Open File 144

A WELL LOG METHOD FOR

EVALUATING THE DEVONIAN SHALES

IN THE APPALACHIAN BASIN

by

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ABSTRACT

The Devonian Shale formations of the Appalachian, Illinois, and Michigan Basins are being studied by the Morgantown Energy Technology Center (U.S. Department of Energy) and industry (Eastern Gas Shales Project) in order to accelerate the development of the natural gas potential of the shales. Total gas resource estimates for the Appalachian Basin alone range from 3 to 2400 TCFG.

Although relatively complete well log suites have been recorded in wells drilled for characterization and stimulation research experiments, the Devonian Shale is an unconventional gas resource and the reservoir is not readily evaluated by conventional well log analysis. The economics of shale wells and the sensitivity of the shales to drilling muds require that an operator be able to evaluate a well using a minimum of well logs, preferably recorded in an empty borehole.

Log suites recorded in empty and liquid-filled boreholes have been analyzed from a total of seven wells in three states in the Appalachian Basin. Several techniques were attempted to identify gas- and kerogen-rich and naturally fractured intervals, including construction of resistivity and porosity overlays, calculation of Production Indices[1], analysis of temperature, bulk density compensation and Sibilation[1] curves. The information extracted from the logs was compared to conventional core desorption (offgas), fracture and geochemical data as well as to computer-generated synergetic logs. A suite of empty-borehole logs has been defined which will yield maximum formation evaluation data at a minimum cost.

[1]Trademarks of Birdwell

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INTRODUCTION

Since the initiation of the Eastern Gas Shales Project (EGSP) in 1975, relatively complete research suites of geophysical well logs have been recorded in EGSP-sponsored wells.

Analysis of the well logs is extremely difficult since the Devonian Shale reservoir is an unconventional reservoir and the response of the logging sondes to the kerogen, fracture systems and enclosing shale matrix is inadequately understood. There are no published charts or nomograms available for interpretation of the well log signatures, so log analysis must be conducted by comparing anomalous and/or potentially productive zones with known production/show, offgas and fracture data. The log analysis seeks to identify fractures in conjunction with gas-rich shale zones.

Sporadic analyses of some of the EGSP wells has been performed by Columbia Gas System Service Corporation (Smith, 1976), Birdwell Division of Seismograph Service Corporation (Myung, 1976) and Schlumberger (Hilton, 1977). A northern Ohio and two Lincoln County, WV wells are the only wells for which detailed log analyses are available, even though several years have elapsed since other wells were drilled and logged.

The analytical approaches taken by the two logging service companies naturally favor their respective proprietary logging tools and techniques. A practical log suite must be defined for the Devonian Shales which optimizes the amount of formation evaluation information gained in view of logging and rig time costs. EGSP researchers often hear the statement that only a gamma ray, bulk density, resistivity, temperature and a noise log are required, but there has been no previously published proof to verify the statement.

OBJECTIVES

Science Applications, Inc. (SAI) undertook this study within the Appalachian Basin with five objectives in mind. The Appalachian Basin was chosen since the greatest amount of data were available.

1. A practical log suite would be defined which would be the optimum in terms of information gained versus the cost of recording the logs. Due to the cost of rig time and logging charges, only the minimum required logs that will yield the required formation evaluation will be recorded by the majority of oil and gas operators.

2. All known manual analytical techniques for determining fractured and/or gas-rich shale zones from well logs would be applied to determine if any of the techniques are applicable to the eastern Devonian Shales.

3. The information derived from the manual log analysis would be compared to the more sophisticated and expensive computer-generated synergetic well logs to determine the utility of the synergetic logs to the commercial operator.

4. A wide area of the Appalachian Basin encompassing varying lithologies, and structural and stress regimes would be studied.

5. If feasible, a "cookbook" interpretation scheme would be recommended.

TECHNIQUES AND THEORY

Six separate log analysis techniques for locating fractured and/or gas-rich zones were applied to the shale sections of seven wells in the Appalachian Basin. Over 75,000 feet of well logs were analyzed. The well logs analyzed were both dry- and wet-hole suites, i.e. the logs were recorded in air-filled and liquid-filled boreholes. The liquid was a water and KCl solution or its equivalent.

The following log analysis techniques were utilized:

1. Porosity Curve Overlays (Dry and Wet Hole)

If available, acoustic, neutron and bulk density curves for a well were overlaid and the relationships studied. Precise porosity values cannot reliably be determined in the shales, but secondary (fracture) porosity would be indicated by comparison of the acoustic curve readings, which records only primary (matrix) porosity, to the porosity values indicated by the neutron and bulk density curves, which respond to both primary and secondary porosity.

Additional information can be gained from the porosity curves if the logs respond to gas near the borehole. The acoustic porosity values will increase, compared to nearby non-hydrocarbon bearing zones of similar lithology, and the neutron and density curves will respond in opposite directions due to the fact that the neutron tool will respond to the gas by indicating a false low porosity while the bulk density tool will indicate a high porosity.

2. Temperature (Dry-Hole)

Temperature logs respond to gas leaking from a fracture system into a borehole by recording a cooling effect on the well's geothermal temperature gradient, near the point of gas entry. A more sophisticated approach involves the calculation, by computer, of Joule-Thompson Coefficients and resultant prediction of the degree of natural fracturing, by calculation of a fracture index (Myung and Caldwell, 1977). A qualitative indication of fracturing is derived through the equations and techniques in the cited reference. Both types of temperature data were available for study.

3. Sibilation (Dry-Hole)

Sibilation logging, as referred to in this report, is a trademark of the Birdwell Division of Seismograph Service Corporation. The tool responds to several frequency bands of "noise" and is able to locate, by sound detection, the escape of gas from a fracture into a borehole. It is important to realize that both Sibilation and temperature logging will indicate the presence of fractures only if gas is present in the fracture and the fracture communicates with the borehole.

4. Resistivity Curve Overlays (Dry and Wet-Hole)

In a similar fashion to the porosity tools, the curves recorded by resistivity devices were overlaid and analyzed. The resistivity tools employed have different depths of investigation, i.e. a tool may read only the resistivity of the mudcake, or the formation immediately adjacent to the borehole, or it may read varying distances into the formation. The net result is that some shallow-reading resistivity devices (Laterolog[1], Microlaterolog[1]) will respond to vertical, mud-filled fractures, while deeper-reading induction tools will not respond and will read a higher value of resistivity. Ideally, the curve separation will be apparent in a fractured interval, while the curves will not separate as much and will track each other in a non-fractured interval. This technique is a "quick-look" method and must be used with care and in conjunction with other techniques.

[1]Trademarks of Schlumberger

5. Production Indices (Dry Hole)

Production Indices (PI) as referred to in this paper are a development of Dr. John I. Myung of Birdwell Division of SSC (Myung, 1976).

Potential pay zones and fracturing may be indicated by an increase in gamma-ray intensity and resistivity due to the presence of kerogen, other organic matter, and gas-filled fractures and an accompanying decrease in bulk density due to the lower bulk density of kerogen and/or the presence of fractures which would appear as increased porosity.

This relationship, the Production Index, may be expressed mathematically as

$$\text{Production Index (P.I.)} = \frac{G + R}{D_b}$$

Where: $G = \dfrac{\text{API units from gamma ray log}}{\text{Average API units of Shale}}$

$R = \dfrac{\text{Resistivity from induction log}}{\text{Average Resistivity of Shale}}$

D_b = The bulk density value from a Density Log

The average values must be chosen for each well. Production Indices for this study were calculated on two foot intervals. The P.I. may be proportionally related to the number of gas productive fractures in a shale formation (Myung, 1976).

Production Indices were calculated for five of the seven wells. The remaining two wells had the Indices previously calculated by Birdwell on their Com-Pro Log[2].

