for water from the sampled wells is shown in figures 5-7. The concentrations of sodium (fig. 5) and chloride (fig. 6) in the test wells installed around brine-disposal well SWD-1 reflect the generalized ground-water movement in the area. Water from wells to the south and east have larger concentrations than does water from wells to the north and west. The reason for the smaller concentrations in water from well W-14 than in water from wells W-12 and W-15 is not known. It might be the result of differences in concentration with depth, permeability changes in the alluvium, or localized sources of brine such as pipelines. The concentration of sulfate (fig. 7) does not follow this pattern. Water in well W-16 has a concentration considerably less than water in well W-15. The reason for the decrease is unknown, but the decrease may be caused by geochemical reactions as the water moves through the alluvium.

During the sampling of the test wells, the water temperature in well W-15 was 25.0°C, about 15°C greater than in the other test wells. Well W-15 is 238 feet southeast of brine-disposal well SWD-1. The temperature of the injected brine is about 80°-85°C.

Water is a byproduct in the production and recovery of most crude oil. Most of the water comes from the producing zone and represents the quality of water in those zones. In the study area, the Charles Formation is composed of limestone, anhydrite, dolomite, halite, and shale. The halite has been dissolved by the formation water, resulting in the brine produced in the East Poplar oil field. The quality of water in the Charles Formation varies both vertically and laterally throughout the field. The dissolved-solids concentration of samples collected during drill-stem tests, from flows sampled during the drilling process, or from production water ranges from about 16,000 to 201,000 mg/L (Feltis, 1980). The major constituents present in the brine are sodium and chloride.

Surface water

The Poplar River, a tributary to the Missouri River, is a perennial stream in the study area. During September 1981, discharge measurements were made at three of the sites shown in figure 8. Based on these measurements, the reach of the stream between sites PR-1 and PR-5 lost 0.96 ft^3/s to the ground-water system. However, a seep along the right bank about 0.6 mile downstream from site PR-3 indicates that the potentiometric surface was above the level of water in the river and was contributing inflow to the river. Although the net effect of the measurements confirms that this is a losing reach, the ground-water system contributes flow to the stream where perched ground water exists.

During the September measurements, water samples were collected at the three measurement sites for standard analysis and at two additional sites for chloride analysis (table 4 in Supplemental Data at back of report). These analyses indicate

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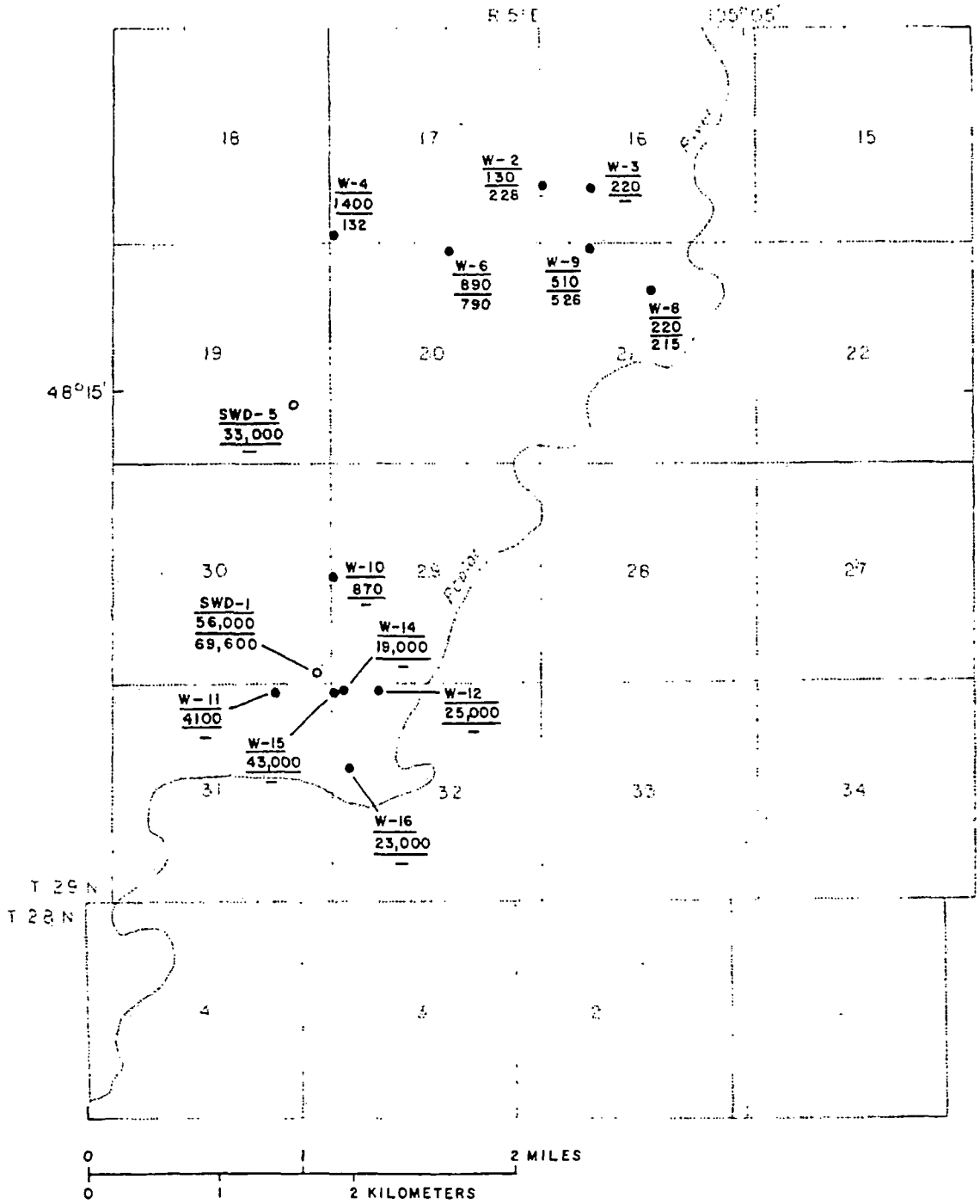


