

THE CAVERN DENSITY LOG

PRESENTED AT THE KDHE TECHNOLOGY FAIR
JULY 2003

RON HICKS

SONIC SURVEYS

INTRODUCTION

- THE CAVERN DENSITY LOG IS THE MOST COMMON TOOL USED BY CAVERN SPECIALIST TO MONITOR DOWN HOLE CAVERN AND WELL FEATURES AND CONDITIONS IN UNDERGROUND STORAGE CAVERNS AND SOLUTION MINING WELLS

INTRODUCTION

- NATURAL GAMMA RADIATION LOGS AND PULSED NEUTRON LOGS ARE ALSO USED IN CAVERN LOGGING TO IDENTIFY CAVERN FEATURES, BUT NOT TO THE EXTENT THE CAVERN DENSITY LOG IS, THEREFORE THIS PRESENTATION FOCUSES ON THE CAVERN DENSITY LOG

INTRODUCTION

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- THE DENSITY TOOL USED TO RECORD THE CAVERN DENSITY LOG IS A SIMPLE TOOL
- *HOWEVER*, THE ANALYSIS OF THE LOG RECORDED FROM SUCH A SIMPLE TOOL CAN BE EXTREMELY DIFFICULT

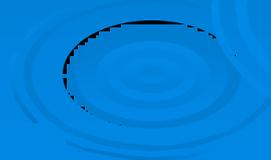
TOPICS

➤ HISTORY AND BACKGROUND



TOPICS

- HISTORY AND BACKGROUND
- THEORY



TOPICS

- HISTORY AND BACKGROUND
- THEORY
- LOGGING PROCEDURE

TOPICS

- HISTORY AND BACKGROUND
- THEORY
- LOGGING PROCEDURE
- DOWN HOLE APPLICATIONS

TOPICS

- HISTORY AND BACKGROUND
 - THEORY
 - LOGGING PROCEDURE
 - DOWN HOLE APPLICATIONS
 - EXAMPLES
- 

HISTORY

- THE DENSITY TOOL HAS BEEN USED IN THE OIL AND GAS INDUSTRY FOR DECADES TO PRIMARILY MEASURE FORMATION DENSITY

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- THE CAVERN DENSITY TOOL EVOLVED FROM THE FORMATION DENSITY TOOL IN THE EARLY 1950'S USING CESIUM AND SHORT SOURCE TO DETECTOR SPACING AND BY THE EARLY 1960'S TO THE DENSITY TOOL SIMILAR TO THE TOOL IN USE TODAY USING COBALT 60 AND MUCH LONGER SPACING

NATURAL GAMMA LOG

THE NATURAL GAMMA TOOL HAS ALSO BEEN IN USE FOR DECADES AND IS THE CORNERSTONE OF LITHOLOGY DETERMINATION IN ALL BOREHOLE LOGGING

NATURAL GAMMA LOG

NATURAL GAMMA LOG IS THE MEASUREMENT OF RADIATION ADJACENT TO THE WELL BORE

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SHALE CONTAINS MORE RADIOACTIVE MINERALS THAN SANDSTONE

NATURAL GAMMA LOG

THEREFORE, THE MORE NATURAL RADIATION DETECTED FROM THE ADJACENT WELL BORE, GENERALLY THE GREATER THE PERCENTAGE OF SHALE THE FORMATION CONTAINS

NATURAL GAMMA LOG

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USED FOR LITHOLOGY
DETERMINATION IN BEDDED SALT

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DETERMINATION IN BEDDED SALT

MOST IMPORTANTLY – IDENTIFYING
THE TOP OF THE SALT FORMATIONS

PULSED NEUTRON

- THE PULSED NEUTRON TOOL HAS BEEN IN USE IN THE OIL AND GAS INDUSTRY FOR FORMATION EVALUATION, BUT ONLY RECENTLY HAS BEEN USED IN THE CAVERN INDUSTRY AS AN INTERFACE TOOL

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- PULSED NEUTRON CONTAINS A DOWNHOLE NEUTRON GENERATOR BOMBARDING THE WELL BORE WITH NEUTRONS AND A GAMMA DETECTOR MEASURES THE CHANGES IN CHLORINE CONTENT

PULSED NEUTRON

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- ESPECIALLY, THE DIFFUCLT TO LOCATE DIESEL BRINE INTERFACE THROUGH MULTIPLE HANGING STRINGS

PULSED NEUTRON ADVANTAGES

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- NO RADIOACTIVE GAMMA SOURCE

PULSED NEUTRON DISADVANTAGES

- COST

PULSED NEUTRON DISADVANTAGES

- COST
- LICENSING

PULSED NEUTRON DISADVANTAGES

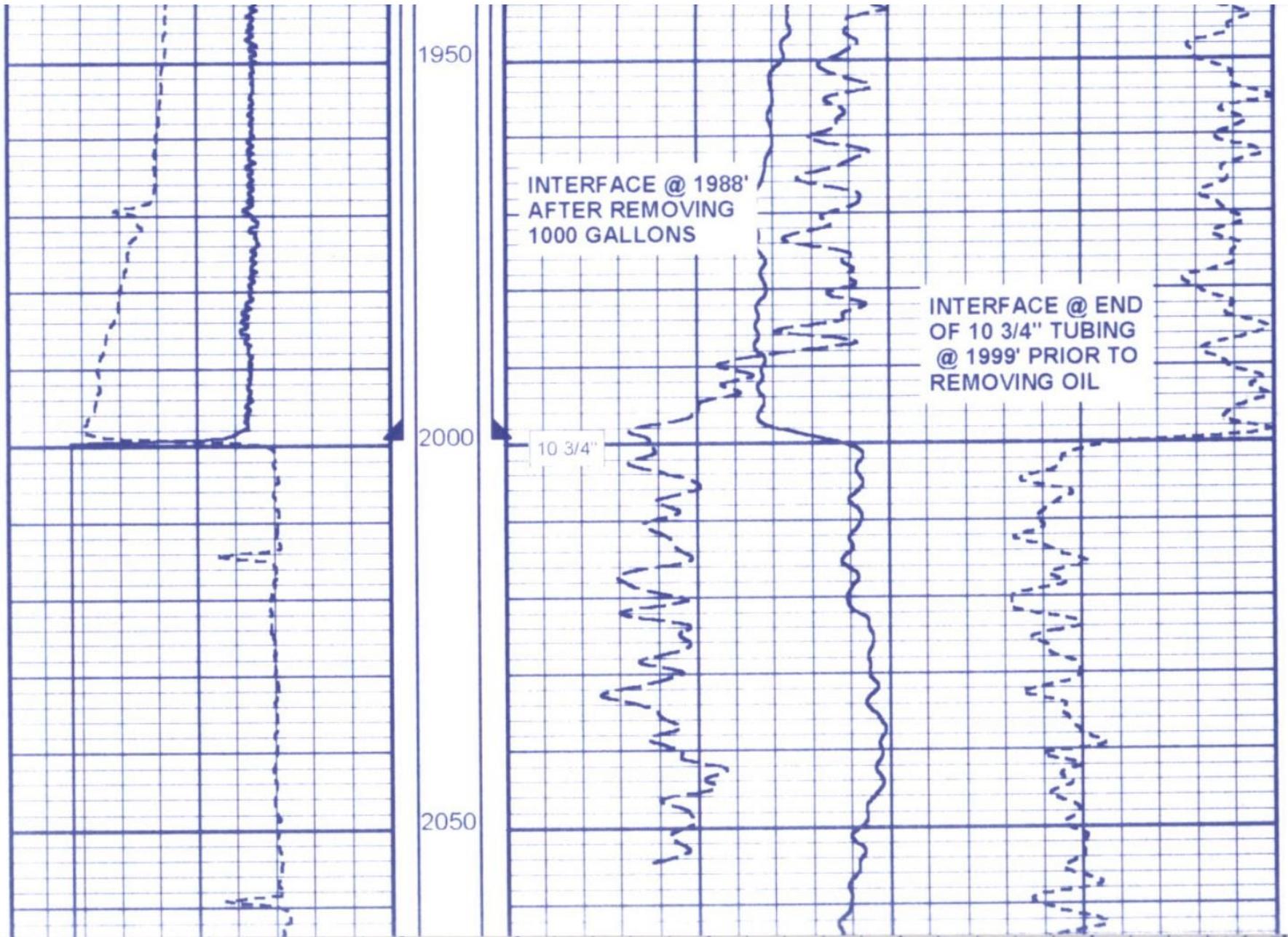
- COST
- LICENSING
- SHORT LIFE OF GENERATOR

PULSED NEUTRON DISADVANTAGES

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- EXTREMELY DANGEROUS WHEN ACTIVATED ON THE SURFACE

PULSED NEUTRON DISADVANTAGES

- COST
- LICENSING
- SHORT LIFE OF GENERATOR
- EXTREMELY DANGEROUS WHEN ACTIVATED ON THE SURFACE
- AMBIGUOUS INTERPRETATION OF CAVERN FEATURES OTHER THAN THE INTERFACE



CAVERN DENSITY LOG

- TECHNICAL NAME OF THE CAVERN DENSITY LOG IS GAMMA GAMMA DENSITY

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- SOMETIMES CONFUSED WITH THE TERM GAMMA/DENSITY, A NATURAL GAMMA RADIATION LOG COMBINED WITH A CAVERN DENSITY LOG

CAVERN DENSITY LOG

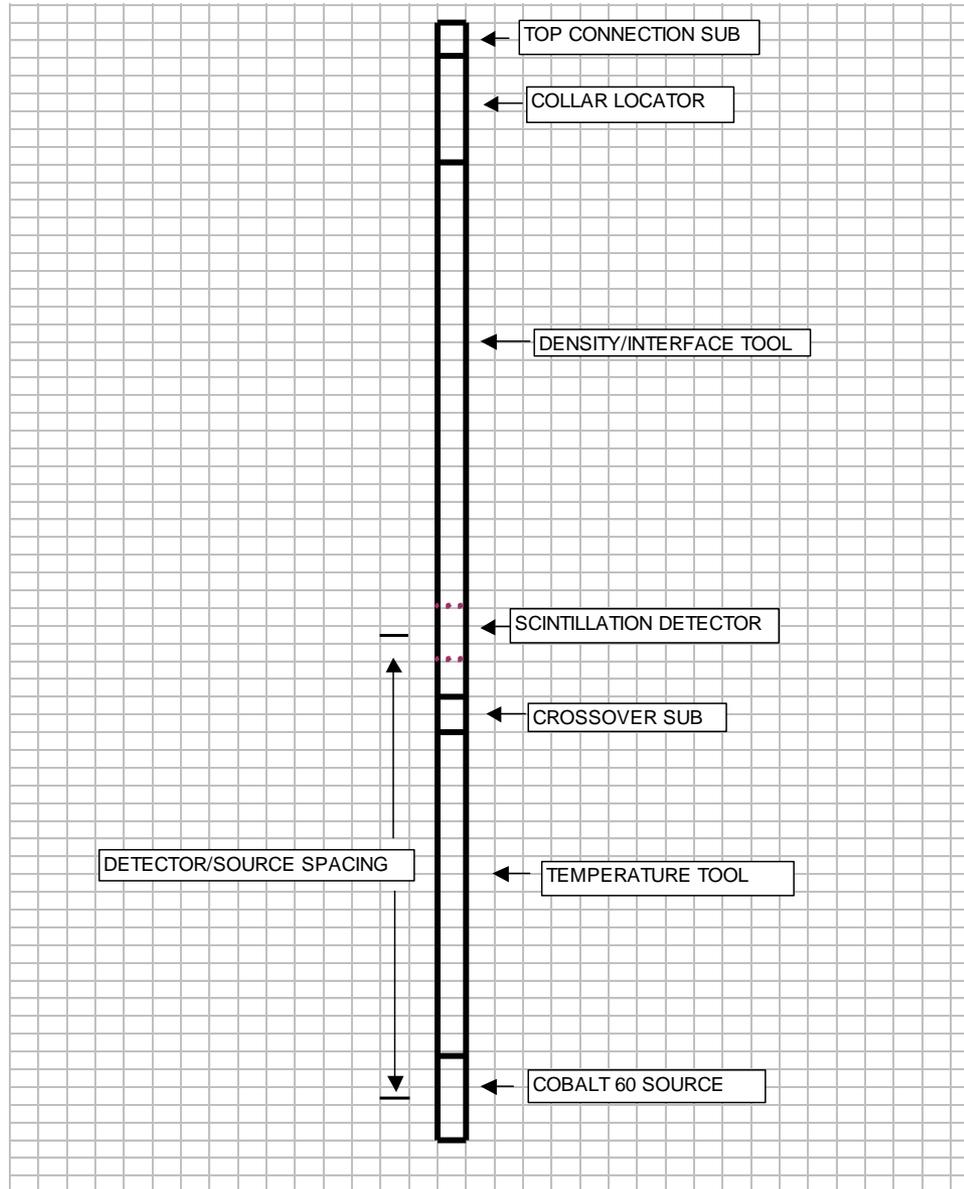
- THE CAVERN DENSITY LOG IS DERIVED FROM AN OMNI-DIRECTIONAL NON COLLIMATED DENSITY TOOL