6. Delta Rho (Dry Hole)

The final technique employed in this study was to analyze the delta rho or bulk density compensation curve to locate zones where the compensation increased while the caliper showed a uniform borehole. The increase in compensation may be due to the effects of fracturing communicating with the borehole. If the caliper indicates a washed out borehole and the compensation increases, a fracture system may be present and the borehole may be washed out as a result of the fracture. Because of this ambiguity, the delta rho technique is a "quick-look" method and

[2]Trademark of Birdwell Division of Seismograph Service Corporation

not a firm indicator of fracturing.

All six of these techniques were applied to all of the study wells, if the logs had been recorded.

As previously stated, the log analysis of the Devonian Shales must compare log data to known fracture, production and offgas data in order to identify the log signature for fractured, gas-rich zones.

This study employed data from Columbia Gas Service Transmission Corporation (Ranostaj, et al, 1976), the continuing monthly and quarterly reports of data generated by Battelle Columbus Laboratory and Mound Facility, reports compiled by DOE/METC (Byrer, et al, 1976; Komar, et al, 1978) and SAI (Kucuk, et al, 1978) and fracture data generated by C. S. Dean and B. Kulander (Dean, 1979).

The evaluation of the utility of each of the six previously mentioned techniques was determined by analysis of well logs from the following wells:

Columbia Gas #20337, Martin County, KY
Columbia Gas #20338, Wise County, VA
Columbia Gas #20401, Lincoln County, WV
Columbia Gas #20402, Lincoln County, WV
Consolidated Gas #11940, Jackson County, WV
Consolidated Gas #12041, Jackson County, WV
Reel Energy D/K Farm # 3, Mason County, WV

A discussion of each technique's utility follows.

DISCUSSION OF RESULTS

Each of the six analytical techniques are discussed separately. The uniformity or non-uniformity of the result of each technique is compared among the study wells. Each technique is compared to production, core fracture, offgassing, and carbon content data where it is available. Supporting figures are presented for each technique. These figures are intended to demonstrate what the expected curve responses should be in a gas-filled fracture system and what responses were actually observed in the study.

Examples from the study wells were chosen for discussion of each technique. The well log analysis results for all the study wells are presented in Appendix A.

Porosity Curve Overlays

This technique involved the comparison of acoustic, neutron porosity, and bulk density curves. This analysis was performed to determine if secondary porosity (fractures) and gas accumulation could be identified in the shales. Secondary porosity might be indicated by a constant acoustic porosity reading through an interval while the neutron and bulk density curves indicate higher porosity values through that interval. Gas accumulation may be indicated by an anomalous curve deflection toward lower porosities in the neutron curve and a deflection toward higher porosity in the bulk density and acoustic curves. Figure 1 is an example of the "gas effect" on these curves in a sand-silt interval.

The analysis for secondary porosity was performed on three of the seven wells (DK#3, #20402, and #20401). These three wells were the only wells with a complete suite of acoustic, neutron, and bulk density curves. No zones were found in which the acoustic curve remained constant and the neutron/bulk density curves indicated higher porosities. For example, natural fractures were identified through core examination of the D/K #3 well in the interval 2859-2875 feet (Dean, 1979). Through this interval, the three porosity curves show no response that would indicate secondary porosity (fractures). Figure 2 shows this interval and the response of the curves. The absence of curve signatures indicating the presence of fractures was typical throughout the D/K#3 well and the other two wells.

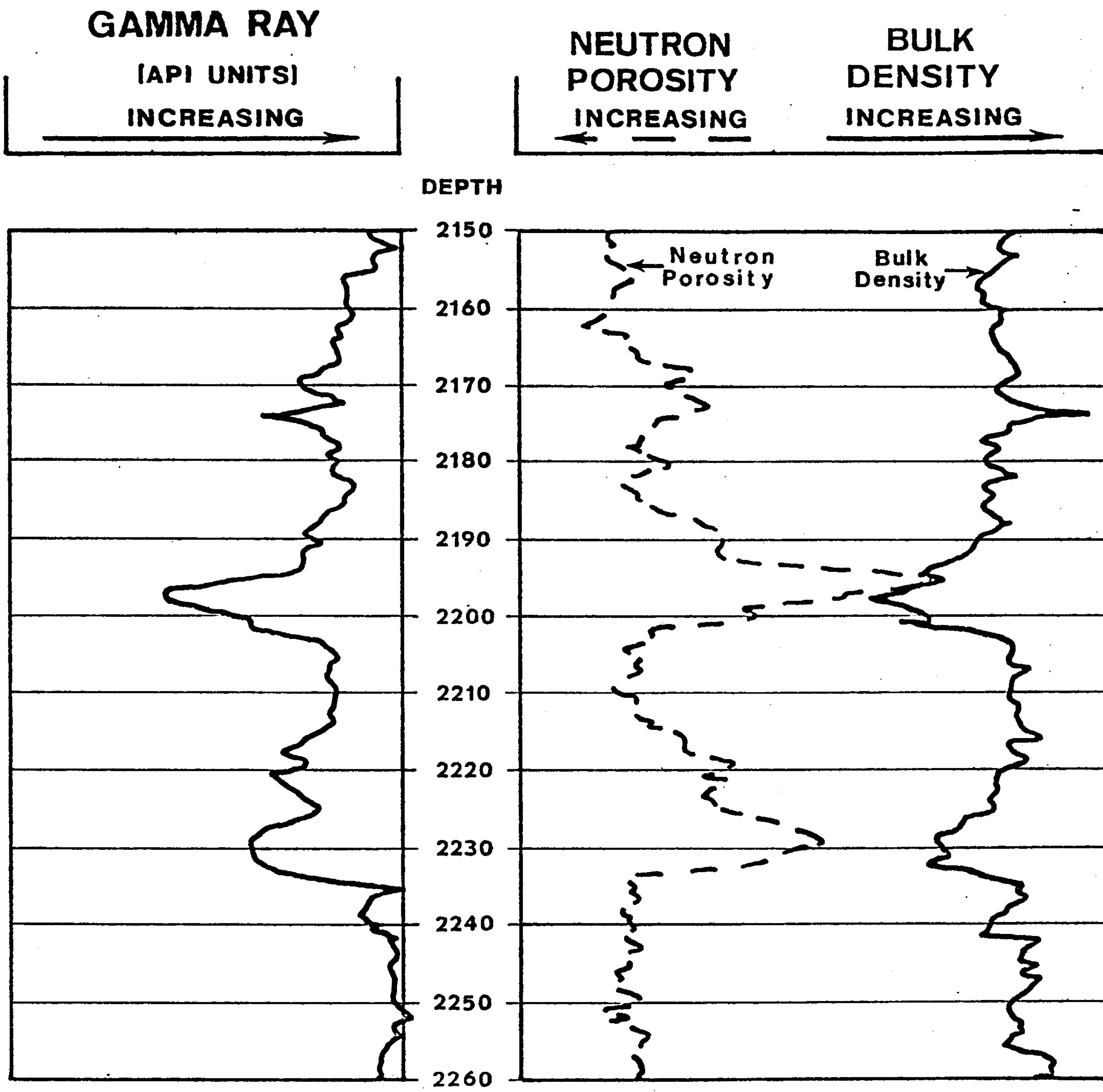

Figure 1. Well #20337 showing a typical example of curve deflection ("gas effect") on the neutron and bulk density curves in a sand-silt zone.