EXPLANATION

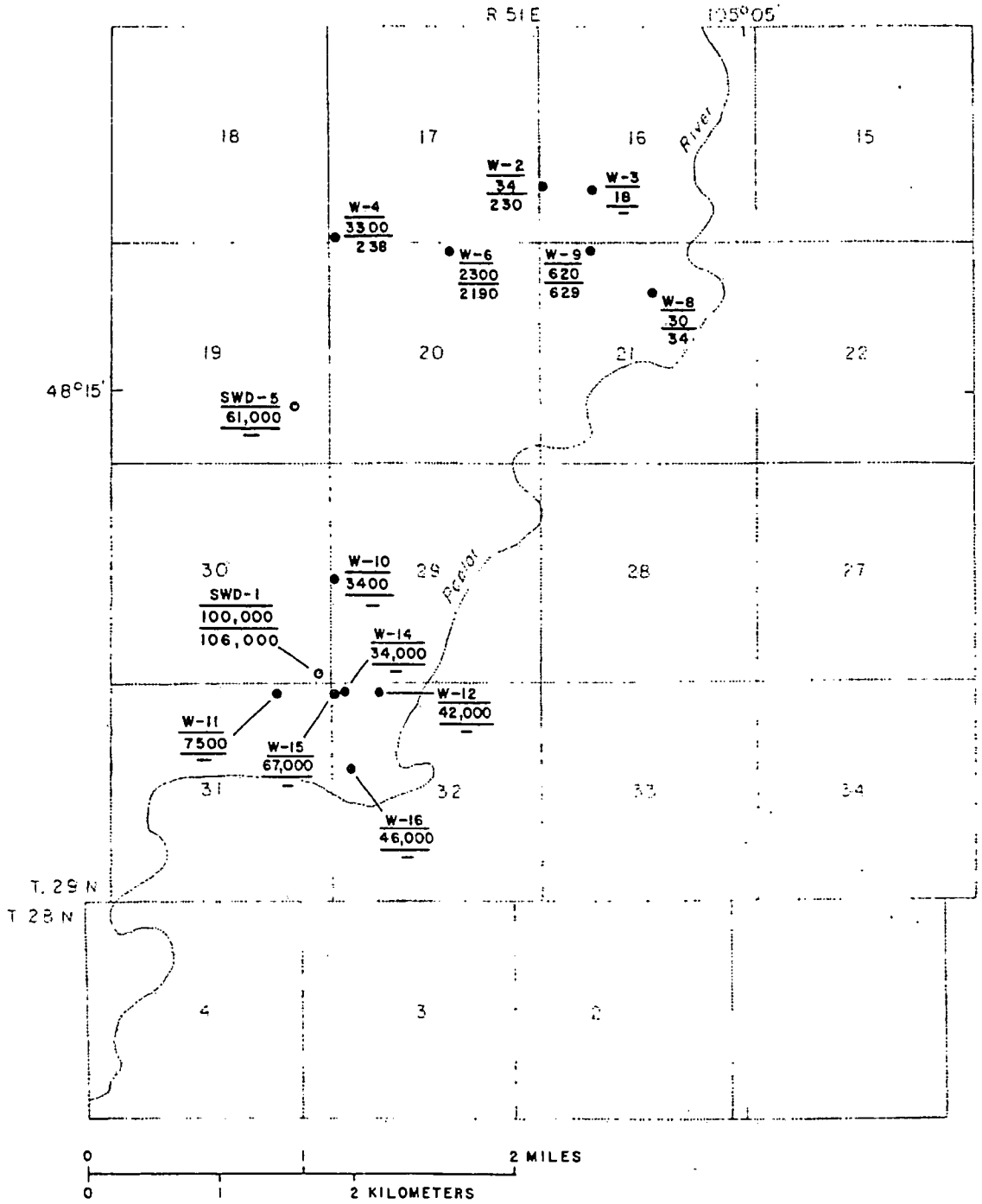
DATA SITE

W-4 / 1400 / 132 ● — Water-supply, unused, or test well--Upper number is well number; middle number is sodium concentration, in milligrams per liter, of sample collected in 1982; lower number is sodium concentration, in milligrams per liter, of sample collected in 1979

SWD-1 / 56,000 / 69,600 ○ — Brine-disposal well--Upper number is well number; middle number is sodium concentration, in milligrams per liter, of sample collected in 1982; lower number is sodium concentration, in milligrams per liter, of sample collected in 1979

Figure 5.--Sodium concentration of water from wells.