CAVERN DENSITY LOG

- THE CAVERN DENSITY LOG IS DERIVED FROM AN OMNI-DIRECTIONAL NON COLLIMATED DENSITY TOOL
- CONSISTS OF A RADIOACTIVE GAMMA SOURCE BELOW A FIXED GAMMA RADIATION DETECTOR

1.5 INCHES
TO 2 INCHES
OUTSIDE
DIAMETER

TOOL
LENGTH
FROM 5 FT.
TO 13 FT.

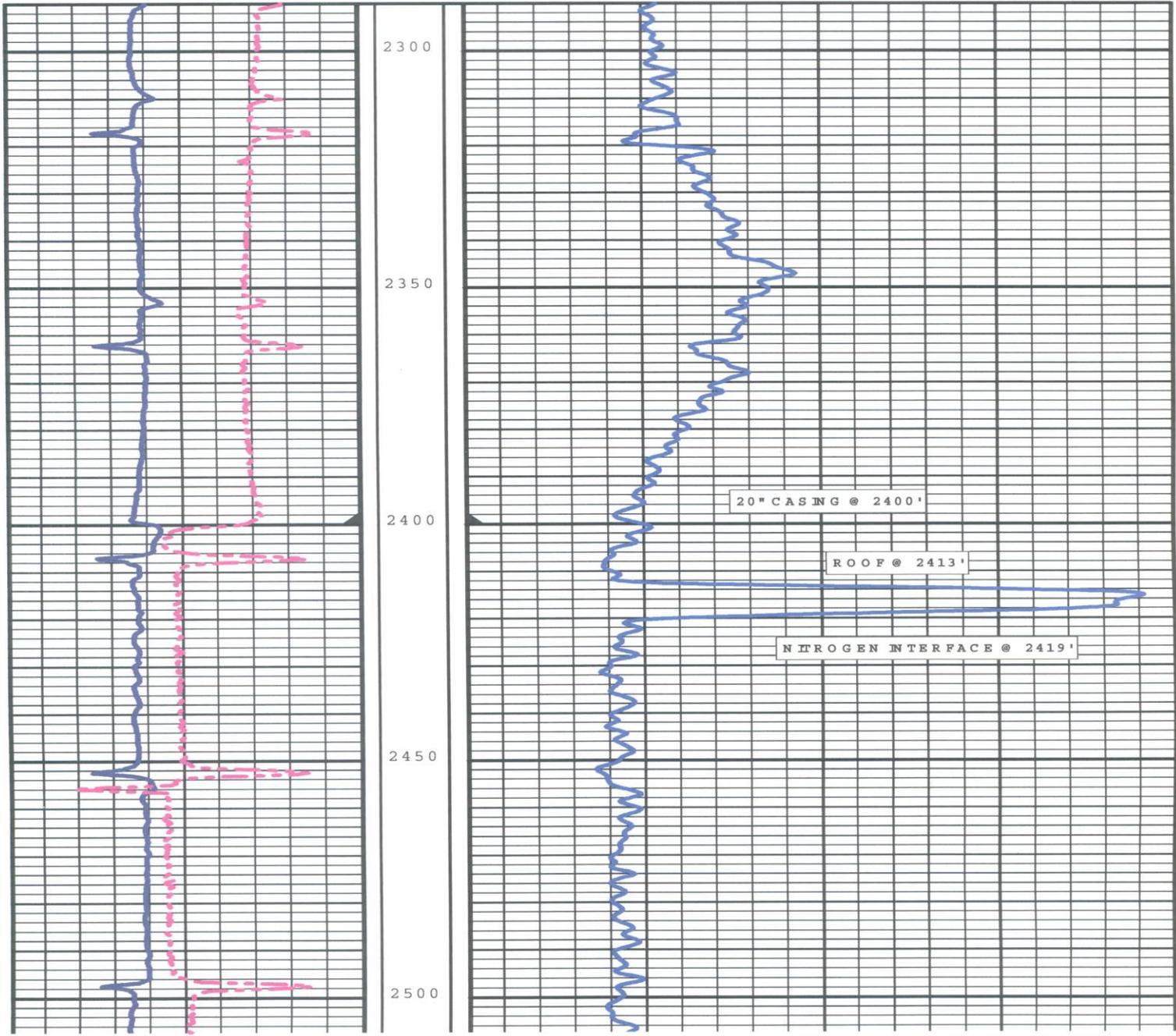


CAVERN DENSITY TOOL CONFIGURATION

- THE TOOL CONFIGURATION NORMALLY CONTAINS A CASING COLLAR LOCATOR

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- THE NEWEST GENERATION OF CAVERN DENSITY TOOLS COMBINE NATURAL GAMMA RAY, DENSITY, TEMPERATURE, AND THE MULTIPLE STRING COLLAR LOCATOR IN ONE TOOL DIGITIZED IN THE TOOL AND SENT TO THE SURFACE COMPUTER VIA TELEMETRY

CAVERN DENSITY TOOL THEORY OF OPERATION

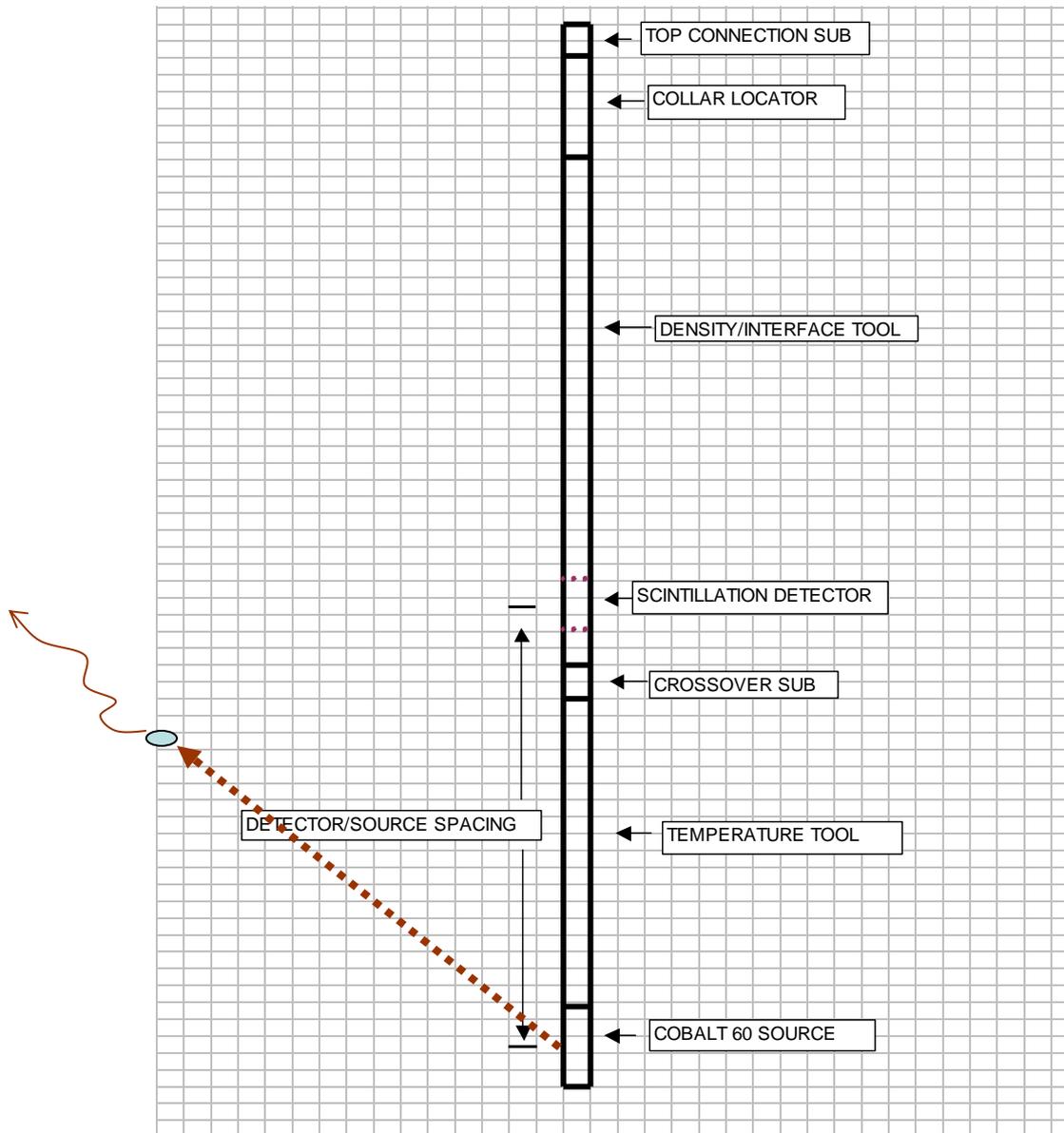
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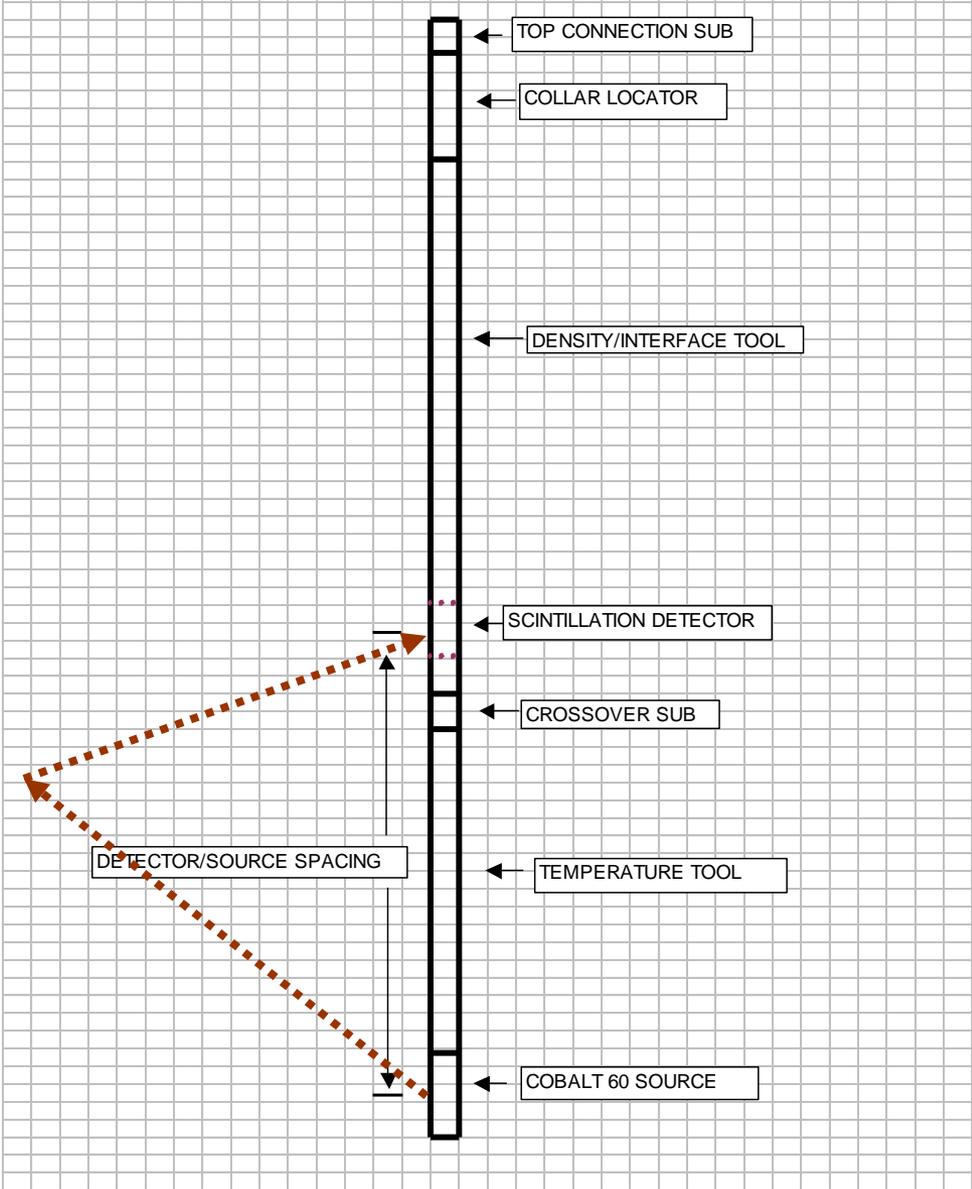
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- THE PHOTONS' ENERGY DISIPATES DUE TO THE SCATTERING



