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The Potential of Enhances Oil Recovery in Mississippi Volume 1

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Volume I

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The Potential of Enhanced Oil Recovery in Mississippi

Volume I

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SUMMARY

The oil industry had its beginning in Mississippi in 1939 with the Tinsley Field. Severance taxes have subsequently yielded a cumulative revenue for Mississippians of approximately $800 million from the production of its oil alone; cumulative gas severance tax revenues have added another $350 million since that tax began in 1948. Although Tinsley still produces 48 years later, it is symbolic of many old fields in Mississippi, and to some extent, to the state's overall oil production. For the state's production peaked in 1971; its tax revenues peaked in 1981. From a high of $66,000,000 in tax revenues from oil production in 1981 to a 1986 value of $24,000,000, the state's prosperity has been seriously affected by the decline; it has made us more aware of the importance to Mississippi of this non-replaceable, valuable natural resource.

This study undertook to determine the quantity of incremental production (that which would not otherwise occur) under scenarios of various crude oil prices, profitabilities of companies, and state incentives; incremental revenues to the state were predicted. Computer programs developed by DOE and the National Petroleum Council were used. A current database for Mississippi reservoirs was established. (The only such computer file in the state.) Data of 1315 reservoirs were assimilated and put in the file. The database was used to estimate incremental oil possible from five tertiary processes: carbon dioxide, polymer, in situ combustion, steam, and chemical floods.

This study shows that enhanced oil recovery, particularly from carbon dioxide miscible flooding, can have a substantial impact on the economy of the state. Furthermore, companies investing in the process could realize an attractive rate of return. The naturally occurring CO_2 reserves of the state provide an incentive to this process development.

Some of the economic benefits solely from the carbon dioxide process were determined to be as follows. (1) Gross sales of incremental oil could range from $500 million, net present value, at $30 per barrel to $1.5 billion at $50 per barrel. (2) as much as $45 million (present value) of additional severance taxes could be collected by the state from incremental oil. (3) $50 million of additional corporate income taxes could be realized by the state on incremental oil. (4) Capital investments in CO_2 projects could amount to $82 million in the peak year. (5) $62 million of operating expenditures would be expected in the peak year. (6) Mineral right owners of the state could expect at least $60 million of royalty payments, as present value, from incremental oil from the CO_2 process.

A pipeline network to distribute carbon dioxide to the oil fields of south Mississippi would be a primary need. Research to characterize the reservoirs for CO_2 injection would be needed. The rewards to the state and industry are such that all incentives should be investigated.

INTRODUCTION

Cumulatively, $800 million of severance tax revenues have been collected from oil production in Mississippi since 1944. This amount is in addition to other intangible benefits to the state's economy as well as $350 million of revenues from the production of natural gas. The figure emphasizes the great importance of crude oil production to the economic well-being of the state of Mississippi.

However, disconcerting trends exist in the source of this income. Consider the following facts. Annual oil production peaked in the state in 1971 at 65,000,000 barrels; production decreased to 30,000,000 barrels in 1986 with expectations that the decline will continue. Severance Tax collections peaked in 1981 at $66,000,000 per year and have declined to $24,000,000 for the year of 1986. The main reason for the decline is basic: many fields in the state have matured with primary and secondary means of production becoming less effective. (See graphs in Appendix).

After primary and secondary production, possibly 65% of the known oil in place in Mississippi will remain. To emphasize this statement, consider that 1.9 billion barrels of oil[3] have been produced from the state since the initial discovery well at Tinsley in 1939; as a minimum, then, 5.4 billion barrels remain in those fields and will remain unrecovered unless tertiary means of recovery are used.

The outlook is discouraging to the state in terms of predicted revenue from primary and secondary crude production into the 21st century. However, the known presence of 5.4 billion barrels that would remain suggests that the state should carefully consider the potential recovery of this resource--how many barrels might be produced by tertiary means and what tax incentives, if any, would promote its production.

The problem of tertiary production is twofold—a technical problem of which tertiary method, if any, would be applicable and an economic problem of the effort being profitable enough to the oil companies for them to attempt it. The two aspects of the problem are inseparable; economic and technical details must be studied together to evaluate future state revenues and to increase those revenues.