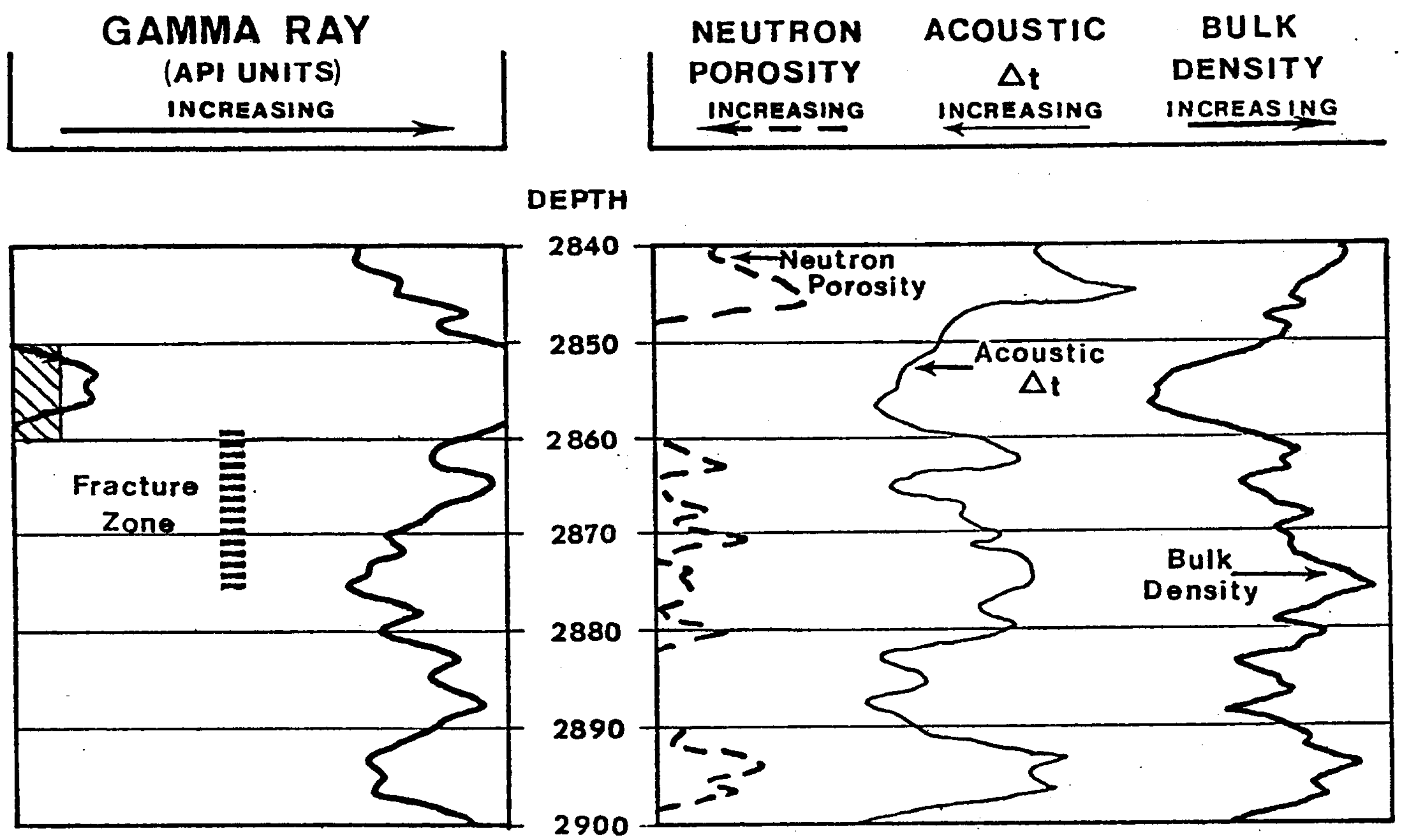

Figure 2. Well D/K#3 showing an example of how porosity curve overlays do not respond to indicate a zone of known fractures.

Six of the seven study wells were analyzed for the effect of gas on the neutron and bulk density curves. Well # 12041 did not have a neutron porosity survey run so it could not be included in the analysis. Wells #20337 and #11940 were the only two wells where the anomalous deflection (gas effect) of the porosity curves was observed in the shales. In Well #20337 three zones (2530-2610 feet, 2758-2904 feet, and 3094-3267 feet) and in Well #11940 two zones (3426-28 feet and 3450 feet) were identified as exhibiting the anomalous deflection. Figure 3 is an example of this deflection in Well #20337. The interval 3094-3267 feet in Well #20337 was stimulated, but the after stimulation data was not available. No other intervals displaying this effect were stimulated. Examination of the core from Well #11940 found one fracture in or near each of the two zones showing the "gas effect" on the curves. No core was taken in Well #20337.

If the anomalous deflection of the porosity curves observed in Wells #20337 and #11940 is really the result of gas accumulation in fractures, it is difficult to explain why this effect was not observed in any of the other wells. This problem certainly warrants further consideration.

Temperature Curves

Temperature surveys are utilized to identify zones where the liberation of gas into the borehole results in a cooling effect (temperature kicks). It is generally believed that the gas is released through fractures that are in communication with the borehole.

Analysis of temperature curves was performed on all seven study wells. Two of these wells (#20337 and #20402) had computer generated Joule-Thompson Coefficients that were used to derive a thermal fracture index. This index is used as a relative indicator of fracture size based on the degree of cooling of the gas entering the borehole.

It is obvious that inspection of the temperature curve can give the quickest indication of gas accumulation if it is in communication with the borehole. In many cases, a "cooling kick" on the temperature curve was the only criteria used for stimulating an interval. In Well #20337, the zone from 3526 to 3574 feet was investigated. Analysis of all available logs and application of the techniques of this study over this zone showed indications of gas accumulation and fracturing as evidenced by a