CAVERN DENSITY TOOL THEORY OF OPERATION

- PHOTONS NOT SCATTERED ARE DETECTED AND "COUNTED" BY THE TOOL



CAVERN DENSITY TOOL THEORY OF OPERATION

- NUMBER OF PHOTONS DETECTED BY THE TOOL IS INVERSLY PROPORTIONAL TO THE ELECTRON DENSITY OF THE MATTER SURROUNDING THE TOOL AND THEREFORE THE RELATIVE DENISTY OF THE MATTER

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- THE MORE RADIATION RETURNING TO THE TOOL, THE LESS DENSE THE MATTER WITHIN THE TOOL'S SPHERE OF INFLUENCE

CAVERN DENSITY TOOL THEORY OF OPERATION

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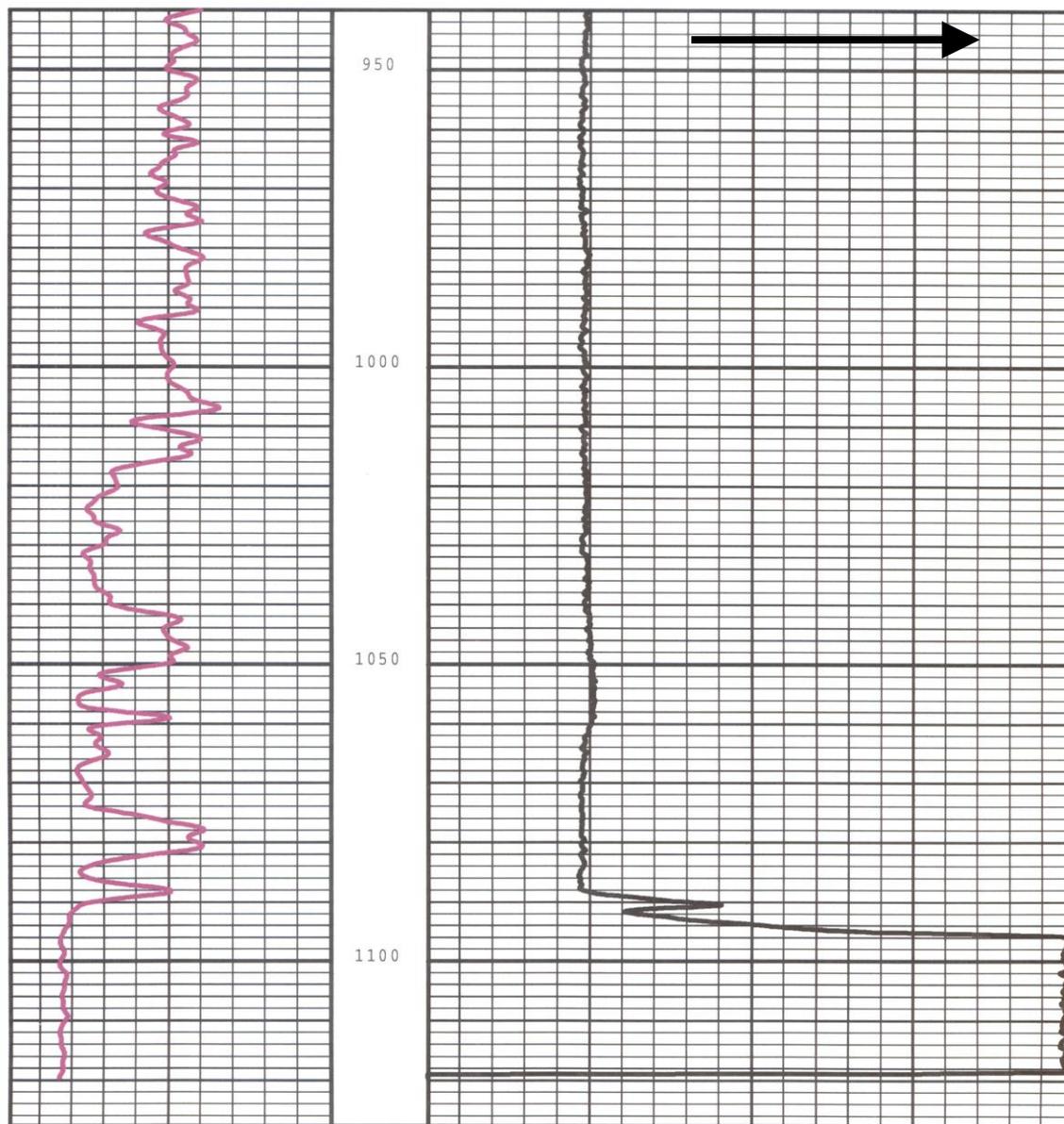
CAVERN DENSITY TOOL THEORY OF OPERATION

- THE MORE RADIATION RETURNING TO THE TOOL, THE HIGHER THE OBSERVED COUNT RATE RECORDED AT THE SURFACE
- THE HIGHER THE RECORDED COUNT RATE, THE LESS DENSE THE MATTER WITHIN THE TOOL'S SPHERE OF INFLUENCE
- THE LOWER THE RECORDED COUNT RATE, THE MORE DENSE THE MATTER WITHIN THE TOOL'S SPHERE OF INFLUENCE

CAVERN DENSITY TOOL THEORY OF OPERATION SUMMARY

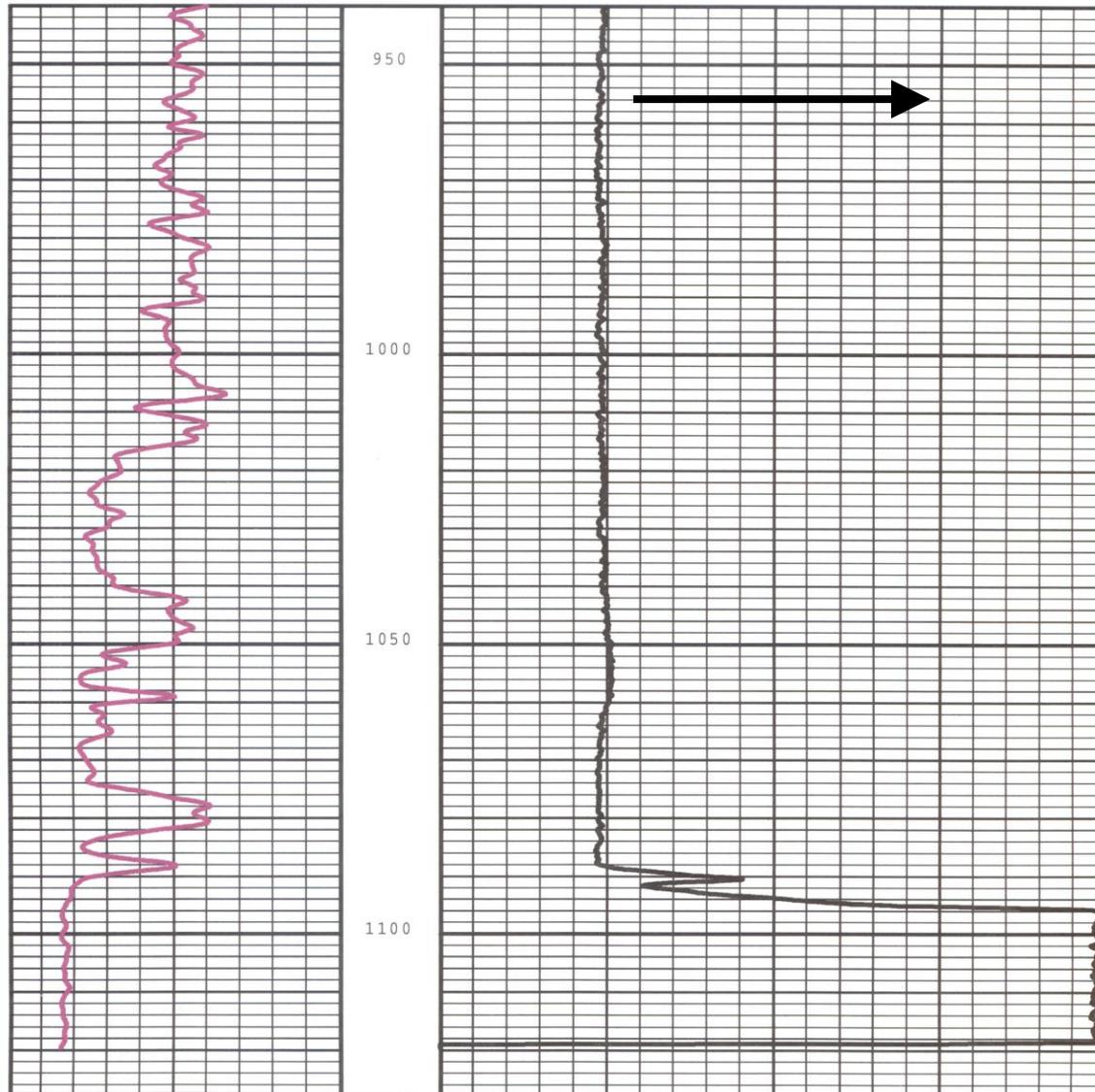
- RECORDED TOOL OUTPUT DESCRIBED AS THE COUNT RATE IS INVERSLY, LOGARITHMICALLY PROPORTIONAL TO THE DENSITY OF THE MATTER WITHIN THE TOOL'S SPHERE OF INFLUENCE