First, the economic aspects of the problem of tertiary recovery revolve around whether it is profitable for the company to employ the relative expensive methods. For example, will they realize a minimum measure of profitability such as a discounted cash flow rate of return of, say, 10%? To attempt the recovery, such a minimum measure of profitability must be highly probable. Therefore, it is feasible that some tax incentive could supply the boost to profitability to attain the minimum rate of return. If so, Mississippi might realize tax revenues on oil that otherwise would not be produced.

Besides the economic incentive to produce tertiary oil, there are difficult technical questions to answer. The current state of the art dictates that about five methods are available to consider for tertiary recovery: carbon dioxide flooding, chemical flooding, in situ combustion, polymer flood, and steam injection. These are the methods that have been studied by theory, laboratory, pilot plant, and field trials sufficiently to have confidence of success under selective conditions. But one must go deeper in evaluating the applicability of these methods—some work superbly under certain conditions but not under the different conditions of another field.

The National Petroleum Council in a recent work through INTERCOMP, has developed and validated computer models to determine the applicability of the tertiary methods mentioned above; these programs were developed over a two year period in a 50 professional-person-year study.[4] From an input of reservoir characteristics and costs, the programs will calculate the quantity of incremental oil that is possible, as well as the rate of return a company would realize in the production. By evaluating the reservoirs of Mississippi with each tertiary model, one could determine the incremental production and additional revenues that would accrue to the state beyond secondary recovery.

It should be noted that the state of Oklahoma commissioned the Interstate Oil Compact Commission (IOCC) to study the fields of their state, since their production peaked years ago in a manner similar to Mississippi. Using the computer models developed for NPC, the commission found that at $24 per barrel and 15% ROR, 100 million barrels of incremental oil could be produced with a revenue input to the state of $140 million. In addition the direct economic gain to the state in jobs, etc., topped $800 million.

Another important point is to be made. Carbon dioxide flooding has received more attention than any other tertiary method in the past few years. Mississippi is fortunate to have one of the largest and purest reserves of carbon dioxide in the country. Furthermore, these huge reserves, near the corners of Madison, Scott, and Rankin counties, are near the Mississippi oil fields. There exists with these reserves the chance to produce large amounts of incremental oil-oil that otherwise would not be recovered, generating severance taxes that otherwise would not be realized. Mississippi should benefit from this carbon dioxide. (Otherwise pipelines may take it to Louisiana fields for another state to reap the taxes on incremental recoveries.) The DOE programs could be used to determine the potential value of this carbon dioxide to the state of Mississippi and maximize returns from it.

EOR Models Utilized in Study

To evaluate reservoirs for enhanced oil recovery (EOR), the Department of Energy (DOE), along with the National Petroleum Council had five predictive models developed by INTERCOMP. These models can be used to determine oil and gas recovery by carbon dioxide miscible flooding, in-situ combustion methods, steamflooding, polymer-flooding, and chemical methods.

The five models consist of predictive and economic programs. The process models are analytical tools and not detailed simulators but they allow estimates with publicly available data. Since this data is limited, the models have extensive defaults and therefore can run with minimal inputs of permeability, porosity, depth, reservoir pressure, pay thickness, and API gravity. These data can be obtained for Mississippi fields from reports at the Oil & Gas Board. Better accuracy, understandably, can be obtained with increased "non-defaulted" input data.

Economic calculations for each of the models varies only in process dependent means. Predictions are based on single pattern performance and the economic programs use pattern development schedules to scale to a field-wide basis. Each model's predicted performance is converted into a cash flow. They include costs, tax treatments, capital requirements, and risk. The models compute discounted cash flows, payouts, present value profit-to-investment ratios, and internal rates of return. By varying economic and reservoir variables, sensitivity analysis can be obtained.

Note that these models were developed and validated over a two-year, 50 professional-person-year study. They have been used in Oklahoma and New Mexico for evaluations similar to this study. The computer models are available from DOE.