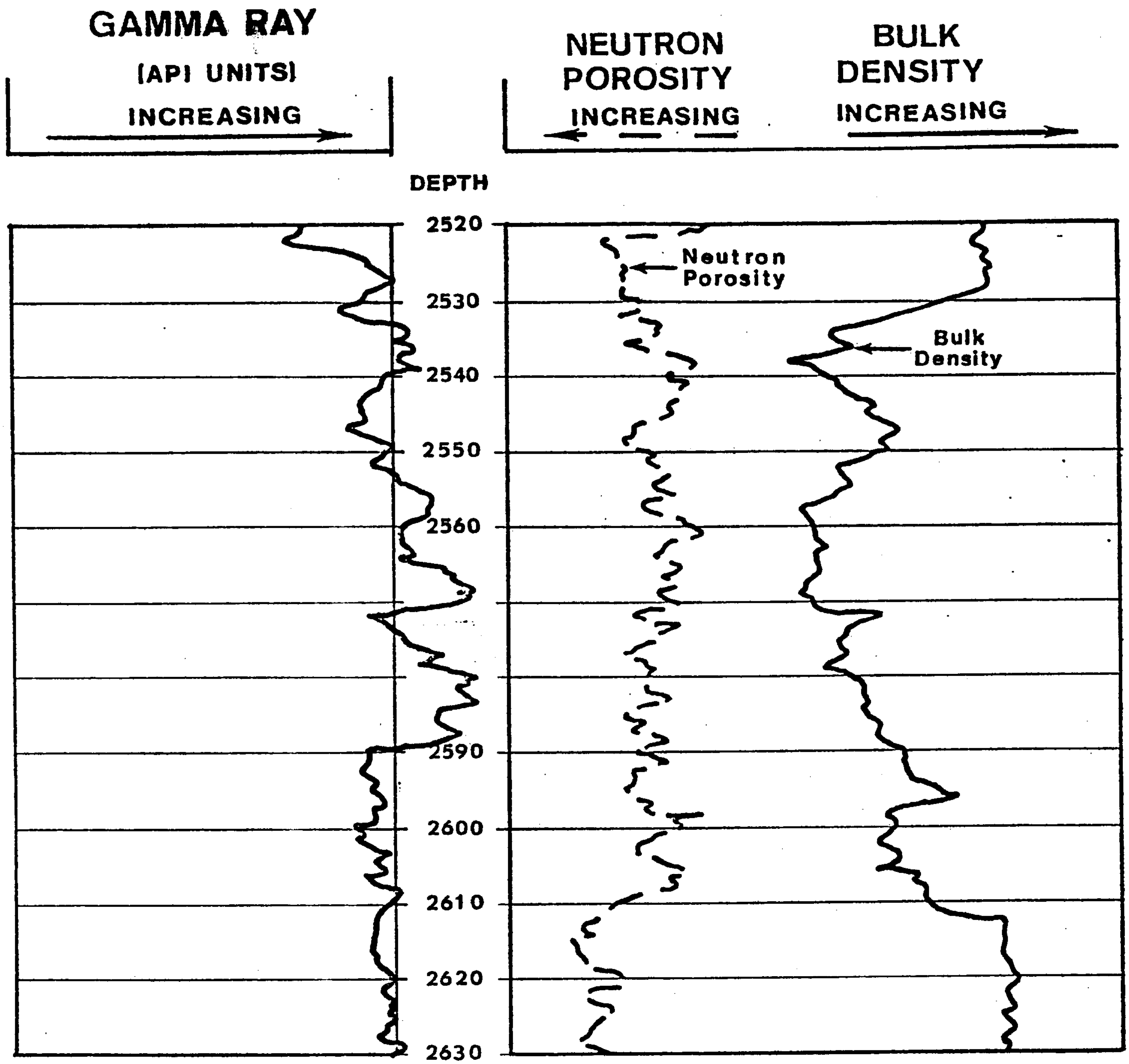

Figure 3. Well #20337 showing an example of curve deflection (possible "gas effect") on the neutron and bulk density curves in a shale zone.

"cooling kick" on the temperature curve. Based on the temperature kick and possible Sibilation kick, the zone was stimulated (Figure 4). Before stimulation production was zero MCFG/day and after stimulation was 133 MCFG/day.

The temperature curve is a good tool for the analysis of the shales as long as the natural fractures are in communication with the borehole. In one study well, #20338, inspection of the temperature curve showed no obvious "cooling kicks" yet two zones were stimulated (4890-4910 feet and 5450-5480 feet). Before stimulation results were zero MCFG/day for both zones and after stimulation results were 40 MCFG/day and 107 MCFG/day respectively. The absence of "cooling kicks" through these two zones may be the result of the borehole not encountering a fracture system but the fracture system could be penetrated and enlarged through stimulation. Fracture data from core analysis were not available to determine if fractures were encountered in the well in the two stimulated zones.

Sibilation Curves

As discussed above, the Sibilation survey is run to "listen" for gas being liberated into the borehole. Typically, the Sibilation survey is run in conjunction with the temperature survey. It should be expected that with a "cooling kick" on the temperature curve there should be a corresponding "noise kick" on the Sibilation curve, thus providing an additional tool for locating gas accumulation and fracture systems.

Six of the seven study wells had Sibilation curves available for analysis. A typical example of the Sibilation/temperature response to gas liberation into the borehole is shown in Figure 5. This example was taken from Well #20402 and includes the interval from 3340 to 3420 feet. The laboratory analysis of the core from this interval indicates offgassing of approximately 1.2 cu.ft.gas/cu.ft.shale and organic carbon content ranging from approximately 3.5 to 4.8 percent. Examination of the core indicates open fractures through this interval. These fractures may have been induced during the coring operations. Before stimulation test data was zero MCFG/day and after stimulation data was 112 MCFG/day. In Well D/K#3, several zones were identified as potentially gas productive based on "noise kicks" in the Sibilation curve but the corresponding "cooling kick"

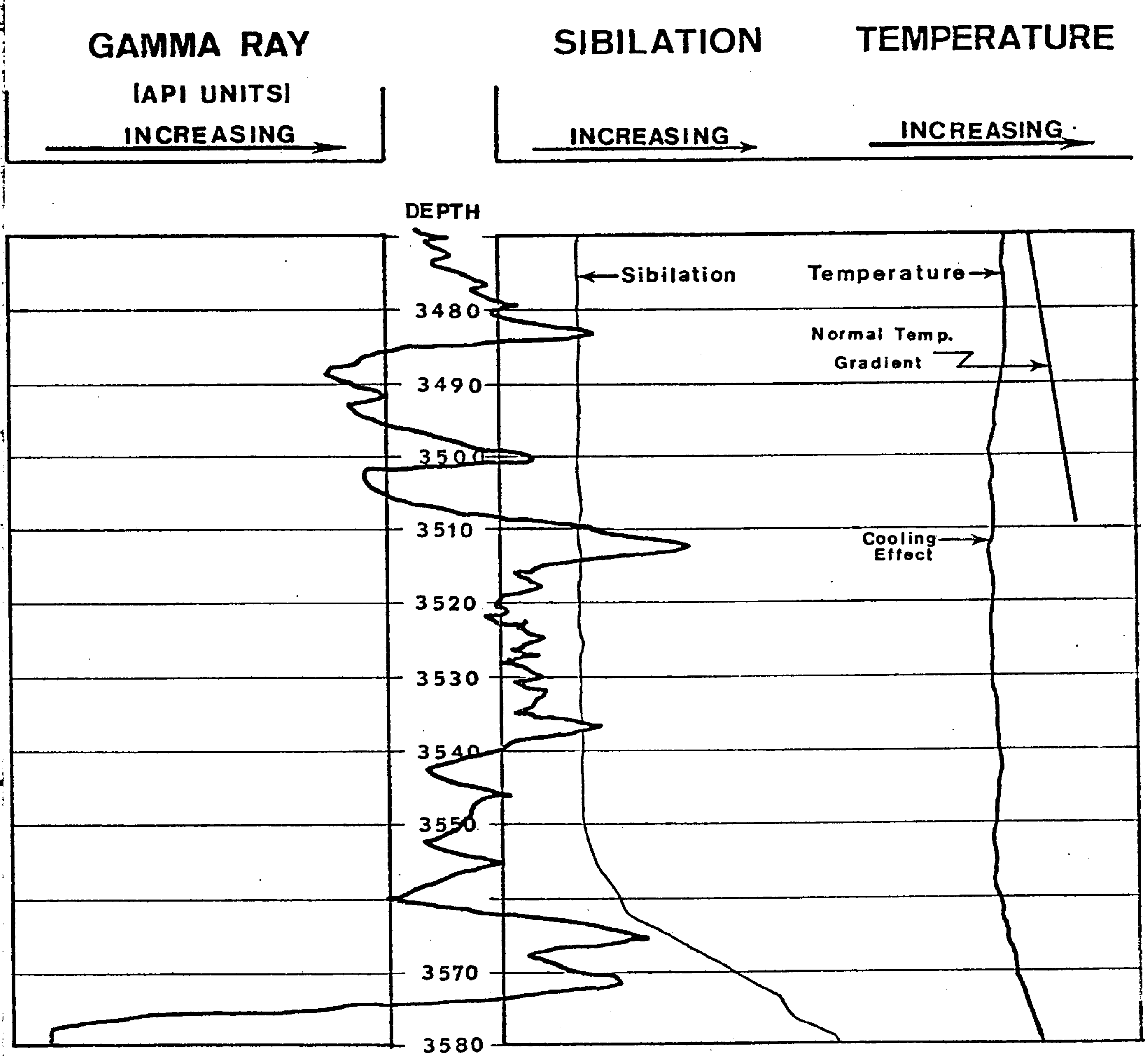

Figure 4. Well #20337 showing an example of temperature curve deflection ("cooling effect") with possible Sibilation curve kick through a zone which tested 133 MCFG/day after stimulation.