COUNT RATE INCREASES



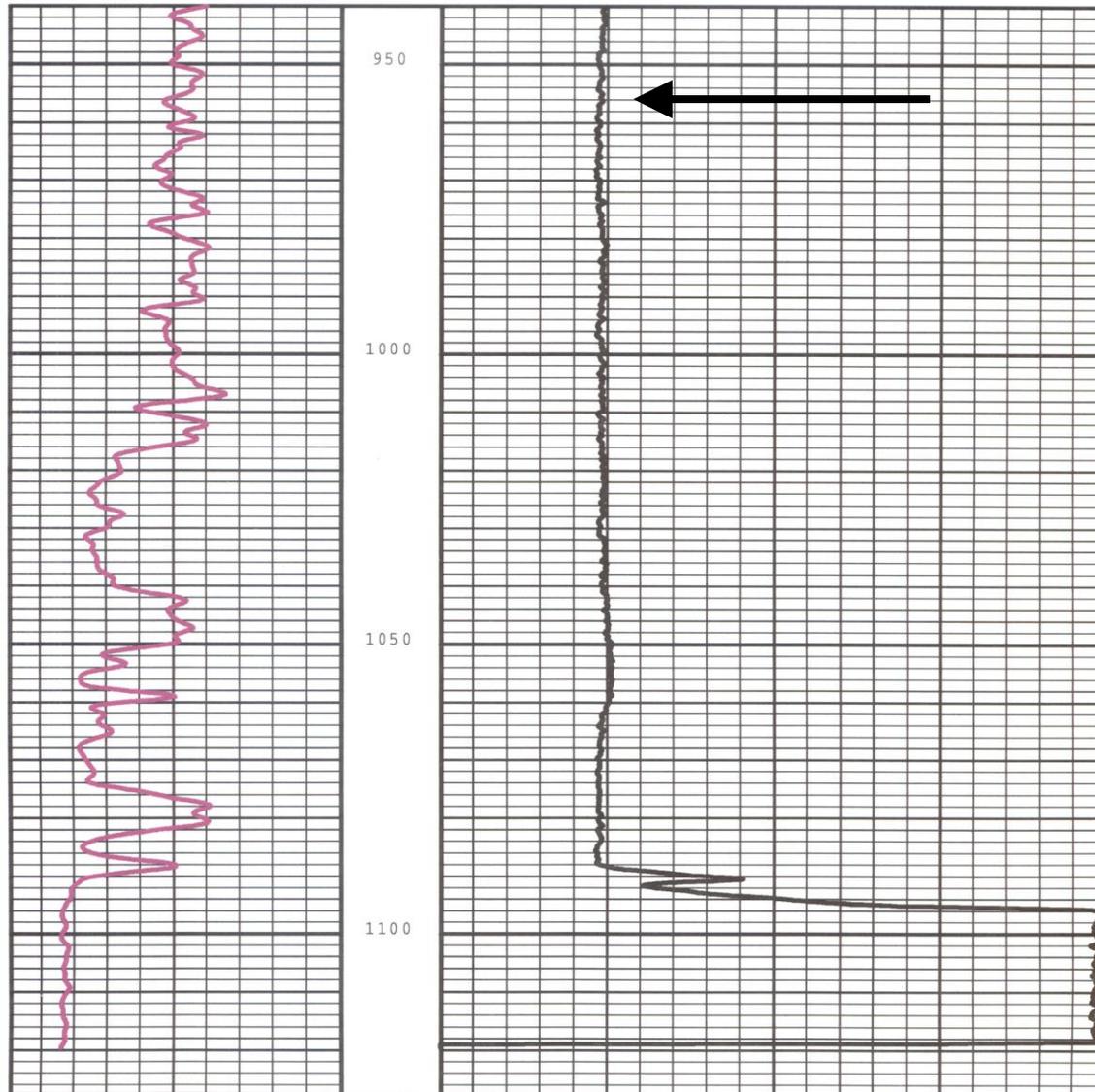
COUNT RATE INCREASES

DENSITY DECREASES



COUNT RATE DECREASES

DENSITY INCREASES



CAVERN DENSITY TOOL LOGGING PROCEDURE

- THE DENSITY TOOL IS LOWERED INTO THE WELL BORE AS ANY OTHER WIRELINE OPERATION

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- NORMALLY RAN WITH A CONTACT WEIGHT BAR

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- THE DENSITY TOOL IS LOWERED INTO THE WELL BORE AS ANY OTHER WIRELINE OPERATION
- NORMALLY RAN WITH A CONTACT WEIGHT BAR
- CAN BE RAN UNDER PRESSURE OR IN FLOWING CONDITIONS

CAVERN DENSITY TOOL LOGGING PROCEDURE

- NORMALLY RAN WITH A WELL HEAD LUBRICATOR AND WIRELINE PRESSURE SEAL ASSEMBLY FOR PRESSURE CONTROL

CAVERN DENSITY TOOL LOGGING PROCEDURE

- NORMALLY RAN WITH A WELL HEAD LUBRICATOR AND WIRELINE PRESSURE SEAL ASSEMBLY FOR PRESSURE CONTROL
- WIRELINE BLOWOUT PREVENTOR

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- NORMALLY RAN WITH A WELL HEAD LUBRICATOR AND WIRELINE PRESSURE SEAL ASSEMBLY FOR PRESSURE CONTROL
- WIRELINE BLOWOUT PREVENTOR
- TOOL TRAP







CAVERN DENSITY TOOL LOGGING PROCEDURE

- TOOL IS NORMALLY LOWERED TO THE BOTTOM OF THE CAVERN AND RAISED SLOWLY – FROM 15 TO 25 FEET PER MINUTE – IN THE LOGGING MODE

CAVERN DENSITY TOOL LOGGING PROCEDURE

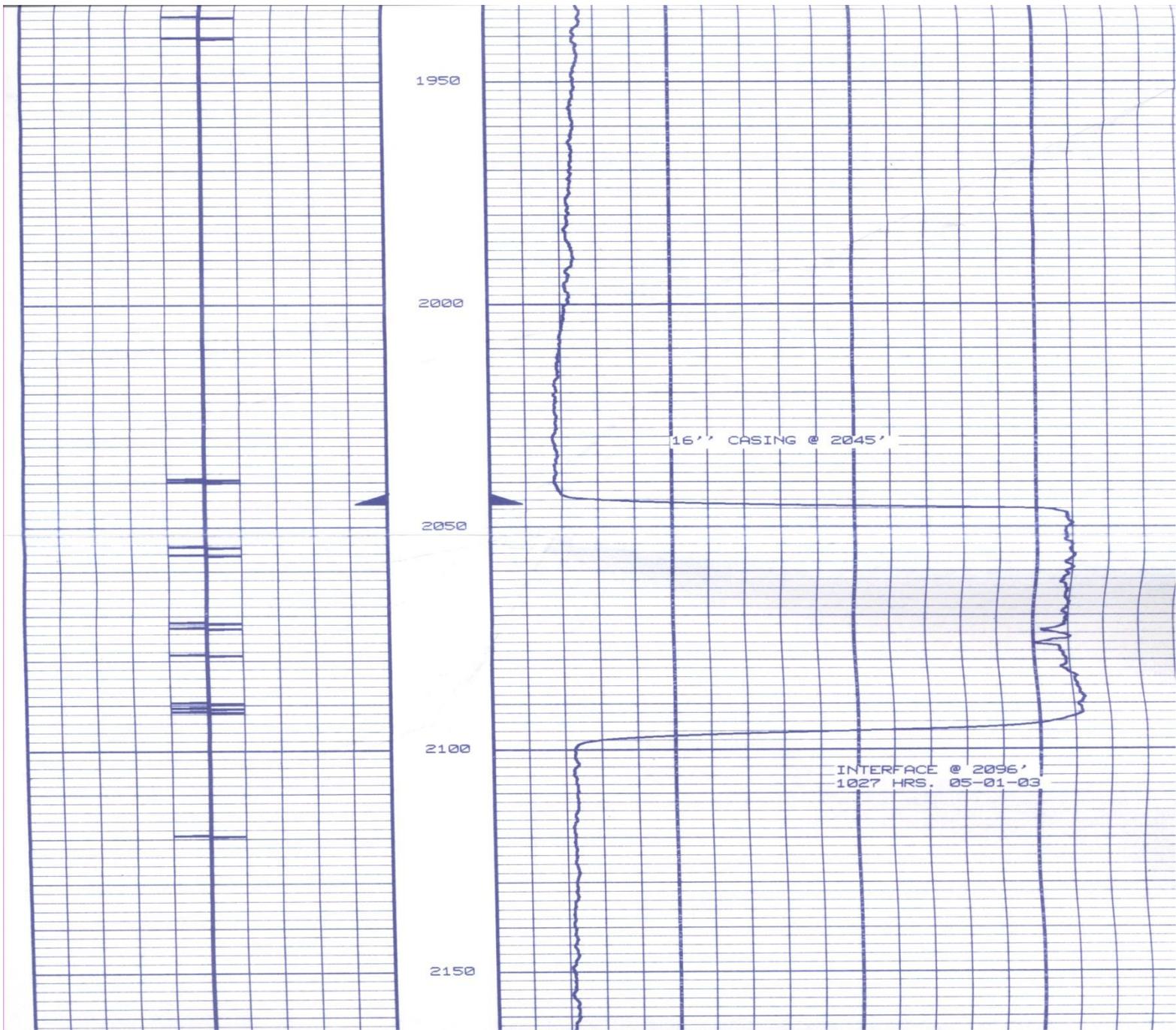
- TOOL IS NORMALLY LOWERED TO THE BOTTOM OF THE CAVERN AND RAISED SLOWLY – FROM 15 TO 25 FEET PER MINUTE – IN THE LOGGING MODE
- THE TOOL STRING IS ALWAYS “ZEROED” AT THE PERMANENT ZERO BENCHMARK AT THE SURFACE

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- THE TOOL STRING IS ALWAYS “ZEROED” AT THE PERMANENT ZERO BENCHMARK AT THE SURFACE
- THE LOG SHOULD ALWAYS BE DEPTH CORRECTED TO THE BOTTOM OF THE CEMENTED CASING SO THAT ALL LOGS PERFORMED ON A GIVEN WELL WILL BE DEPTH CONSISTENT