MAR02-1440



EXPLANATION

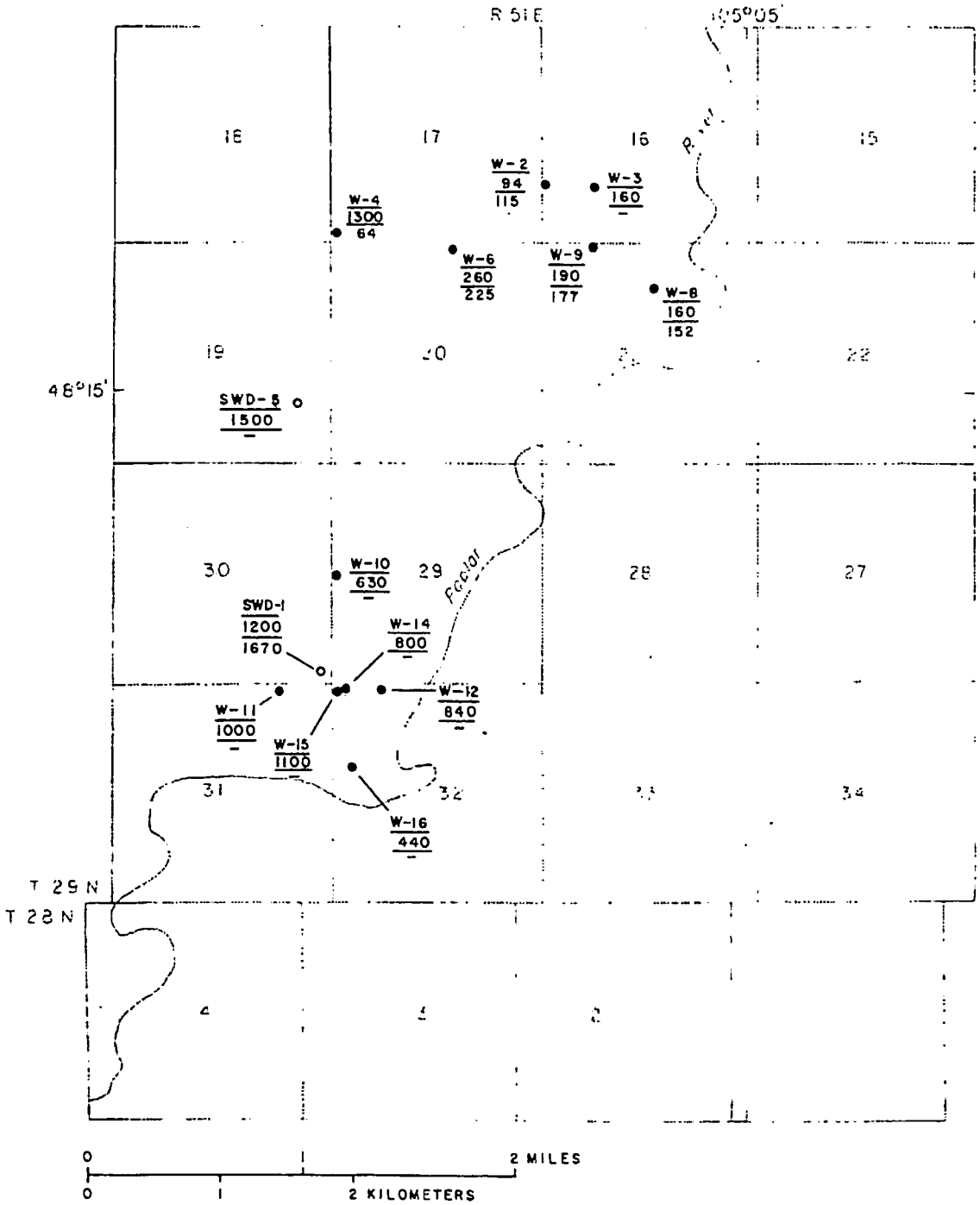
DATA SITE

W-4 / 3300 / 238 ● Water-supply, unused, or test well--Upper number is well number; middle number is chloride concentration, in milligrams per liter, of sample collected in 1982; lower number is chloride concentration, in milligrams per liter, of sample collected in 1979

SWD-1 / 100,000 / 106,000 ○ Brine-disposal well--Upper number is well number; middle number is chloride concentration, in milligrams per liter, of sample collected in 1982; lower number is chloride concentration, in milligrams per liter, of sample collected in 1979

Figure 6.--Chloride concentration of water from wells.

MAR02-1441



EXPLANATION

DATA SITE

W-4 / 1300 / 64 ● Water-supply, unused, or test well--Upper number is well number; middle number is sulfate concentration, in milligrams per liter, of sample collected in 1982; lower number is sulfate concentration, in milligrams per liter, of sample collected in 1979

SWD-1 / 1200 / 1670 ○ Brine-disposal well--Upper number is well number; middle number is sulfate concentration, in milligrams per liter, of sample collected in 1982; lower number is sulfate concentration, in milligrams per liter, of sample collected in 1979

Figure 7.--Sulfate concentration of water from wells.

MAR02-1442

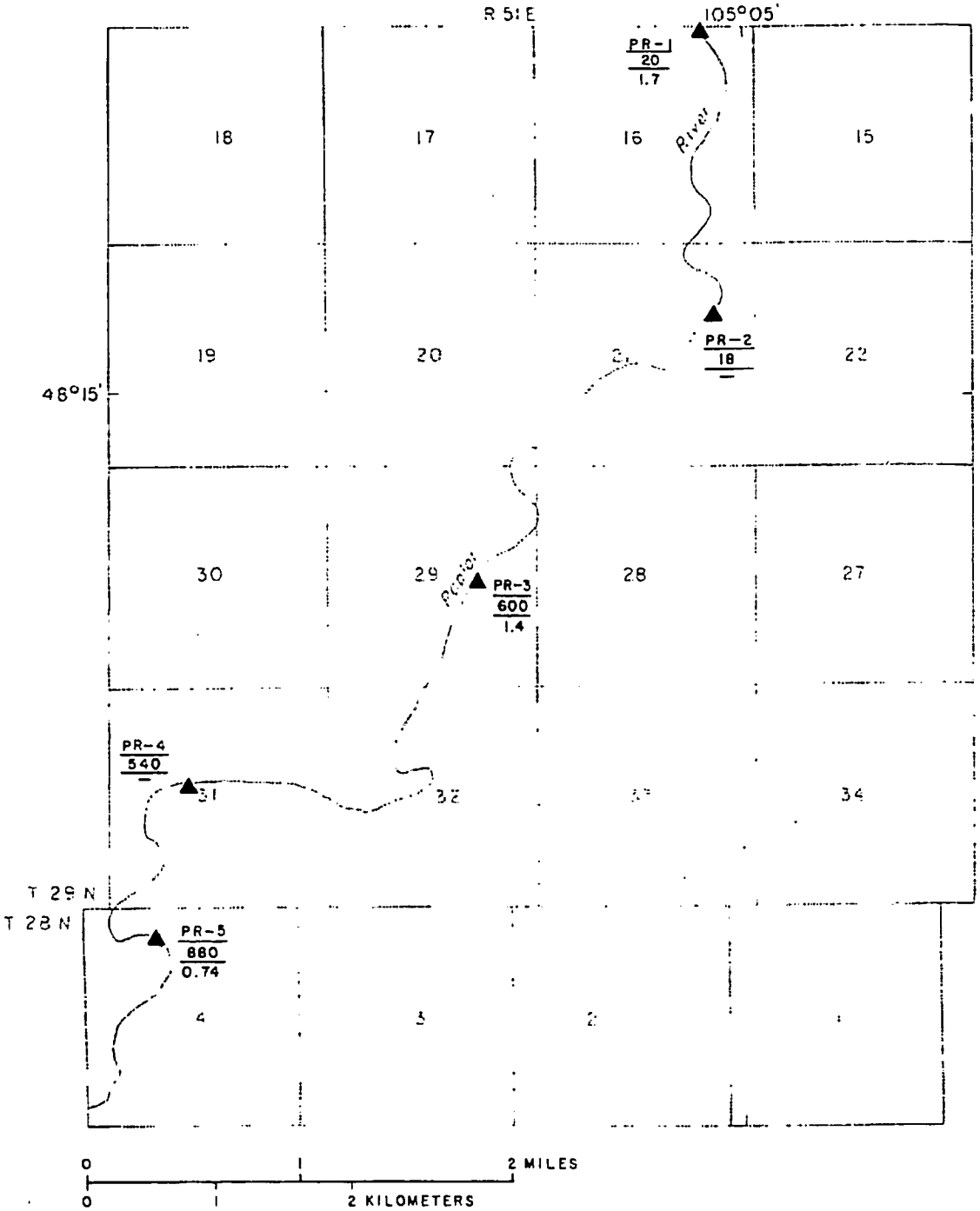


Figure 8.--Discharge and chloride concentration at sites along the Poplar River, September 1981.