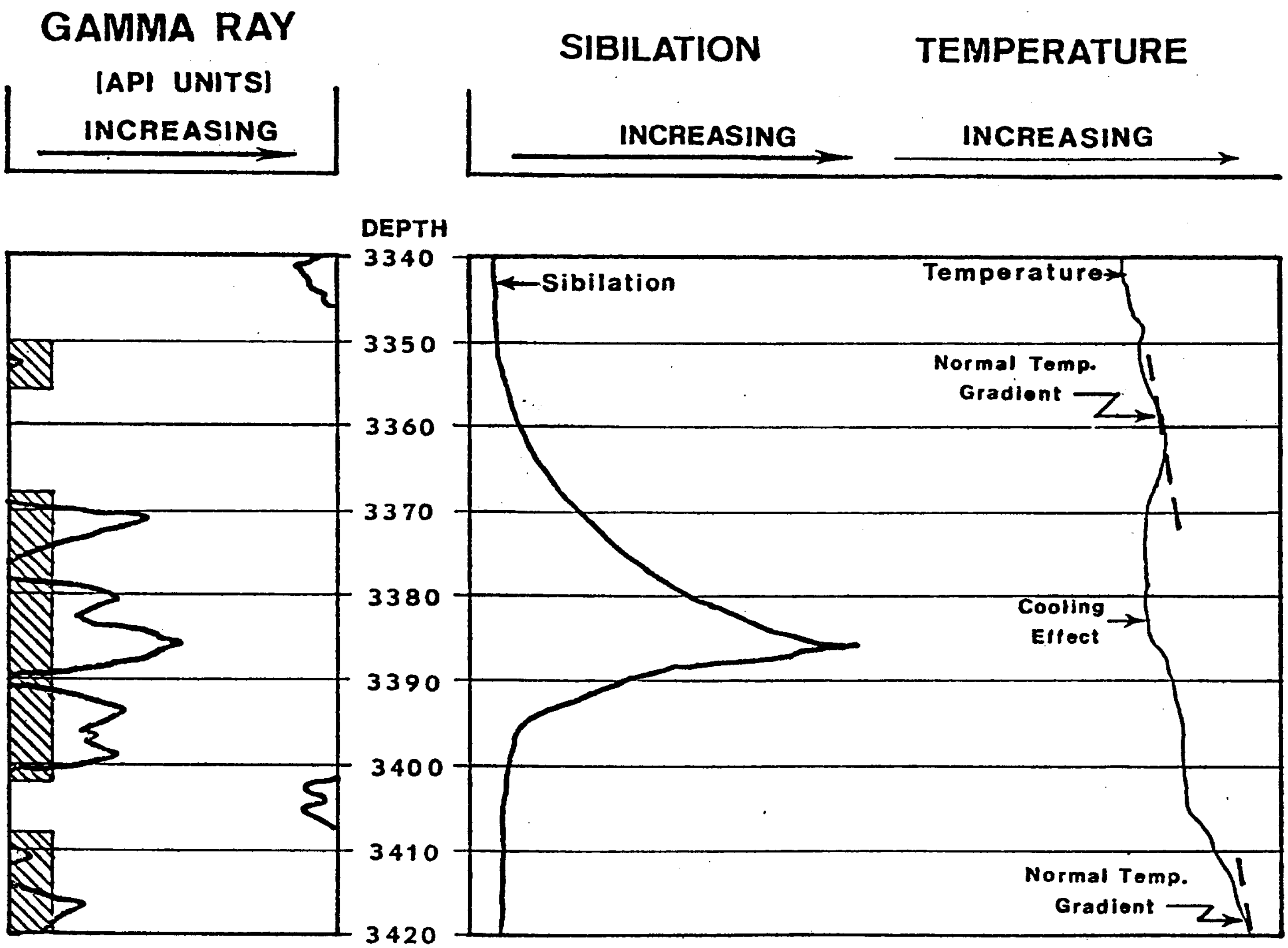

Figure 5. Well #20402 showing an example of Sibilation and temperature curve response to gas entering the borehole.

on the temperature curve was not apparent (Figure 6). Also, in Well D/K#3, a very good "cooling kick" was apparent through a zone from 2730 to 2820 feet but on the Sibilation curve there was only a marginal or no apparent response through the zone (Figure 7). This problem was also found in Well #20337 through the zone 3526 to 3574 feet. It should be noted that in Well #20337, the zone 3526 to 3574 feet was stimulated and after stimulation results show a 133 MCFG/day gas potential. Corresponding Sibilation and temperature kicks on the logs are certainly good evidence for gas accumulation and fractures but zones where either one of the two curves do not respond still warrant further evaluation.

Resistivity Curve Overlays

The purpose of this technique is to identify zones of increased porosity (fractures) as indicated by separation of a shallow investigation resistivity curve from a deep investigation resistivity curve or curves.

Three of the seven study wells have the appropriate logs available for this analysis (#20402, D/K#3, and 20401). Well #20402 was the only well where separation of the resistivity curves was apparent. In this well, these zones are located at 3370 to 3381 feet and 3392 to 3400 feet (Figure 8). These zones were also characterized by Sibilation and temperature kicks. Examination of the core indicates open fractures through the two zones. Offgassing values of 1.2 cu.ft. gas/cu.ft.shale and relatively high organic carbon content range from 3.5 to 4.8 percent were determined for the two zones. Before stimulation testing indicated zero MCFG/day and after stimulation 112 MCFG/day.

Examination of the D/K#3 well core indicates several zones of fracturing, yet the resistivity curves show no apparent separation.

Based on the limited number of wells available for the resistivity tool overlay analysis, it appears that this technique gives very limited indications for the location of fractures. Additional wells with the appropriate resistivity logs and cores are needed for a more conclusive analysis of this technique.

Production Index

Production Indices were calculated or previously computer generated for all seven study wells. The future value of using Production Indices as a relative indicator of potential gas production will require many more