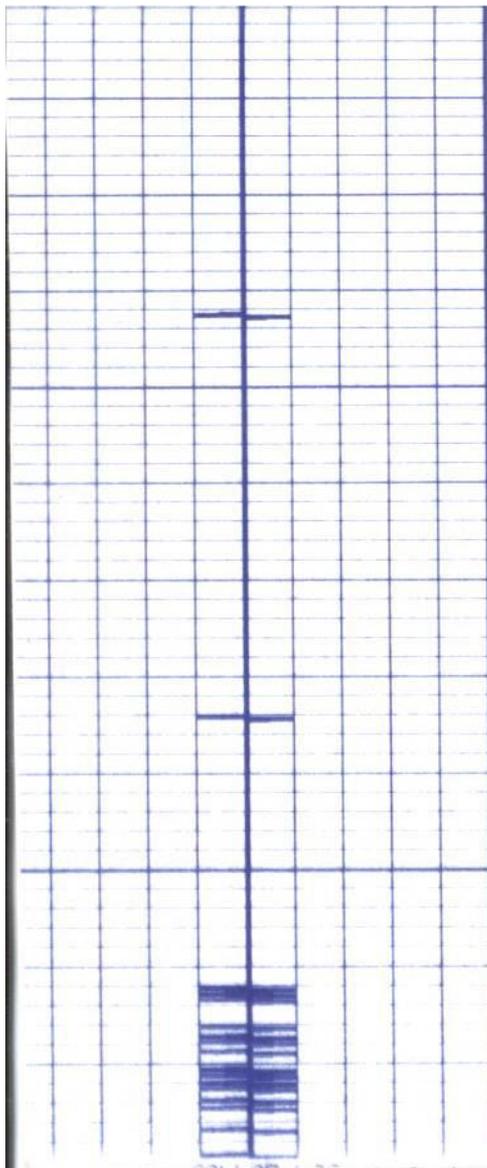
CAVERN DENSITY TOOL APPLICATION

- INTERFACE DETECTION



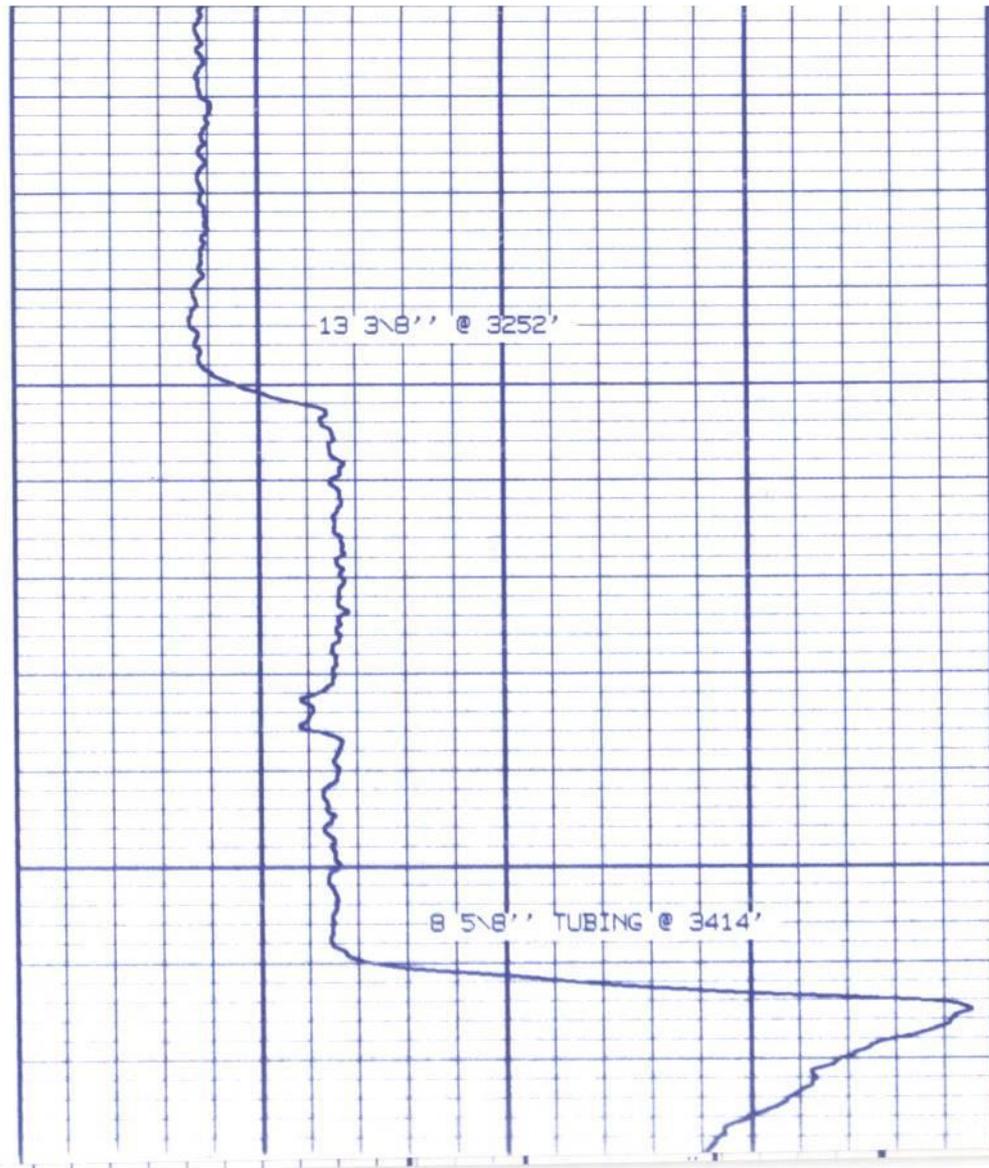
CAVERN DENSITY TOOL APPLICATION

- INTERFACE DETECTION
- CASING AND TUBULAR IDENTIFICATION



3350

3400



13 3/8'' @ 3252'

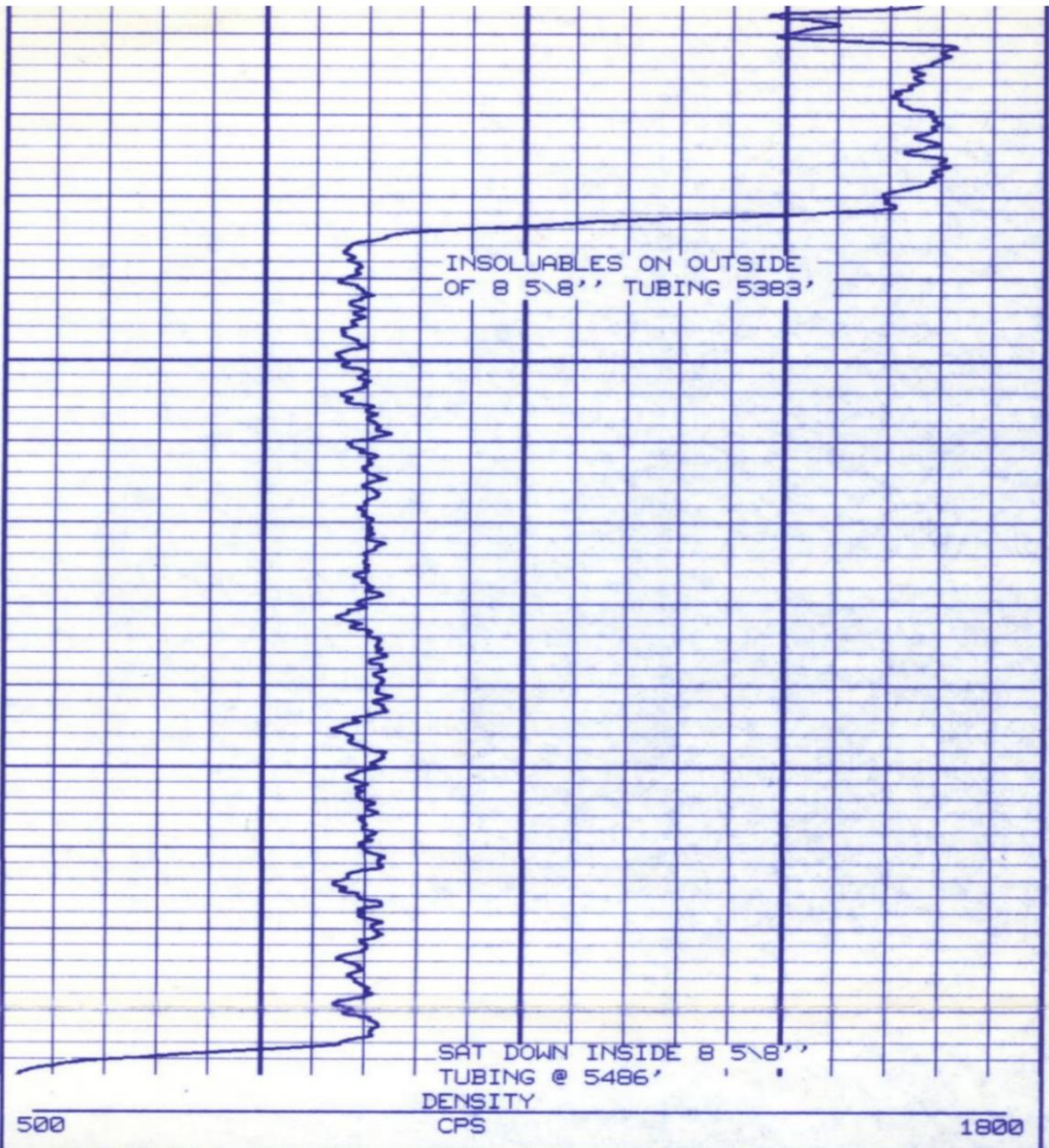
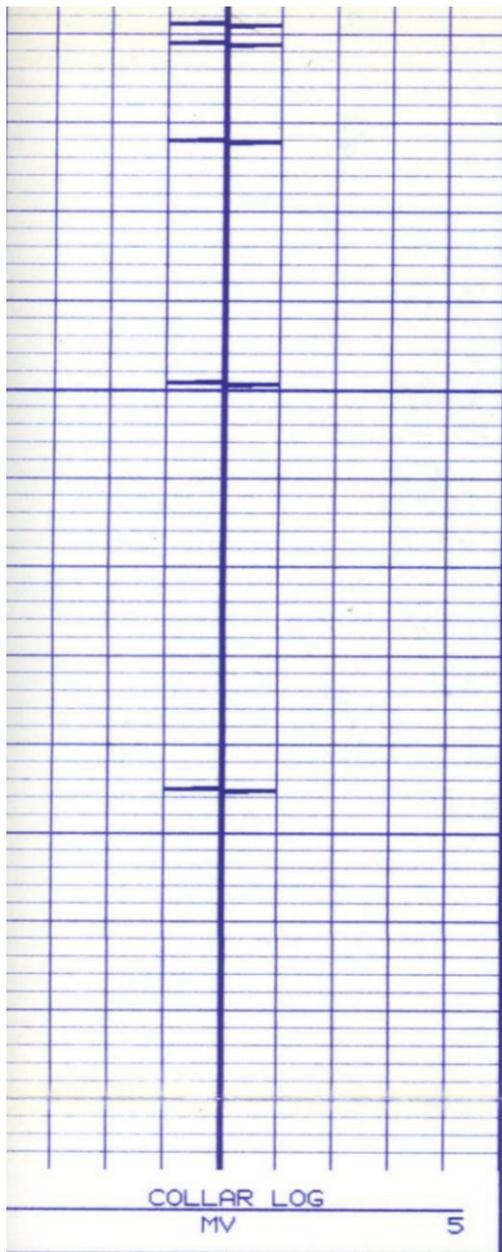
8 5/8'' TUBING @ 3414'