MAR02-1443

a significant increase in chloride concentration between sites PR-2 (18 mg/L) and PR-3 (600 mg/L) (fig. 8). From site PR-3 to PR-4, the concentration decreases, then increases again at site PR-5.

Analysis of the major constituents of the stream water indicates that the water is a sodium bicarbonate type at site PR-1 (similar to Type 1 ground water) and changes to a sodium chloride type at sites PR-3 and PR-5 (similar to Type 2 ground water) (fig. 9). The dissolved-solids concentration increases from 970 mg/L at PR-1 to 2,310 mg/L at PR-5.

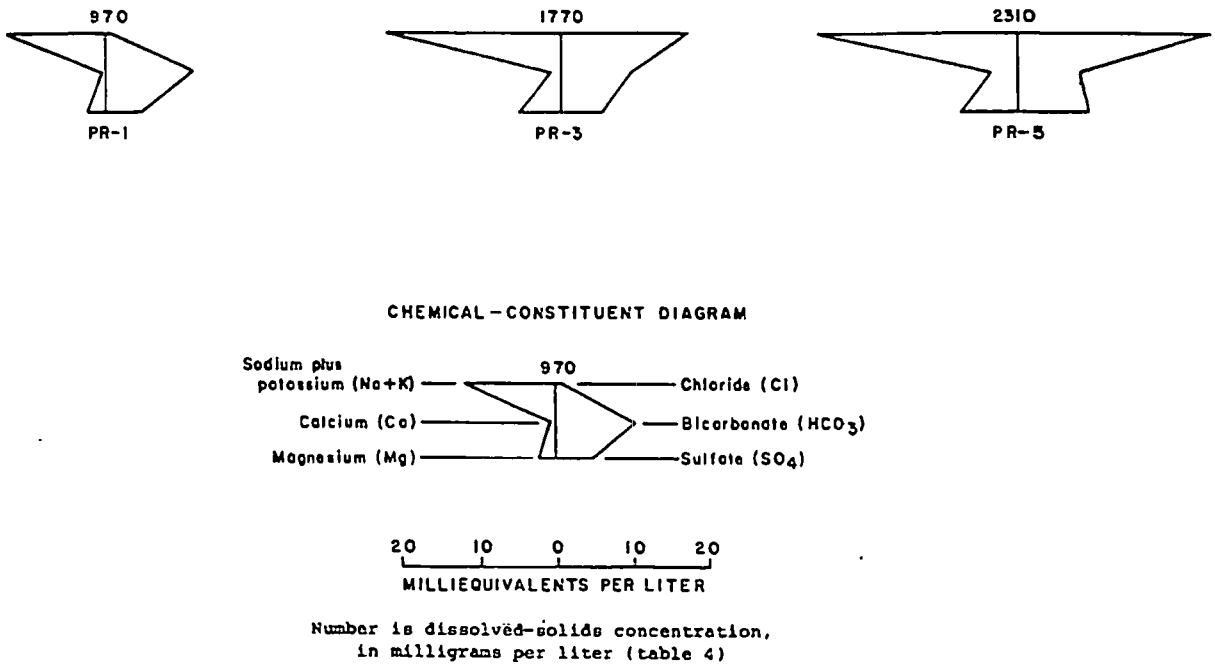


Figure 9.--Chemical-constituent diagrams for water from the Poplar River, September 1981.

In 1979, stream discharge was measured and a water sample was collected at site PR-1 (table 4). Comparison with the 1981 data does not indicate any significant differences in water quality even though the discharge was considerably greater in 1979.

CONTAMINATION OF THE ALLUVIAL AQUIFER

Indication of contamination

Contamination of the alluvial aquifer is indicated by analysis of chemical-quality data for water samples from wells and the Poplar River. A brine/fresh-water interface appears to exist between uncontaminated water in alluvium to the north (wells W-2 and W-3) and brine-contaminated water in alluvium to the south (wells W-6 and W-9), based on the difference in type of water (fig. 4). The concentrations of sodium, sulfate, and chloride in water from well W-2 decreased from 1979 to 1982

MAR02-1444

(table 2). This decrease may have resulted from the interface moving south, the direction of ground-water movement. If the source of contamination has been decreased, the water moving into this area from the north will begin to mix with, and dilute, the contaminated water. The significant increase in all major constituent concentrations in well W-4 from 1979 to 1982 indicates that no recharge is occurring in this part of the aquifer or the well may be close to a source of contamination or both.

Another water-quality change that may indicate contamination is an increase in concentration of iron and manganese in ground water in the area around brine-disposal well SWD-1. The concentration of iron in the brine is 1,400 µg/L (micrograms per liter) in brine-disposal well SWD-1 and 730 µg/L in well SWD-5 (fig. 10). The concentration of iron in water from the test wells near brine-disposal well SWD-1 ranges from 9,500 to 55,000 µg/L and increases with distance to the south and east. The manganese concentrations are less but have a similar pattern. The geochemical reaction resulting in the increase in iron and manganese concentrations cannot be determined with the data available; however, the variables that affect solubility include the pH and redox potential (Eh) and the dissolved carbon dioxide and sulfur species.

The downstream increase in chloride concentration between sampling sites PR-2 and PR-3 is an indication of brine-contaminated ground-water flow to the Poplar River. The change from sodium bicarbonate water at site PR-1 to a sodium chloride type at PR-3, coupled with a downstream increase in dissolved-solids concentration, is further indication that brine-contaminated ground water is entering the stream.