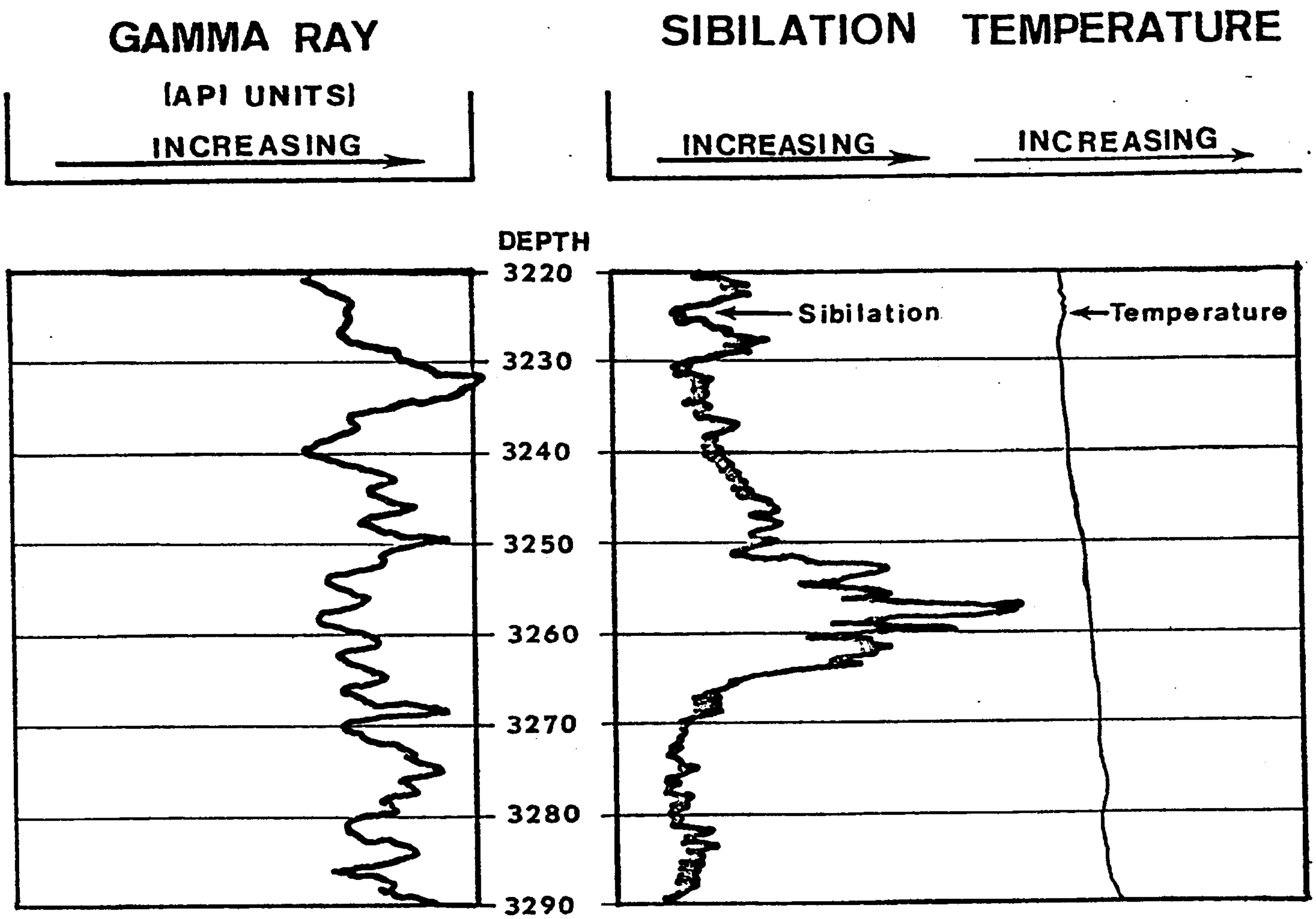

Figure 6. Well D/K#3 showing Sibilation curve response and no corresponding temperature curve response to gas possibly entering the borehole.

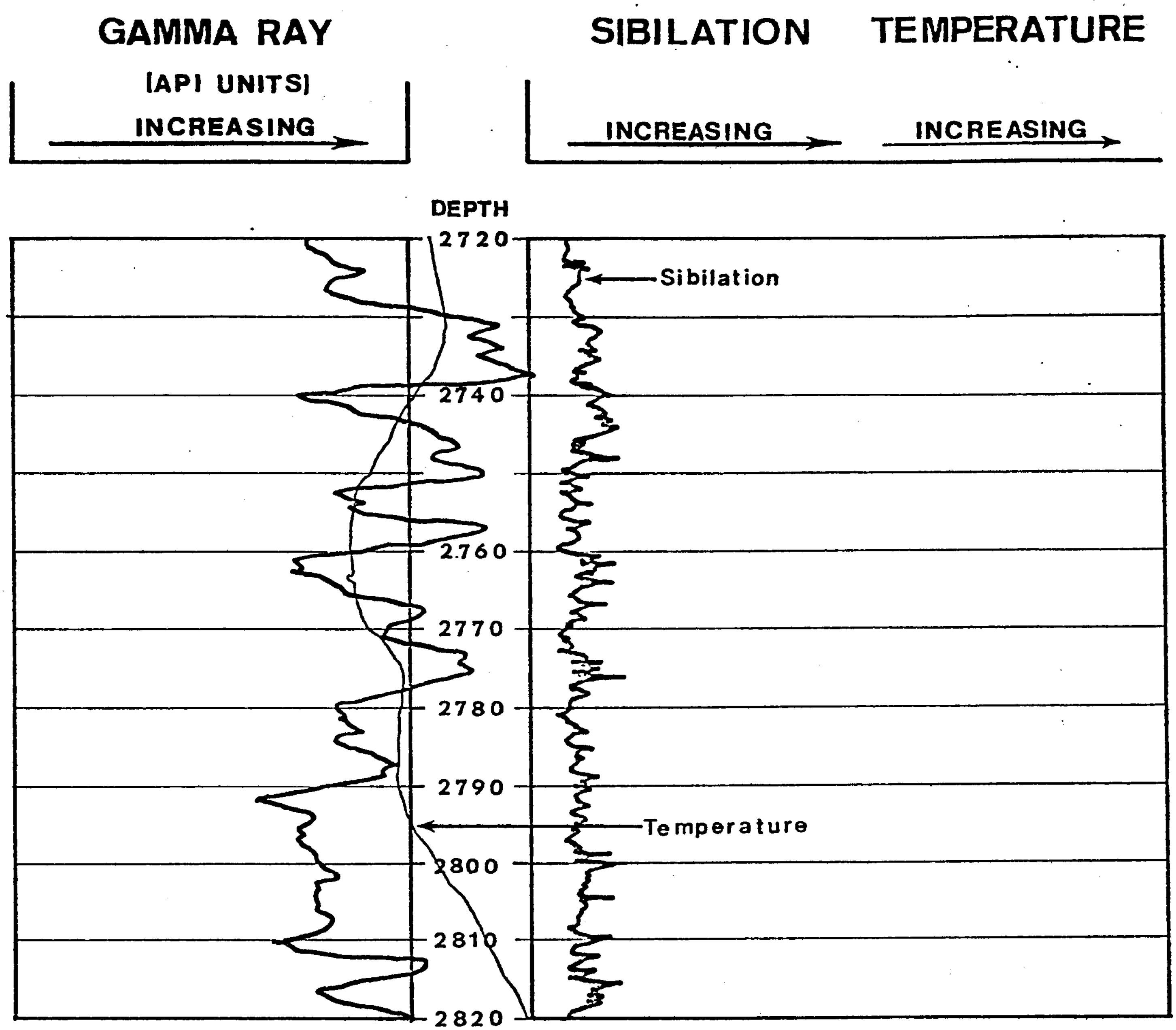

Figure 7. Well D/K#3 showing an example of a good temperature curve kick with little or no response on the Sibilation curve.