Carbon Dioxide Model^

The carbon dioxide model is based on a one-dimensional solution to the fractional flow equation by the method of characteristics. The fractional flow method is modified for the effects of viscous fingering, reservoir heterogeneity, and gravity segregation. To generate 3-dimensional oil, water, and carbon dioxide rates, areal sweep equations are included.

To validate the model, it was compared to simulator, laboratory, and field results. When compared in 1-dimension with an equation-of-state compositional simulator, the results were nearly identical for some cases. The model accurately predicted breakthrough in laboratory experiments but deviated from after-breakthrough results. The deviation could be reduced with changes in the KOVAL factor. On some pilots the predicted oil rate fell within the acceptable range and recovery compared well with actual results. The carbon dioxide model was compared with field results of the Slaughter (West Texas) pilot. The comparison with Slaughter proved to be compatible. The predicted oil rate fell within the acceptable range and recovery compared well with actual results.

The model takes predicted reservoir performance data and converts it into a cash flow analysis. The model includes costs, tax treatments, capital requirements and risk. The model can be used for various sensitivity cases to determine the bounds of optimum carbon dioxide flooding.

The model requires 350,000 bytes on a 32-bit processor.

Polymer Model^

The polymer flood model is a 3-dimensional (stratified, 5-spot), 2-phase model that computes water front breakthrough and oil recovery using fractional flow theory. Injection rates into each layer are combined with formulas to take into account depth, thickness, permeability, and viscosity. An option for either polymer or waterflood allows calculation of incremental oil recovery.

In most cases the model compared well to a finite-difference simulator. When varied, an adjustment in the injectivity coefficient was found to be the key. History matching of field cases was found to be successful for both pilot waterflood and field scale secondary polymer flooding.

The model requires 320,000 bytes.

<u>Chemical Model</u>^

The chemical model takes reservoirs which have previously been waterflooded to residual oil saturation and models micellar (surfactant) polymer flooding. An option allows a rough estimate by caustic (alkaline) or caustic polymer flooding. The model uses the theory and result of numerical simulation to predict oil recovery in 5-spot patterns. Fractional flow is used to calculate oil bank and surfactant breakthrough.

In laboratory tests the model agrees favorably with a simulator in oil recovery and timing of breakthrough. In field comparisons the model is optimistic for oil breakthrough and peak production rate.

The model requires 280,000 bytes.

In-Situ Combustion Model^

The in-situ model is based on the work of Brigham, Satman, and Soliman/[9] Air injected and reservoir volume is related to oil burned and oil produced.

The method to include wet combustion performance was added by NPC based on laboratory data of Garon and Wygall) and Prats." Reasonable correlations with field data are found with dry combustion.

The model requires 140,000 bytes.

Steamflood Model ·^[2]^

The model is applicable to steam drive but not steam soak (cyclic). It contains algorithms of Aydelotte, Gomaa, Williams, and Jones/[2]) The model requires 600,000 bytes.

In comparisons with California field data on a wide variety of reservoirs, the model was found to match surprisingly well.

PROCEDURE

The proposed work was accomplished as follows.

1. Computer file of data on Mississippi oil fields was created.
2. The potential recovery of each field was evaluated by the tertiary methods:
   a. Carbon dioxide flood
   b. Polymer flood
   c. Chemical flood
   d. In-situ combustion
   e. Steam flood
3. Tertiary method for each field was selected.
4. Incremental oil to be produced by tertiary means was estimated.
5. Potential tax revenues if incremental oil produced was calculated.
6. Effects on recovery from price per barrel, rate of return, state severance taxes were determined.
7. The potential of the carbon dioxide reserves in Mississippi for incremental oil and the dollar value to the state in severance taxes was determined.

DISCUSSION OF RESULTS

After establishing the database, securing the process models from DOE, uploading them on the MSU mainframe computer, debugging, and making trial runs, an evaluation was begun of the reservoirs in Mississippi that could be candidates for enhanced recovery by any of the five process models: steam, fire, carbon dioxide, chemical, polymer flooding.