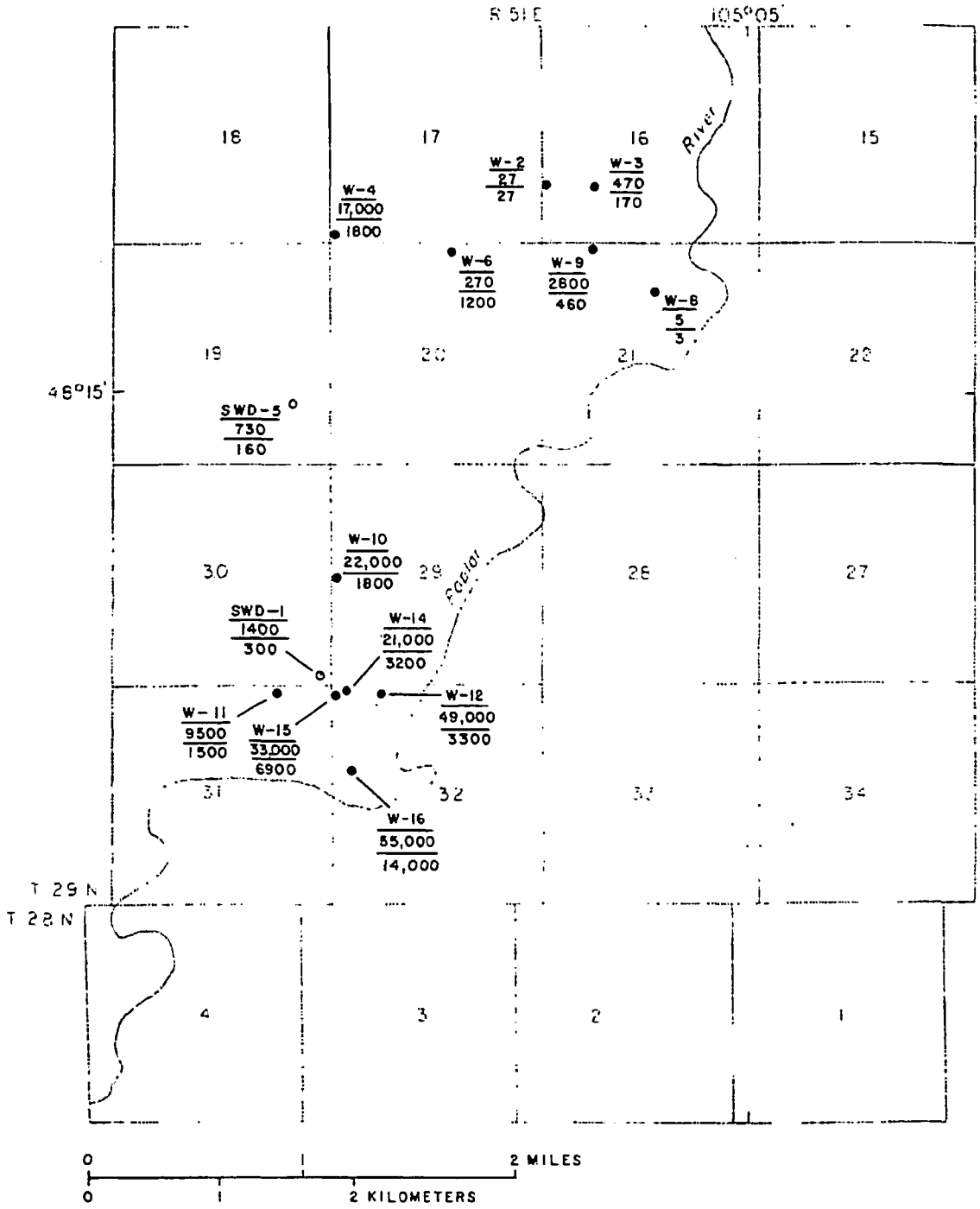
Possible sources of contamination

The two most common means of disposal of brine produced in the East Poplar oil field are brine-disposal wells and storage or evaporation pits. Brine-disposal wells are used for two purposes: (1) The disposal of brine into non-producing subsurface formations and (2) the disposal of brine into the producing zones for pressure maintenance to increase the quantity of oil recovered from the formation. To date (1982), brine has been injected into the Upper Cretaceous Judith River Formation (about 700 feet deep), the Lower Cretaceous Dakota Formation (about 3,300 feet deep), and the Mississippian Charles and Mission Canyon Formations (about 5,300 feet deep), for disposal, and into the Charles Formation for pressure maintenance.

The brine-disposal wells can become a source of contamination because of the corrosive nature of the brine. The chemical composition and heat of the brine combined with an injection pressure of several hundred pounds per square inch can corrode and rupture steel casing or pipe, resulting in leakage into adjacent formations. Wells in the oil field produce water having temperatures ranging from 93° to 104°C (Sonderegger and Bergantino, 1981). Leakage can also occur in pipelines transporting brine from production wells to tank batteries and then to brine-disposal wells.

Storage or evaporation pits are used to hold brine either for evaporation of the water or as storage reservoirs during periods when a brine-disposal well is inoperative. These pits are usually bulldozed into the alluvium near a brine-disposal well but may be located near tank batteries or production wells. They may or may not be lined with plastic or clay to prevent infiltration of water into the alluvium. Where plastic is used, it is susceptible to punctures or tears, allowing

MAR02-1445



EXPLANATION

DATA SITE

W-15 / 33,000 / 6900 ● Water-supply, unused, or test well--Upper number is well number; middle number is iron concentration, in micrograms per liter, of sample collected in 1982; lower number is manganese concentration, in micrograms per liter, of samples collected in 1982

SWD-1 / 1400 / 300 ○ Brine-disposal well--Upper number is well number; middle number is iron concentration, in micrograms per liter, of sample collected in 1982; lower number is manganese concentration, in micrograms per liter, of sample collected in 1982

Figure 10.--Iron and manganese concentrations of water from wells.

MAR02-1446

brine to infiltrate the underlying formation.

The location of all evaporation or storage pits, pipelines, wells, and tank batteries that have existed in the oil field is unknown. In the study area, as many as 11 wells are known to have periodically been used for disposal of brine. All these wells are assumed to have had storage or evaporation pits at one time. During the study, pits were in use at brine-disposal wells SWD-1 and SWD-5. The area is interlaced with pipelines connecting oil wells to tank batteries, which may be connected to brine-disposal wells.