CAVERN DENSITY TOOL APPLICATION

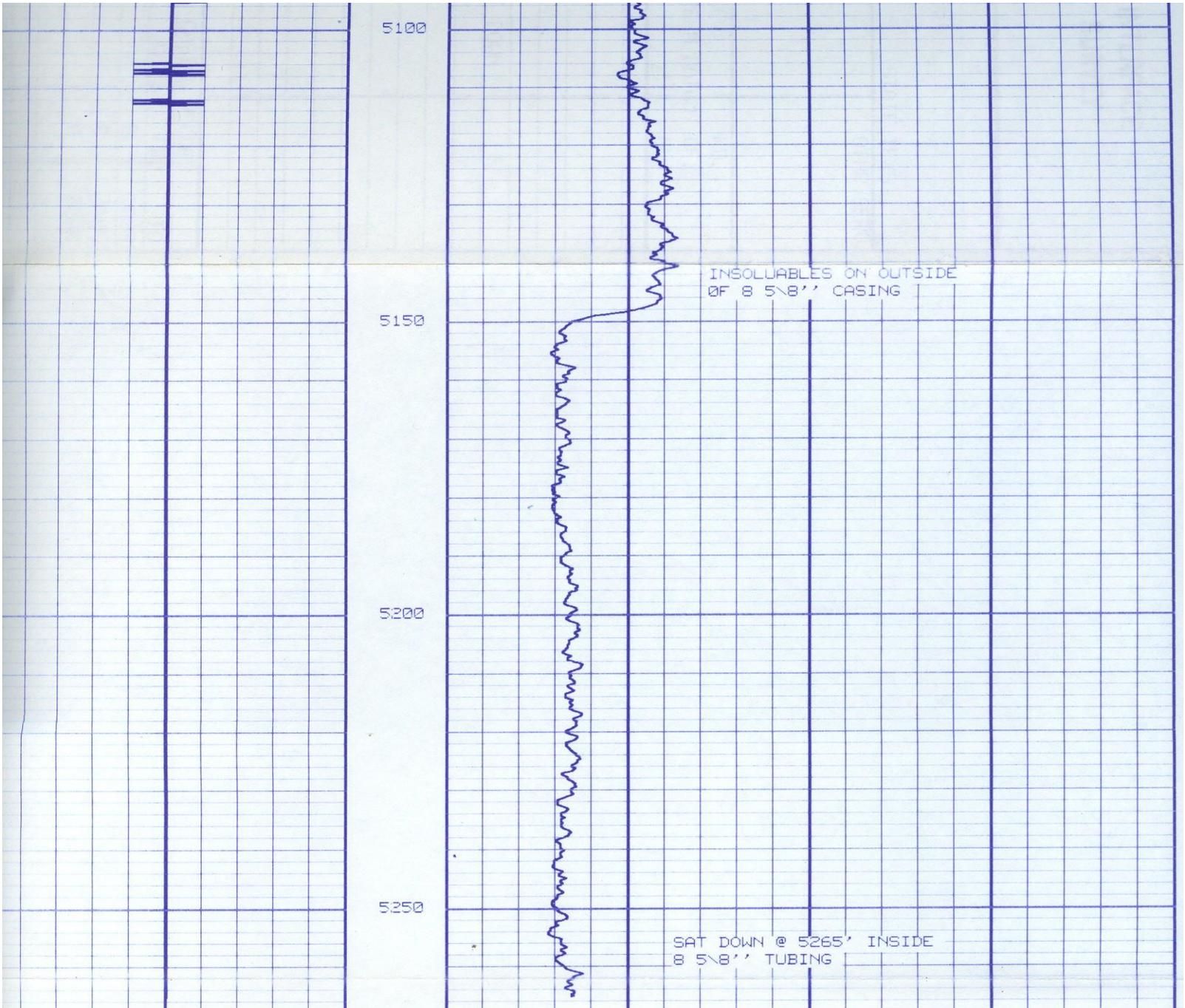
- INTERFACE DETECTION
- CASING AND TUBULAR IDENTIFICATION
- BOTTOM OF CAVERN DETECTION

CAVERN DENSITY TOOL APPLICATION

- INTERFACE DETECTION
- CASING AND TUBULAR IDENTIFICATION
- BOTTOM OF CAVERN DETECTION
- IDENTIFICATION OF INSOLUBLES OUTSIDE OF THE HANGING STRING



INSOLUABLES ON OUTSIDE OF 8 5/8" TUBING @
5383', SAT DOWN INSIDE 8 5/8" TUBING @ 5486'