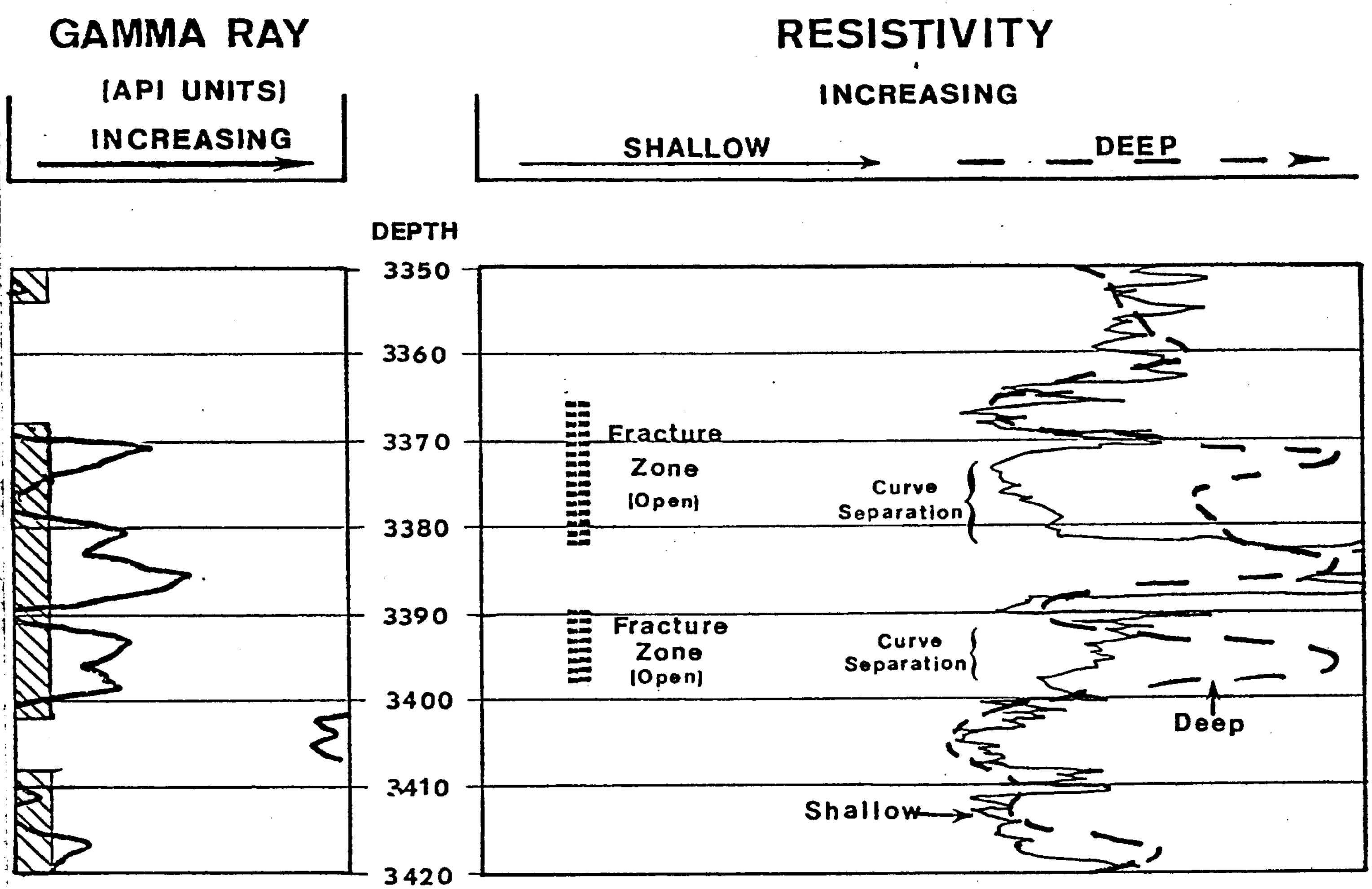

Figure 8. Well #20402 showing an example of shallow and deep resistivity curve separation through a possible zone of fractures. After stimulation testing results were 112 MCFG/day.

comparisons of actual production from zones where the indices have been calculated. Several zones were identified with high indices but were not stimulated. In the wells used in this study, the Production Indices in zones that were stimulated were greater than 0.5 and ranged to a maximum of 2.5. In well #20338, the zone 5354 to 5480 feet was stimulated. The Production Indices through this zone range from 1.0 to 2.5 (Figure 9). After stimulation tests indicated the potential for gas production at 54 to 107 MCFG/day.

Delta Rho

This technique is generally considered as a "quick look" method of identifying possible zones of fracturing. In this study, six wells had the appropriate delta rho compensation curves available for analysis. The initial evaluation of the utility of the delta rho curve as a fracture indicator requires the comparison of the curve to actual core intervals.

In most cases, the delta rho curve did not indicate zones of fracturing even in zones where the Sibilation and temperature curves responded to gas and where fractures were indicated by core examination. In the D/K#3 well, one zone was found (3190-3270 feet) where the delta rho curve response may indicate fracturing that was found in the core (Figure 10).

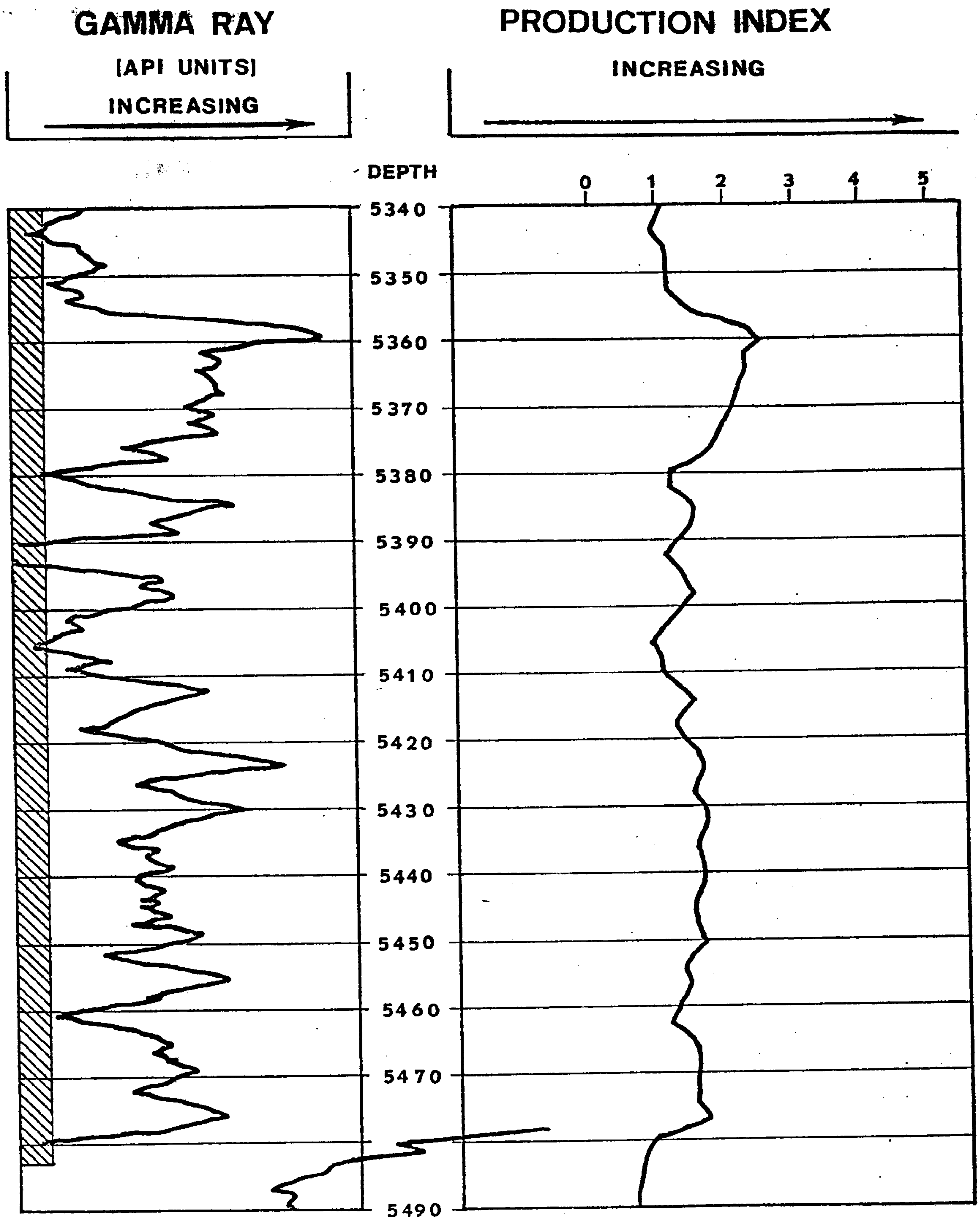

Figure 9. Well #20338 showing an example of Production Index increase through a zone which tested 54 to 107 MCFG/day after stimulation.