NEED FOR ADDITIONAL STUDY

The results of this reconnaissance study indicate that brine from oil-field production is the probable source of sodium chloride contamination in the alluvial aquifer. Additional data collection is necessary to determine the areal extent of the contamination, rates of movement of brine in the alluvium, geochemical reactions that may occur between the brine and alluvium resulting in precipitates, and changes in water quality with depth in the alluvium.

Answers to some of these unknowns may be possible by using resistivity and electromagnetic geophysical techniques to isolate probable sources of the contamination plumes. To supplement these data, the location of all producing and disposal wells, dry holes, tank batteries, pipelines, and storage or evaporation pits needs to be determined. The quantity of brine and period of time that brine was injected in each disposal well also need to be determined.

An analysis of these data could isolate the point sources of contamination throughout the oil field. A detailed drilling and sampling program could then be undertaken to determine the magnitude of contamination and its lateral and vertical distribution from these point sources.

If sufficient data are obtained, contaminant transport models might be used to simulate the system. Depending on the degree of simulation that is achieved, the model could be useful in predicting the movement and residual effects of the contaminant through the alluvium downvalley from the oil field.

SUMMARY AND CONCLUSIONS

In the East Poplar oil field, shallow water occurs in the alluvium beneath the valley floor. The general direction of ground-water flow is from north to south down the Poplar River valley. Localized areas may have directional components of flow toward the river. The alluvium is underlain by the Bearpaw Shale, which is relatively impermeable, preventing downward movement of water and forcing water in the alluvium to move laterally downvalley.

Seven test wells, bottomed in the Bearpaw Shale, were installed around brine-disposal well SWD-1. These wells were sampled, along with several existing wells, to determine the quality of ground water in the study area. Depending on the well location, four distinct types of water exist. Type 1 is a sodium bicarbonate water with dissolved-solids concentration ranging from about 490 to 770 mg/L. Type 2 is sodium chloride water with varying quantities of calcium and magnesium and dissolved-solids concentration ranging from about 1,600 to 7,200 mg/L. Type 3 is also

MAR02-1447

sodium chloride water; however, the concentrations of sodium and chloride are significantly larger than in Type 2. The dissolved-solids concentration ranges from 13,800 to 114,000 mg/L. The wells producing Type 3 water are test wells drilled around brine-disposal well SWD-1. Type 3 water is very similar to Type 4 water, which represents the brine being injected into two disposal wells. The dissolved-solids concentrations of the brine being injected were 97,900 and 161,000 mg/L.

Contamination of the alluvial aquifer by brine is indicated by analysis of chemical-quality data for water samples from wells and the Poplar River. A brine/fresh-water interface appears to exist in the alluvium between wells W-2 and W-3 and wells W-6 and W-9. A downstream increase in chloride concentration (20 to 880 mg/L) and downstream change in water type from sodium bicarbonate to sodium chloride are indications of brine-contaminated ground-water inflow to the Poplar River. Contamination also may be indicated by the distribution of iron and manganese concentrations around brine-disposal well SWD-1.

The probable source of sodium chloride contamination of the alluvial aquifer is by brines from the production of oil in limestones of the Charles Formation of the Madison Group of Mississippian age. The brines contain dissolved-solids concentrations ranging from about 16,000 to 201,000 mg/L. Brine-disposal wells and storage or evaporation pits have been used in the disposal of the brine. The contamination of water in the alluvium can occur from leaks in casing or pipelines caused by the corrosive nature of the brine or from leakage in storage or evaporation pits that have been improperly sealed or have sustained tears in the sealing material.

Additional data collection is necessary to determine the areal extent of contamination. Rates of movement of brine in the alluvium, geochemical reactions that may occur between the brine and alluvium resulting in precipitates, and changes in water quality with depth in the alluvium also could be determined by analysis of additional data.

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MAR02-1449

SUPPLEMENTAL DATA

Table 1.--*Records of water-supply, unused, test, and brine-disposal wells*

[Local number--numbering system in text. Depth of hole--in feet below land surface. Depth of well--in feet below land surface. Finish--P, perforated; X, open hole. Depth to first opening--in feet below land surface. Use of site--D, brine disposal; O, observation; U, unused; W, withdrawal. Use of water--H, domestic; Z, other. Altitude of land surface--in feet above sea level. Water level--in feet below land surface. Remarks--C, chemical analyses in table 2; L, well log in table 3.]

Well No. (fig. 3)	Local No.	Date completed (month-day-year)	Depth of hole (feet)	Depth of well (feet)	Casing diameter (inches)	Finish	Depth to first opening (feet)	Use of site	Use of water	Principal aquifer	Altitude of land surface (feet)	Water level (feet)	Date water level measured (month-day-year)	Remarks
W-1	29N51E16BDAA01	--	110	52.6	5.5	--	--	U	--	Alluvium	2,027	9.14	07-20-82	--
W-2	29N51E16CBCC01	--	--	25	6	P	21	U	--	do	2,030	13.48	05-04-82	C
W-3	29N51E16CCAA01	--	--	23	6	P	19	W	Z	do	2,027	9.31	05-04-82	C
W-4	29N51E17CCCC01	--	--	87	5.5	P	83	U	--	do	2,065	55.66	05-04-82	C
W-5	29N51E20ABBA01	--	--	48	--	--	--	U	--	do	2,035	--	--	--
W-6	29N51E20ABBA02	--	--	44	5.5	--	--	U	--	do	2,037	24.67	07-27-82	C
W-7	29N51E21ABCB01	--	210	197	4.5	X	100	U	--	do	2,016	11.37	05-04-82	--
W-8	29N51E21ABCC01	60	--	12	12	--	--	W	H	do	2,016	9.51	05-04-82	C
W-9	29N51E21BBAA01	--	20	17.4	5.5	P	13.4	U	--	do	2,024	9.40	05-04-82	C
W-10	29N51E29CBBB01	08-30-82	46	45.3	2	P	13.3	O	--	do	2,007	11.23	08-31-82	C,L
W-11	29N51E31AABB01	08-28-82	55	54	2	P	15	O	--	do	2,009	19.55	08-31-82	C,L
W-12	29N51E32BBAA01	08-29-82	44	42.4	2	P	12.4	O	--	do	1,999	8.37	08-31-82	C,L
W-13	29N51E32BBBA01	08-26-82	48	31	2	P	11	O	--	do	2,000	9.50	08-31-82	L
W-14	29N51E32BBBA02	08-27-82	48	47.5	2	P	7.5	O	--	do	2,000	9.48	08-31-82	C,L
W-15	29N51E32BBBB01	08-29-82	49	49	2	P	19	O	--	do	2,000	10.21	08-31-82	C,L
W-16	29N51E32BCCA01	08-27-82	46	39.7	2	P	19.7	O	--	do	1,996	8.84	08-31-82	C,L
SWD-1	29N51E30DDDD01	09-12-57	3,465	3,310	5.5	X	3,146	D	--	Dakota	2,005	--	--	C
SWD-5	29N51E19DDBA01	02-22-76	3,583	3,583	7	P	3,190	D	--	do	2,040	--	--	C