5100

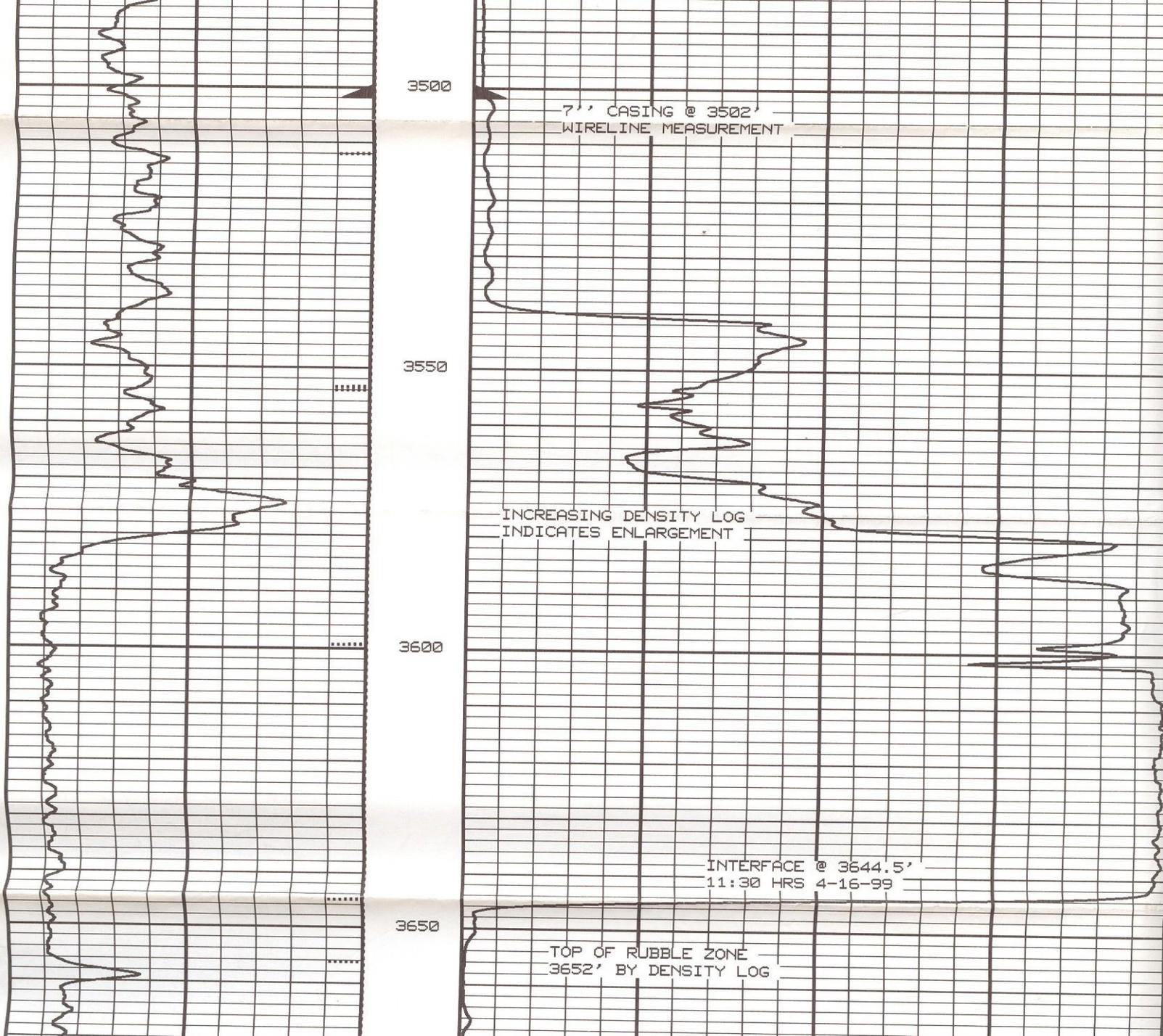
5150

5200

5250

INSOLUBLES ON OUTSIDE
OF 8 5/8" CASING

SAT DOWN @ 5265' INSIDE
8 5/8" TUBING



3500

7" CASING @ 3502'
WIRELINE MEASUREMENT

3550

INCREASING DENSITY LOG
INDICATES ENLARGEMENT

3600

INTERFACE @ 3644.5'
11:30 HRS 4-16-99

3650

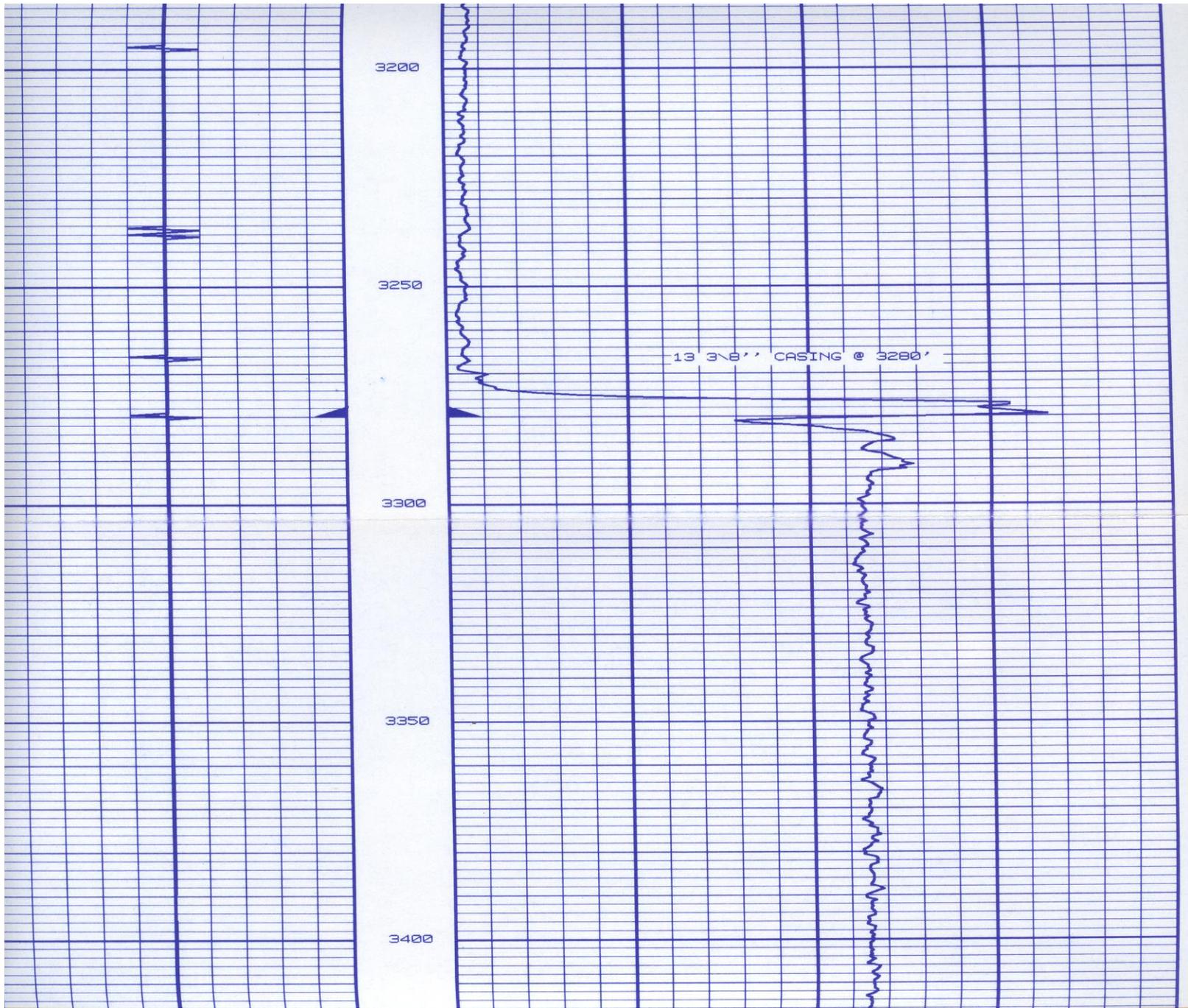
TOP OF RUBBLE ZONE
3652' BY DENSITY LOG

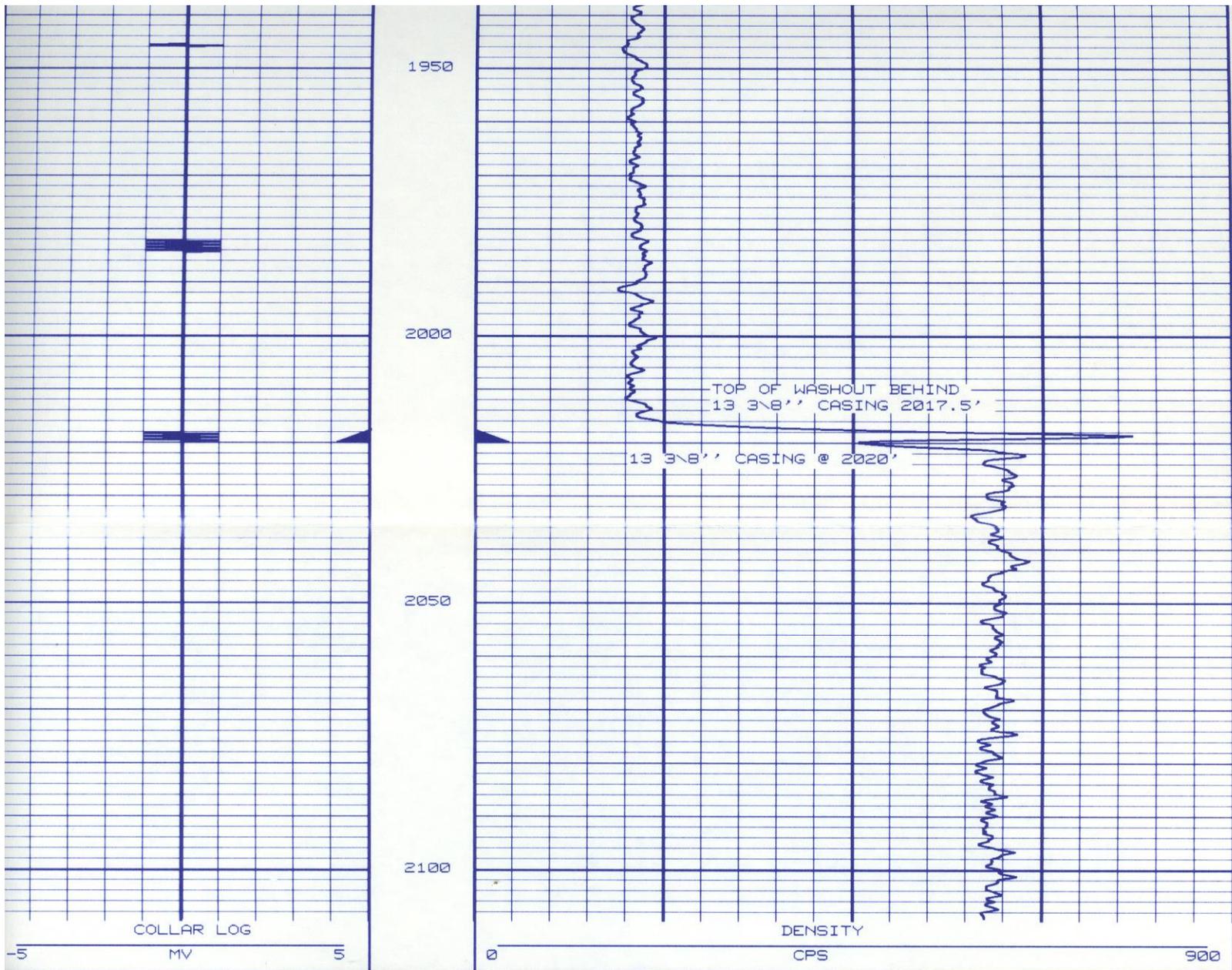
CAVERN DENSITY TOOL APPLICATION

- INTERFACE DETECTION
- CASING AND TUBULAR IDENTIFICATION
- BOTTOM OF CAVERN DETECTION
- IDENTIFICATION OF INSOLUBLES
OUTSIDE OF THE HANGING STRING
- IDENTIFICATION OF LEDGES IN BEDDED
SALT – NO EXAMPLE

CAVERN DENSITY TOOL APPLICATION

- INTERFACE DETECTION
- CASING AND TUBULAR IDENTIFICATION
- BOTTOM OF CAVERN DETECTION
- IDENTIFICATION OF INSOLUBLES
OUTSIDE OF THE HANGING STRING
- IDENTIFICATION OF LEDGES IN BEDDED
SALT
- IDENTIFICATION OF WASHOUTS BEHIND
THE CEMENTED CASING





WARREN PETROLEUM COMPANY, STORAGE WELL #15
 LOG RAN DURING WORKOVER. HANGING STRINGS OUT
 OF WELL 02-16-98

CAVERN DENSITY TOOL ADVANTAGES

- COST

CAVERN DENSITY TOOL ADVANTAGES

- COST
- SIMPLICITY

CAVERN DENSITY TOOL ADVANTAGES

- COST
- SIMPLICITY
- AVAILABILITY

CAVERN DENSITY TOOL ADVANTAGES

- COST
- SIMPLICITY
- AVAILABILITY
- WIDE RANGE OF APPLICATIONS

CAVERN DENSITY TOOL DISADVANTAGES

- RADIOACTIVE SOURCE TO PURCHASE, HANDLE, TRANSPORT

CAVERN DENSITY TOOL DISADVANTAGES

- RADIOACTIVE SOURCE TO PURCHASE, HANDLE, TRANSPORT
- INTERPRETATION

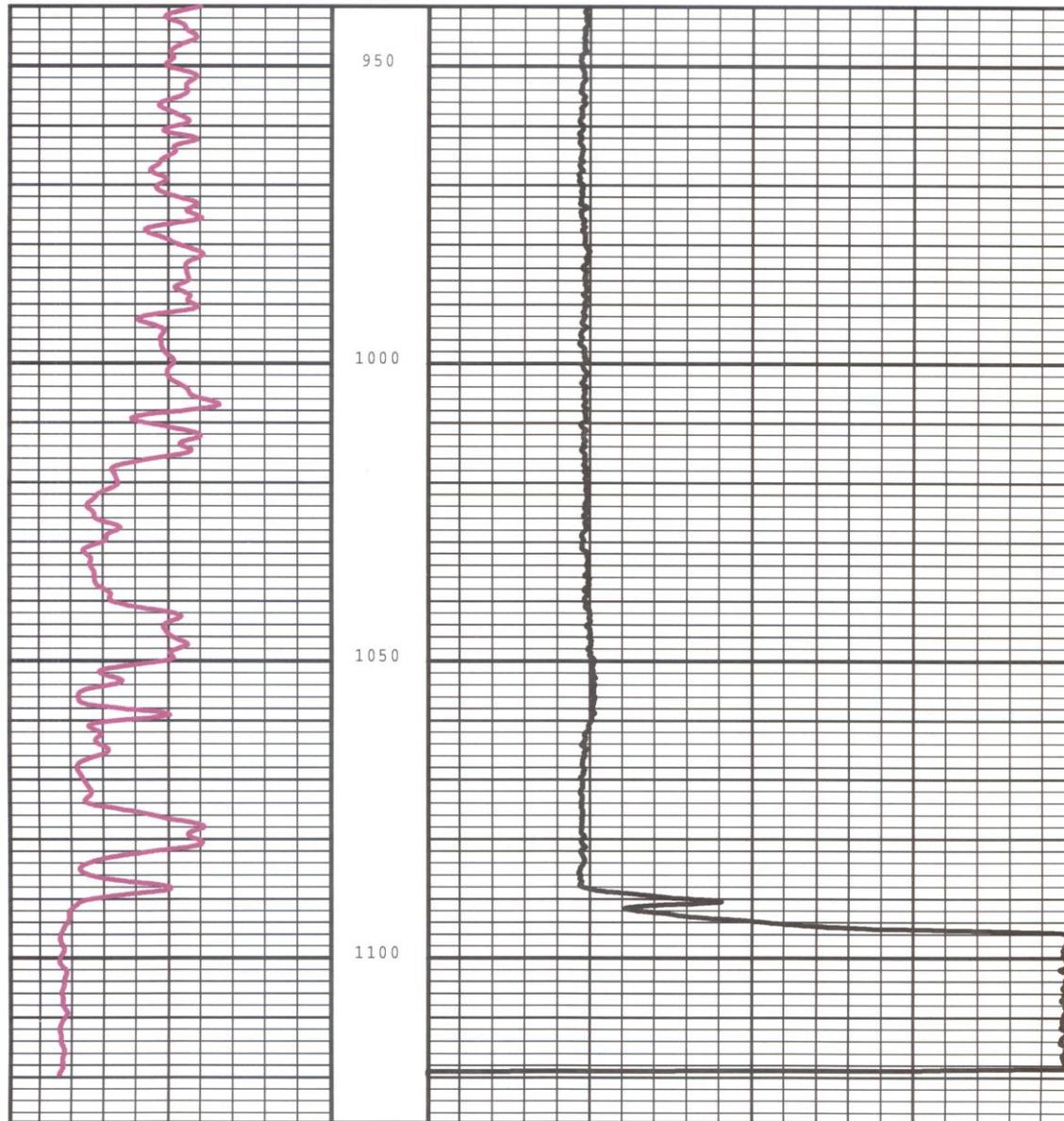
MULTIPLE STRING COLLAR LOCATOR

- THE RECENT INTRODUCTION OF THE MULTIPLE STRING COLLAR LOCATOR HAS TAKEN SOME OF THE UNCERTAINTY OUT OF THE INTERPRETATION OF THE CAVERN DENSITY LOG