The criteria used in the candidate screening of the 1315 reservoirs are presented in Table I. Six factors were considered: pay thickness, depth, bottom hole temperature, permeability, porosity, and oil gravity. Polymer and in-situ combustion processes were screened using all six factors; the chemical process did not utilize pay depth; the steam process did not screen with the bottom hole temperature parameter; the carbon dioxide process screened according to depth greater than 2000 feet and oil gravity greater than 26 API.

The results of the screening are presented in Figure 9. More reservoirs screened to be conducive to carbon dioxide flooding than any other process—some 400+ reservoirs. Three hundred'reservoirs re applicable to polymer flooding; 100+ reservoirs could be produced from chemical flooding; slightly less than one hundred are suitable for in-situ combustion; very few would allow a steam flooding.

With the results of this screening so favorable to carbon dioxide miscible flooding, and given the Mississippi reserves of carbon dioxide, the subsequent economic analysis concentrated on the carbon dioxide process.

Database of Mississippi Reservoir Properties

Data were collected and filed on computer for the reservoir properties of all Mississippi reservoirs. Data for the 1315 reservoirs were established on floppy disc, hard disc, and hard copy. For each reservoir, forty-eight items of information were tabulated in the text, and seventeen additional items were included as supplement to some reservoirs. The compilation is the most comprehensive existing for the state and the only one accessible by computer.

To collect the data, the following sources were used. A file of 36 reservoirs from the DOE 1987 TORIS database was a beginning point; this DOE data was checked and built upon. Properties of the remaining 1279 reservoirs were accumulated from Oil and Gas Board monthly reports, Oil and Gas Board hearing exhibits, well logs on file at the Oil and Gas Board, personal contacts with company representatives, and published reports. Trips were made to the Oil and Gas Board in Jackson, and the researcher reviewed individual files. Although many gaps still exist in the database, the compilation includes all of the publicly available information.

The database of the 1315 reservoirs is contained in Volume II of this report.

R-Base System V software was used to file the reservoir data. However, the data can be downloaded in ASCII format to serve any conventional software or computer; it is available on floppy disc.

Correlations can be chosen from any of the 65 items describing each reservoir in the database. These may be graphically presented to give a readily accessible analysis of Mississippi oil reservoirs. An apparent use, therefore, would be in a technical analysis such as was done in the second phase of the subject work, where the data was used to evaluate the potential for enhanced recovery from the state's reservoirs. But there are many other uses that are also of interest.

Consider a few of the many possible correlations that might be selected from the database:

1. A graph, Fig. 1, of the number of reservoirs operated by major companies in Mississippi.
2. Oil reservoirs discovered in Mississippi since 1939 that are still producing--see Fig. 2.
3. A pie chart, Fig. 3, of the number of gas and oil reservoirs in the state.
4. Mississippi producing wells grouped according to depth and presented as a bar graph, Fig. 4.
5. Mississippi reservoirs grouped according to depth and presented as a bar graph, Fig. 5.
6. Graphs of the wells that are producing in Hinds County as a function of their depths, Fig. 6.
7. Graphs of the reservoirs that are producing in Hinds County as a function of their depths, Fig. 7.
8. A plot of the number of gas reservoirs that have been discovered in Mississippi since 1939 that are still producing, Fig. 8.

It is evident that the database is quite versatile and should be of benefit to the state for planning purposes or technical evaluations.

Economic Analysis of Carbon Dioxide Process on Mississippi Reservoirs

Of course the number of CO2 projects undertaken by companies would depend upon the discounted rate of return obtainable from their investment. Therefore, to calculate the barrels of incremental oil that could be practically expected in Mississippi from this process, separate calculations for two rates of return, 10% and 15%, were made. For each of these rates, oil prices of 20, 30 , 40, and 50 dollars per barrel were assumed. Under these assumptions, and the more detailed assumptions given elsewhere in the report, total incremental oil production in Mississippi by carbon dioxide miscible flooding was determined. A range of 102 million barrels, at the most favorable rate of return and price, to 25 million barrels, at the least favorable rate of return and price, resulted. See Fig. 10.

These results are presented in a different manner in Fig. 11, where millions of barrels of incremental production is plotted versus the year, beginning at the present until the future of 2020. Note that a peak production would result in the year of 1998 of some 10.5 million barrels, at a 10% rate of return. The correlation is repeated in Fig. 12 for a 15% rate of return.