MAR02-1451

Table 2.--Chemical-quality data for water from wells and for injection brines

[Values are reported in milligrams per liter (mg/L), micrograms per liter (µg/L), degrees Celsius (°C), and micromhos per centimeter at 25° Celsius (micromhos). <, constituent present at concentration smaller than detection limit of applied analysis. Agency analyzing sample--MDHES, Montana Department of Health and Environmental Sciences, Water Quality Bureau; USGS, U.S. Geological Survey]

Well No. (fig. 3)	Local No.	Date of sample (month-day-year)	Geologic unit	Onsite specific conductance (micromhos)	Lab specific conductance (micromhos)	Onsite pH (standard units)	Onsite water temperature (°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
W-2	29N51E16CBCC01	07-23-79	Alluvium	--	1,612	--	--	260	0	47	35
		07-26-82	do	900	850	7.9	9.0	150	0	30	18
W-3	29N51E16CCAA01	07-20-82	do	1,140	1,170	7.7	9.5	160	0	27	22
W-4	29N51E17CCCC01	07-23-79	do	--	1,070	--	--	170	100	40	17
		07-27-82	do	9,100	11,500	7.4	9.5	3,100	2,800	700	320
W-6	29N51E20ABBA02	07-23-79	do	--	7,300	--	--	1,800	--	340	242
		07-26-82	do	6,300	7,430	7.5	--	1,600	1,400	290	220
W-8	29N51E21ABCC01	07-23-79	do	--	1,240	--	--	190	--	38	24
		07-20-82	do	1,200	1,240	7.6	9.5	180	0	36	22
W-9	29N51E21BBAA01	07-23-79	do	--	3,070	--	--	230	--	39	32
		07-26-82	do	3,100	2,850	7.5	--	220	0	39	30
W-10	29N51E29CBBB01	11-03-82	do	10,000	10,200	6.9	10.0	3,500	3,300	750	400
W-11	29N51E31AABB01	11-03-82	do	17,000	21,100	7.1	10.0	2,500	2,100	670	210
W-12	29N51E32BBAA01	11-02-82	do	70,000	86,300	6.8	12.0	4,700	4,400	1,300	350
W-14	29N51E32BBBA02	11-02-82	do	58,000	72,000	6.7	10.5	4,700	4,400	1,400	300
W-15	29N51E32BBBB01	11-03-82	do	120,000	127,000	6.6	25.0	7,800	7,600	2,500	380
W-16	29N51E32BCCA01	11-02-82	do	70,000	92,000	6.8	10.0	16,000	15,000	4,100	1,300
SWD-1	29N51E30DDDD01	07-23-79	--	--	100,000	--	--	4,300	--	1,480	141
		07-22-82	--	170,000	150,000	6.6	--	6,000	5,900	2,000	250
SWD-5	29N51E19DDBA01	07-22-82	--	130,000	111,000	6.4	--	4,600	4,500	1,500	200

MAR02-1452

Table 2.--*Chemical-quality data for water from wells and for injection brines*--Continued

Well No. (fig. 3)	Date of sample (month-day-year)	Sodium, dis-solved (mg/L as Na)	Per-cent so-dium	Sodium ad-sorp-tion ratio (SAR)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate, fet-lab (mg/L as HCO_3)	Car-bonate, fet-lab (mg/L as CO_3)	Alka-linity, lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)
W-2	07-23-79	228	--	6.1	--	389	0.0	319	115
	07-26-82	130	65	5.2	3.8	--	--	250	94
W-3	07-20-82	220	75	8.7	4.1	--	--	473	160
W-4	07-23-79	132	--	4.4	--	80	.0	66	64
	07-27-82	1,400	50	11	12	--	--	234	1,300
W-6	07-23-79	790	--	8.0	--	310	.0	254	225
	07-26-82	890	54	9.6	11	--	--	213	260
W-8	07-23-79	215	--	6.7	--	554	.0	454	152
	07-20-82	220	72	8.0	4.1	--	--	474	160
W-9	07-23-79	526	--	15	--	381	.0	312	177
	07-26-82	510	83	15	6.1	--	--	323	190
W-10	11-03-82	870	35	6.4	12	--	--	246	630
W-11	11-03-82	4,100	78	35	20	--	--	395	1,000
W-12	11-02-82	25,000	92	159	250	--	--	245	840
W-14	11-02-82	19,000	90	120	89	--	--	301	800
W-15	11-03-82	43,000	92	221	150	--	--	172	1,100
W-16	11-02-82	23,000	76	80	97	--	--	126	440
SWD-1	07-23-79	69,600	--	457	--	171	.0	140	1,670
	07-22-82	56,000	94	314	910	--	--	153	1,200
SWD-5	07-22-82	33,000	93	212	550	--	--	76	1,500

MAR02-1453

Table 2.--*Chemical-quality data for water from wells and for injection brines*--Continued