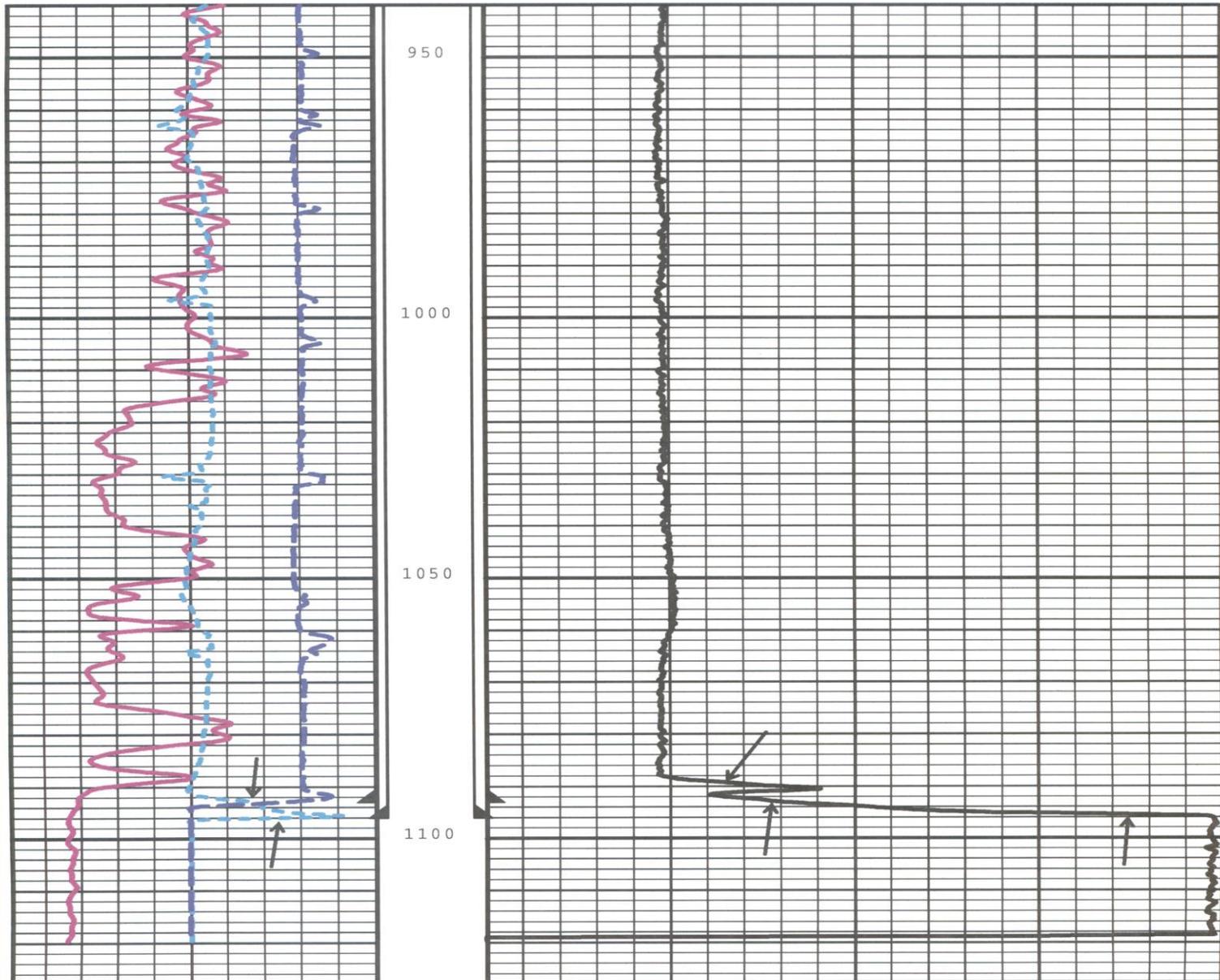
MULTIPLE STRING COLLAR LOCATOR

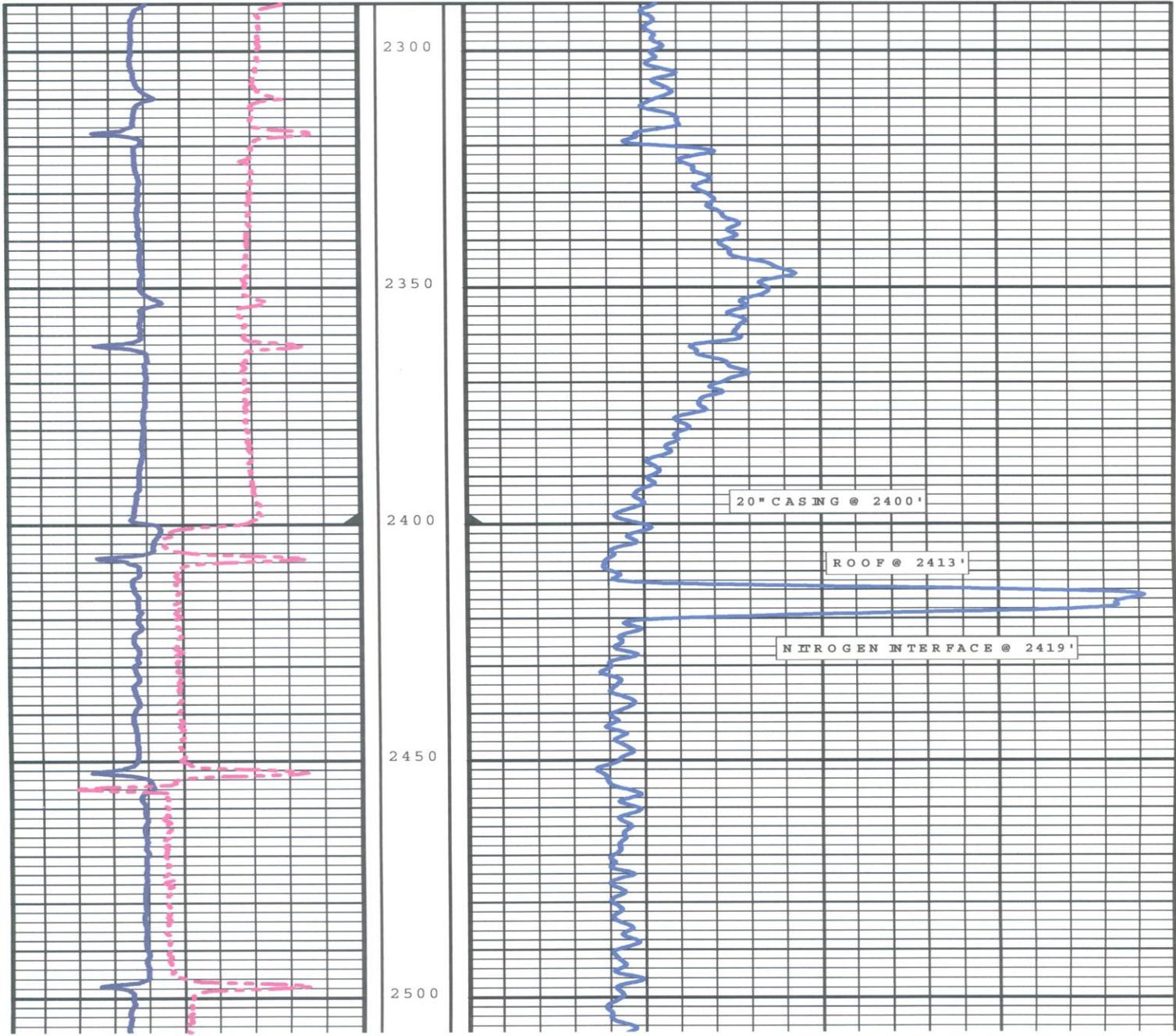
- THE RECENT INTRODUCTION OF THE MULTIPLE STRING COLLAR LOCATOR HAS TAKEN SOME OF THE UNCERTAINTY OUT OF THE INTERPRETATION OF THE CAVERN DENSITY LOG
- THE MULTIPLE STRING COLLAR LOCATOR IS A MAGNETIC DEVICE THAT CAN DETECT TUBULAR COLLARS ON TWO CONCENTRIC HANGING STRINGS AND DETECT THE BOTTOM OF THE CEMENTED CASING THROUGH ONE OR TWO HANGING STRINGS

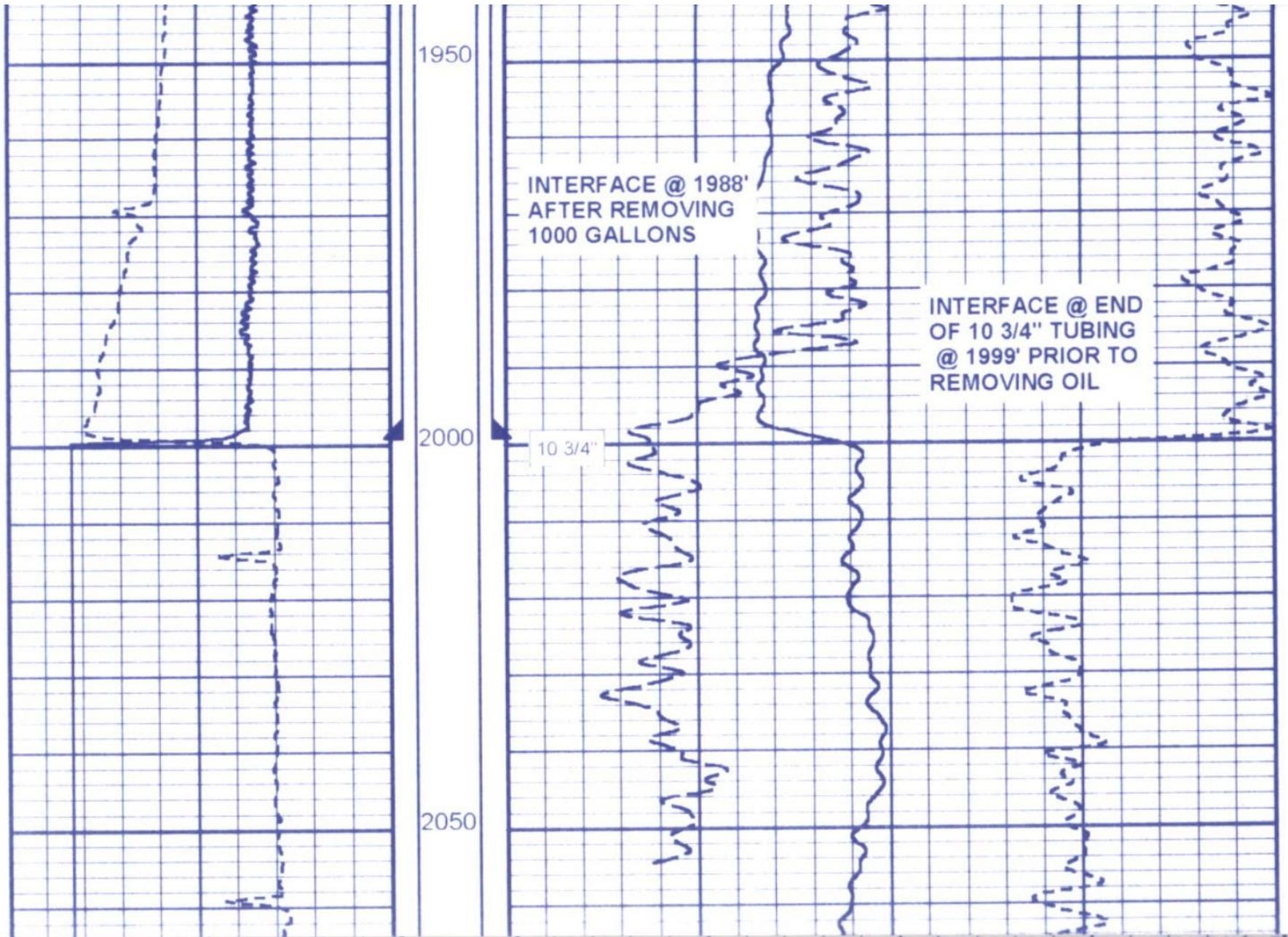
DENSITY AND GAMMA RAY LOGS WITHOUT COLLAR LOCATOR



SAME LOG WITH THE DUAL STRING COLLAR LOCATOR







CONCLUSION

- ALTHOUGH THE CAVERN DENSITY TOOL IS JUST ONE OF THE TOOLS AVAILABLE TO THE CAVERN SPECIALIST, IT IS THE MOST WIDELY USED TOOL FOR CAVERN AND WELL MONITORING
- CARE MUST BE TAKEN WHEN ANALYZING THE CAVERN DENSITY LOG, USING ALL OF THE TOOLS AVAILABLE, TO AVOID MIS-INTERPRETATION