In Fig. 13 is plotted as a bar graph the millions of barrels of incremental crude oil that could be produced with a given rate of return to the companies; note a large amount that would yield over a 25% rate of return.

Now that it is evident that many carbon dioxide miscible projects could be profitable to companies if undertaken, consider the meaning of these profitable ventures to the state.

To do this, begin with the millions of dollars of gross oil sales that would accrue from incremental production from CO2. In Fig. 14 and Fig. 15 are plotted values from now until the year 2020; a peak of $800 million would be realized in 1998 under the most favorable economic conditions. A present value of those yearly gross sales are then determined using a discount rate of 10% and a 7% inflation rate to get a value of gross sales of incremental oil in the state from CO2 of $1.5 billion! See Fig. 16 .

Since the state has a 3% incentive severance tax on $C0_2$, the incremental production would mean $45 million (present value) of revenue to the state coffers from severance tax alone for the CO2 process. See Fig. 17. (Note: In the analyses of 3% severance tax incentive was assumed for the CO_2 project.)

Besides severance taxes, corporate income taxes would accrue to the state. As seen in Fig. 18 and Fig. 19, additional income taxes could amount to $29 million, under the best conditions in 1998; the additional income taxes that would be gathered each year from now until the year 2020 are presented in these two figures. If one takes the present value, at 7% inflation and 10% discount rate, of the incremental state income taxes, as much as $50 million could be realized by the state in present value; See Fig. 20.

The state would indirectly receive other benefits through sales tax, individual income tax on wages, and service on the installation of the carbon dioxide processes. The tangible and intangible capital costs that would be necessary to install the projects are given in Figs. 21-24. For example at a 10% rate of return and a realistic $30 per barrel price of crude oil, approximately $82 million of tangible and intangible costs would be spent in the peak year of 1998 as capital investments in Mississippi.

The operating costs, expenses associated with keeping the property producing, are another indirect benefit to the state. For example, wages and salaries, electrical costs, and maintenance would fall in this category. Figs. 25 and 26 provide the operating costs from now until 2020 to keep the CO_2 projects going. Note that in the peak year of 1998 as much as $100 million could be spent on such projects for the most favorable conditions; however, even at $30 per barrel oil, some $62 million of operating costs would be spent. To put the operating costs in better perspective, those costs have been calculated as present values, discounted at a 10% rate and corrected for 7% inflation; the result gives a present value of as much as $290 million in the case of $50 oil and 10% rate of return. The more realistic conditions of $30 per barrel oil and 15% rate of return results in $115 million of operating costs as net present values. See Fig. 27.

What royalties would go to mineral right owners in the state from CO_2 projects? The answer is presented in Figs. 28 and 29 for the period up to the year 2020. For the best case in the peak year of 1998, almost $100 million would be paid to these mineral rights holders; even in the less favorable scenario of $30 oil and a 15% rate of return, some $42 million extra dollars would be paid to these owners. Remember that these figures apply to incremental oil--that oil produced above that normally expected.' It is impressive to view the royalties, as present values, that would accrue to the mineral owners; see Fig. 30. For the conservative conditions of $30 oil and 15% rate of return, $60 million would be paid in royalties, present value.

Assumptions

To make the economic analysis of the impact of the carbon dioxide process, certain assumptions were necessary regarding the process. Some of the more important ones are as follows.

Reservoir :

1. CO? project starts year field is down to producing 1,000 bbls/yr.
2. Oil cut of past years was plotted and extrapolated to year of project start. This was used as the oil cut at start of project.
3. 0.9 injector wells drilled per pattern.
   1.25 producers converted per pattern.
4. 40 acre patterns.
5. Current CO_2 projects included in analysis.

Economic :

6. Ten-mile pipeline necessary to be built for each project, costing $100,000 per mile to build, $5,000 per mile per year to operate.
7. Reservoir must be at least 100 acres.
8. Five percent escalation in oil price,- 4% escalation in operating and capital costs.
9. No recycling of CO_2.
10. No dehydration of plant.
11. A 3% severance tax incentive for all CO_2 projects.