Well No. (fig. 3)	Date of sample (month-day-year)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Arsenic, dissolved (µg/L as As)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L) as Cr)
W-2	07-23-79	230	--	--	1,464	--	--	--	--	--
	07-26-82	34	.5	10	488	3.9	1	<.5	<1	<10
W-3	07-20-82	18	.4	15	752	<.10	--	--	--	--
W-4	07-23-79	238	--	--	452	--	--	--	--	--
	07-27-82	3,300	.1	14	7,210	.10	7	<10	20	10
W-6	07-23-79	2,190	--	--	4,100	--	--	--	--	--
	07-26-82	2,300	.2	16	4,120	<.10	--	--	--	--
W-8	07-23-79	34	--	--	880	--	--	--	--	--
	07-20-82	30	.4	14	774	.27	1	<.5	<1	<10
W-9	07-23-79	629	--	--	1,780	--	--	--	--	--
	07-26-82	620	.4	14	1,610	<.10	--	--	--	--
W-10	11-03-82	3,400	.1	16	6,250	<.10	--	--	--	--
W-11	11-03-82	7,500	.2	16	13,800	.62	--	--	--	--
W-12	11-02-82	42,000	<.1	7.9	69,900	<.10	--	--	--	--
W-14	11-02-82	34,000	<.1	11	55,800	<.10	.2	<10	130	60
W-15	11-03-82	67,000	<.1	12	114,000	<.10	5	<.5	1	100
W-16	11-02-82	46,000	<.1	6.8	75,100	<.10	--	--	--	--
SWD-1	07-23-79	106,000	--	--	--	--	--	--	--	--
	07-22-82	100,000	4.6	57	161,000	<.10	<1	<10	290	130
SWD-5	07-22-82	51,000	4.4	52	97,900	<.10	<1	<10	170	120

MAR02-1454

Table 2.--*Chemical-quality data for water from wells and for injection brines*--Continued

Well No. (fig. 3)	Date of sample (month-day-year)	Copper, dis-solved (µg/L as Cu)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Zinc, dis-solved (µg/L as Zn)	Agency analyz-ing sample
W-2	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-26-82	<10	27	<100	27	<.1	<100	4	44	USGS
W-3	07-20-82	--	470	--	170	--	--	--	--	USGS
W-4	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-27-82	30	17,000	200	1,800	<.1	200	<1	40	USGS
W-6	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-26-82	--	270	--	1,200	--	--	--	--	USGS
W-8	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-20-82	<10	5	<100	3	<.1	100	<1	320	USGS
W-9	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-26-82	--	2,800	--	460	--	--	--	--	USGS
W-10	11-03-82	--	22,000	--	1,800	--	--	--	--	USGS
W-11	11-03-82	--	9,500	--	1,500	--	--	--	--	USGS
W-12	11-02-82	--	49,000	--	3,300	--	--	--	--	USGS
W-14	11-02-82	70	21,000	600	3,200	.1	500	<1	140	USGS
W-15	11-03-82	<10	33,000	1,600	6,900	.5	1,600	<1	220	USGS
W-16	11-02-82	--	55,000	--	14,000	--	--	--	--	USGS
SWD-1	07-23-79	--	--	--	--	--	--	--	--	MDHES
	07-22-82	200	1,400	4,000	300	<.1	3,200	<1	110	USGS
SWD-5	07-22-82	140	730	1,300	160	<.1	2,700	<1	80	USGS

MAR02-1455

Table 3.--*Drillers' logs of test wells*

[Thickness is in feet. Depth is in feet below land surface]

	Thickness	Depth
29N51E29CBBB01 (W-10)		
Topsoil	5	5
Clay, moist	8	13
No returns, easy drilling	3	16
Fine, silty sand, saturated	7	23
Silty sand and some gravel	7	30
Gravel	9	39
Gravel, fairly moist	6	45
Bearpaw Shale	1	46
29N51E31AABB01 (W-11)		
Topsoil	3	3
Hardpan	2	5
Clay, silt	14	19
Sandy gravel	2	21
Clay with small amount of gravel	33	54
Bearpaw Shale	1	55
29N51E32BBAA01 (W-12)		
Topsoil	7	7
Sand	1	8
Moist sand and silt	.5	8.5
Gravel and sand, moist	7.5	16
Saturated	5	21
Moist	5	26
Saturated	17	43
Bearpaw Shale	1	44
29N51E32BBBA01 (W-13)		
Soil	7	7
Gravel	9	16
Gravel; water at 16 feet	32	48
Bearpaw Shale	--	48
29N51E32BBBA02 (W-14)		
Soil	7	7
Gravel	9	16
Gravel; water at 16 feet	32	48
Bearpaw Shale	--	48
29N51E32BBBB01 (W-15)		
Topsoil	6	6

MAR02-1456

Table 3.--*Drillers' logs of test wells*--Continued

	Thickness	Depth
29N51E32BBBB01 (W-15)--Continued		
Sand, moist with some gravel	5	11
Sandy gravel	1	12
Moist sand	2	14
Sandy gravel	2	16
Mostly sand, little more moist	2	18
Gravel	2	20
Sand-some gravel	2	22
Gravel and sand	3	25
Gravel and sand, saturated	4	29
Same, hard drilling	5	34
Same, easier drilling	5	39
Hard drilling, no returns	9	48
Bearpaw Shale	1	49
29N51E32BCCA01 (W-16)		
Soil	12	12
Gravel	34	46
Bearpaw Shale	--	46

MAR02-1457

Table 4.--*Chemical quality of water in the Poplar River*

[Values are reported in cubic feet per second (ft^3/s), micromhos per centimeter at 25° Celsius (micromhos), degrees Celsius (°C), milligrams per liter (mg/L), and micrograms per liter (µg/L). Analyses by U.S. Geological Survey.]

Site designation (fig. 8)	Date of sample (month-day-year)	Streamflow, instantaneous (ft^3/s)	Onsite specific conductance (micromhos)	Onsite pH (standard units)	Onsite water temperature (°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
PR-1	10-25-79	22	1,380	8.8	7.0	190	--	24	31
	09-09-81	1.7	1,560	9.0	20.0	140	0	12	27
PR-2	09-09-81	--	1,590	9.0	--	--	--	--	--
PR-3	09-09-81	1.4	3,090	8.6	23.0	360	0	36	66
PR-4	09-09-81	--	3,620	8.5	--	--	--	--	--
PR-5	09-09-81	.74	3,790	8.4	25.0	590	220	80	95

Site designation (fig. 8)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (µg/L as Fe)
PR-1	280	76	8.9	7.4	--	250	12	0.4	7.1	918	10
	320	82	14	8.5	560	240	20	.5	1.9	970	21
PR-2	--	--	--	--	--	--	18	--	--	--	--
PR-3	530	75	12	11	460	250	600	.4	2.5	1,770	30
PR-4	--	--	--	--	--	--	540	--	--	--	--
PR-5	610	69	11	13	370	400	880	.4	5.2	2,310	30

MAR02-1458