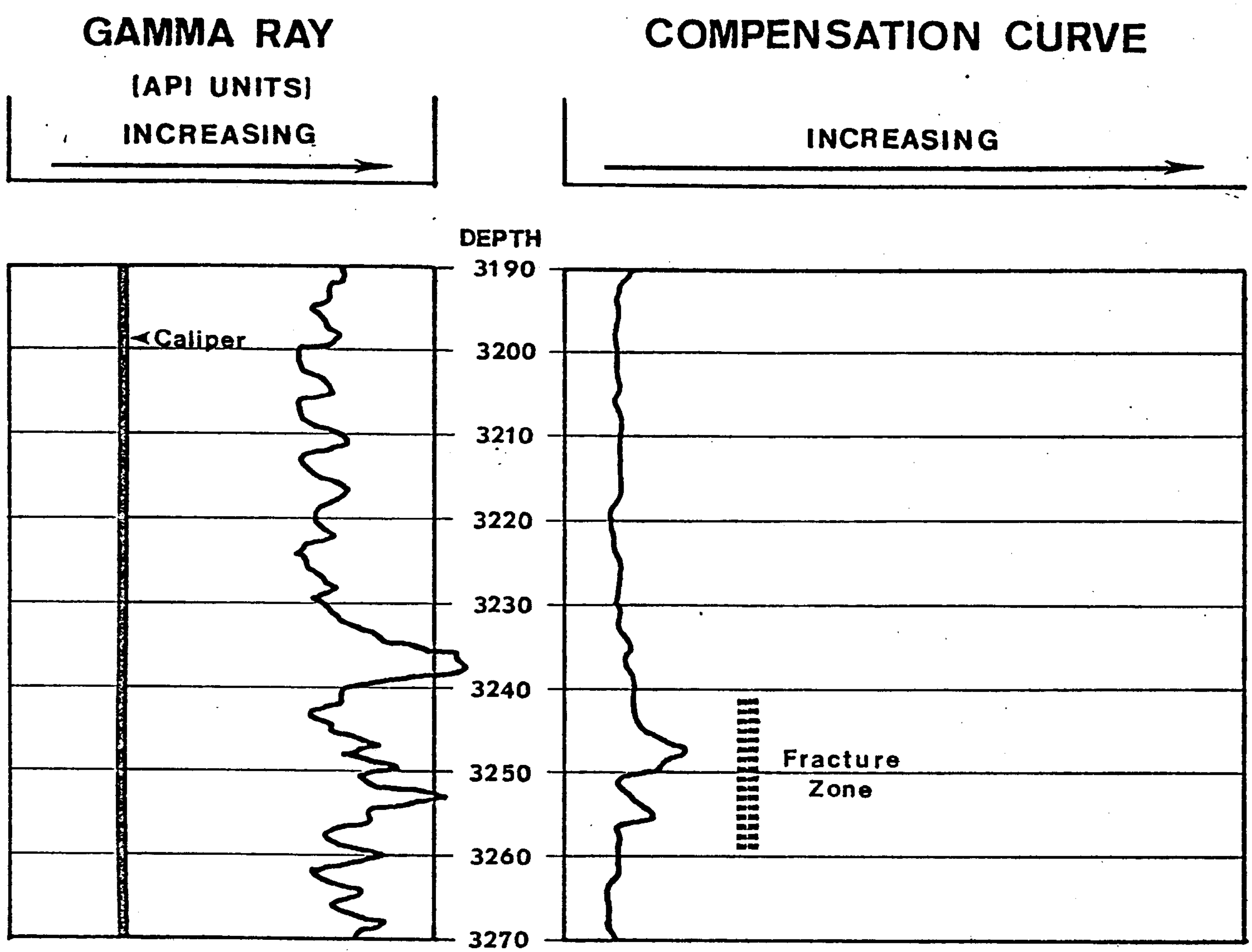

Figure 10. Well D/K#3 showing an example of delta rho compensation increase through a zone of known fractures.

SUMMARY OF OBSERVATIONS

- Detailed analysis of the wet-hole logging suite for the study wells and the computer-generated synergetic logs (D/K#3 and 20402) did not yield any more information on the location of gas accumulation and/or fractures than did the dry-hole suite.
- The analysis of temperature and Sibilation curves provide the quickest and perhaps the most dependable evidence for locating gas-filled fracture systems in communication with a borehole.
- The porosity curve overlays, resistivity curve overlays, Production Indices, and delta rho techniques provide limited and inconsistant evidence for gas accumulation and fractures.
- Due to the variability and undependability of the various curve responses and techniques, the formulation of a "cookbook" method for the well log analysis of the Devonian Shales is not possible.
- The most practical and economical suite of logs that will provide sufficient data for the analysis of the shales is:

  Gamma ray
  Compensated bulk density
  Induction
  Temperature
  Sibilation

RECOMMENDATIONS

- In order tc update the data and observations of this report, it is recommended that the complete research suite (wet- and dry-hole) of logs continue to be run in future Eastern Gas Shale Project wells where appropriate. The Fracture Identification Log[3] should be included in the research suite. Only one well had this log recorded (D/K#3) and future investigation of the utility of it is needed. C. S. Dean and B. Kulander will be publishing a paper comparing the log to the core analysis.
- In the log analysis of any one Devonian Shale well, the complete suite of available logs should be used in the evaluation. All six

[3] Trademark of Schlumberger

techniques should be employed to generate the maximum amount of information, prior to selecting zones for stimulation. Post-stimulation, production data should be compared to the log analysis in order to refine the log analysis.

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APPENDIX A

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Appendix A contains the summary of the log analyses and technique evaluations for the seven wells used in the study. A blank space in the matrix indicates that the log was not recorded and/or other data was not available.

Well No. 20337

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
2530-2610	X	--	--		X	--				
2758-2904	X	--	--		X	X				
3094-3267	X	X	--		X	X		0/NA 3100-3250		
3526-74	--	X	X		X	--		0/133 3526-3574		

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

— - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. 20338

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
4782-4796	--	--	--		X	--				
4842-4940	--	--	--		X	--		0/40 4890-4910	X	X
5034-5086	--	--	--		X	--				
5354-5480	--	--	--		X	--		0/54-107 5450-5480	X	X
5554-5562	--	--	--		X	--				
5664-5676	--	--	--		X	--				
5624	--	X ?	--		--	--				

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

— - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. 20401

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
2982-2994	--	--	X	--	--	--				
3081-3087	--	--	X	--	--	--				
3194-3212	--	--	--	--	X	--				
3238-3490	--	--	--	--	X	--				
3266-3314	--	curve quality (?)	X	--	X	--				
3382-3450	--	curve quality (?)	X	--	X	--				
3818-3840	--	--	--	--	X	--				
3854-3878	--	--	--	--	X	--				

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

__ - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. 20402
1 of 2

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
3072-3089	--	X		--	--	--	--	X	X	--
3084-3092	--		X	--	--	--	--	0/145 2816- 3204	--	
3368-3412	--	X	X 3370- 3390	X 3370-81 3392-3400	X	--	X open	0/112 X 3386-3966	X	X
3440-3458	--	X	X 3440-60	--	X	--	X open		X	
3514-3543	--		X	--	X	--	X open		X	
3525-3554	--	X		--	X	--	X open		X	X
3570-3590	--	X 3580-92	X	--	X	--	X		X	
*3774-3800	--	X 3784- 3801	X	--	--	--				
3806-3809	--	--	--	--	--	X				
3156-58	--	--	--	--	--	X				

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

— - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-
3640- Interval

Well No. 20402
2 of 2

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
3208-10	--	--	--	--	--	X				
3230-32	--	--	--	--	--	X				

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

__ - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. 11940

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
3426-28	X	--		X		X				
3450	X	--		X		X				
3650-3846	--	X		X		X				
3877	X	--		--		--				

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

__ - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. 12041

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
3070-3216*		Bad temp	--		--	X				
3225-3348			--		--	X		3228-3273 ?		
3412-3414			X		--	X				
3454-3634			--		X	--		0/173 3483-3640		
*caliper good to 3190 feet										

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

__ - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval

Well No. D/K#3

ZONE	POROSITY OVERLAYS	TEMPERATURE	SIBILATION	RESISTIVITY OVERLAYS	PRODUCTION INDEX	DELTA RHO	FRACTURE DATA	PRODUCTION DATA	OFFGAS DATA	ORGANIC CARBON DATA
2735-2845	--	X	X ?	--	X	--	X		X	X
2894-2921	--	--	X	--	X	--	X	0/0 2730-3042	X	X
3044-47	--	--	X	--	X	--	--		X	X
3082-93	--	--	X	--	--	--	--		X	X
3190-3270	--	--	X	--	--	X	X		X	X
3302-80	--	--	X	--	X	--	X		X	X

LEGEND

X - curve response or correlation with fractures, off-gassing, or carbon content data

__ - No curve response or correlation

0/173 Before and after stimulation results in MCFG/day

3483-3640- Interval