Miscellaneous :

12. No escalation in CO_2 ($0.75 per MCF) or gas ($2.50 per MCF) prices.
13. Flaring produced gas.
14. Operating (fixed) costs of $36,000 per pattern per year.
15. Water treated costs of $0.30 per bbl.

CONCLUSIONS

Although Mississippi production of crude oil has declined steeply in recent years, this study shows that enhanced oil recovery, particularly from carbon dioxide miscible flooding, can have a substantial impact on the economy of the state. Although capital and operating costs would be high, the companies investing in the process would also realize an attractive rate of return. The unique, high-purity carbon dioxide reserves of the state, located near many of the old oil fields, provide an incentive to this process development.

Mississippi should initiate the steps to utilize these resources. A pipeline network to transport the carbon dioxide to those fields in the southern part of the state should be encouraged. Some pipelines already in place (Shell's line to Week's Island and Pennzoil's line to Tinsley) serve as models. See the map provided by Amerada Hess as Fig. 31. The pipeline network is a primary requirement.

Second, the state should support research that would help develop the carbon dioxide process. The candidate reservoirs should be characterized for behavior in the process. Results would be very helpful and essential to the small companies operating in the state who might initiate projects but do not have the capability to perform the necessary characterizations.

Some other conclusions are as follows.

1. The database that was established on the 1315 reservoirs in the state makes possible analyses heretofore not practical.

2. Screening of the reservoirs in the state indicated those conducive to EOR projects: 400+ amenable to CO_2, 300 to polymer, 100 + chemical, slightly less than 100 to in-situ combustion, and very few to steam flooding.

3. Many carbon dioxide miscible floods could be undertaken profitably by companies.

4. Gross sales of incremental oil could range from $500 million (net present value) at $30 per barrel to $1.5 billion at $50 per barrel oil.

5. $45 million (present value) of severance taxes could be collected by the state on incremental oil.

6. $50 million of additional corporate income taxes could be realized by the state on incremental oil.

7. Capital investments in the CO2 miscible projects would total $82 million in the peak year. (Tangible and intangible capital costs on projects that would return at least a 10% rate of return to the company under an oil price of $30 per barrel.)

8. Operating costs of ongoing projects would require about $62 million in the peak year, assuming the 10% ROR and $30 per barrel; $100 million required for 10% ROR and $50 per barrel; $115 million in operating costs as present values for 10% ROR and $30 per barrel oil.

9. $60 million of royalties, as present value, would be paid to mineral right owners for the conservative 15% ROR and $30 per barrel oil.

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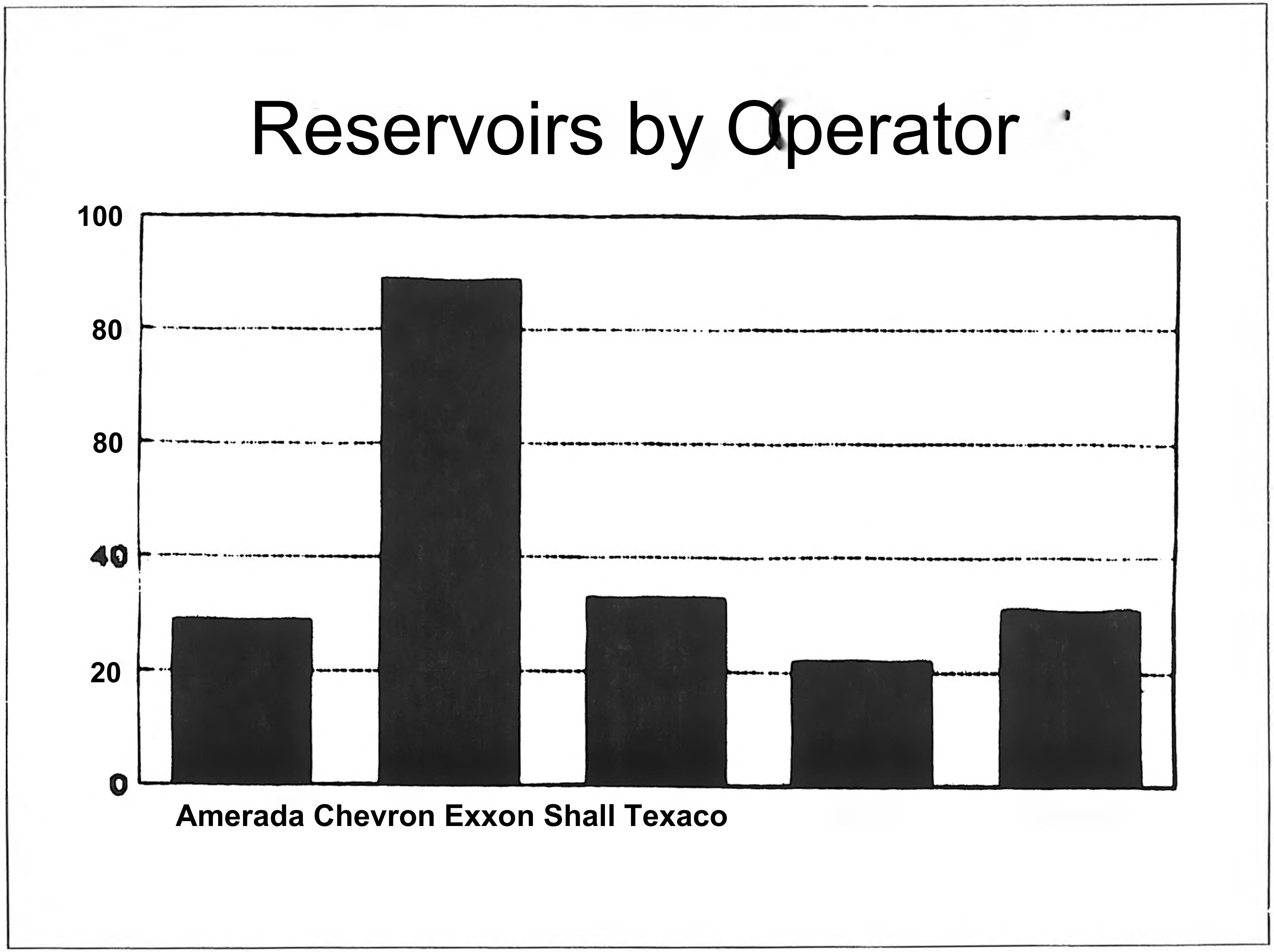
Table I

SCREENING CRITERIA

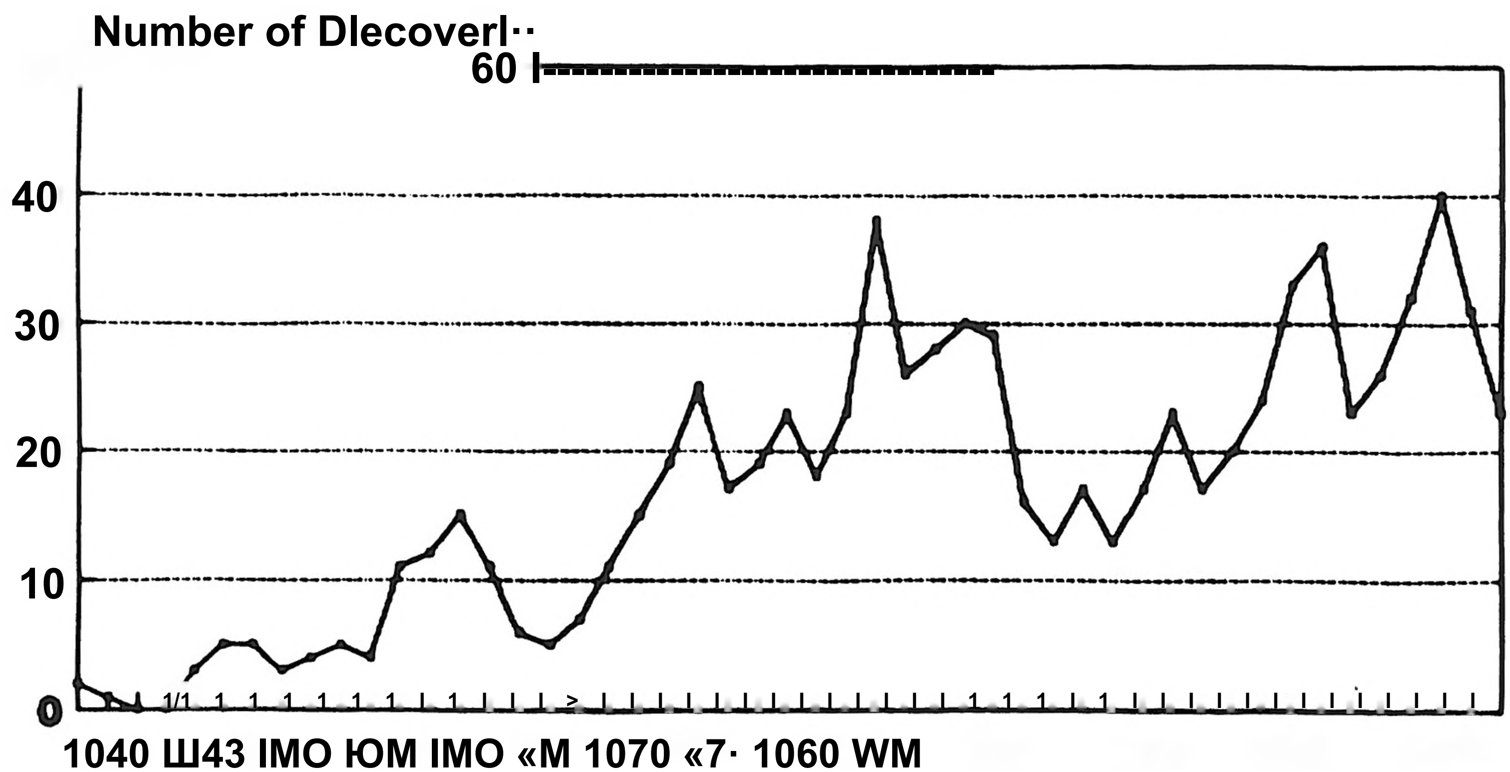
	PAY (ft)	DEPTH (ft)	BHT (OF)	K (md)	POROSITY (%)	GRAVITY (oAPI)
Polymer	>10	<0000	<200	>20	>20	>25
Chemical		<9000	<200	>20	>20	<30
CO2		>2000				>26
Inai tu	>20	<11600	>150	>35	>20	10-35
Steam	>20	<3000		>250	>20	10-34

Figure 1


Reservoirs by Operator
100
80
80
40
20
0
Amerada Chevron Exxon Shall Texaco

Oil Reservoir Discoveries

(still producing 11/30/88)



Mississippi Producing Reservoirs
(as of 30 April 89)

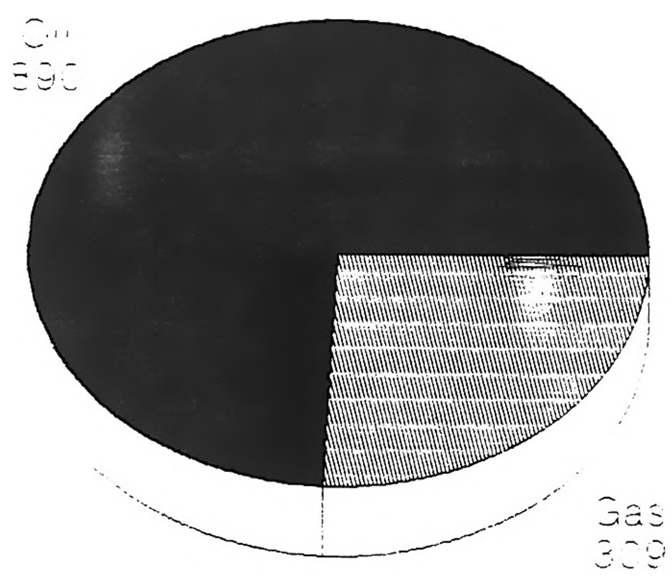
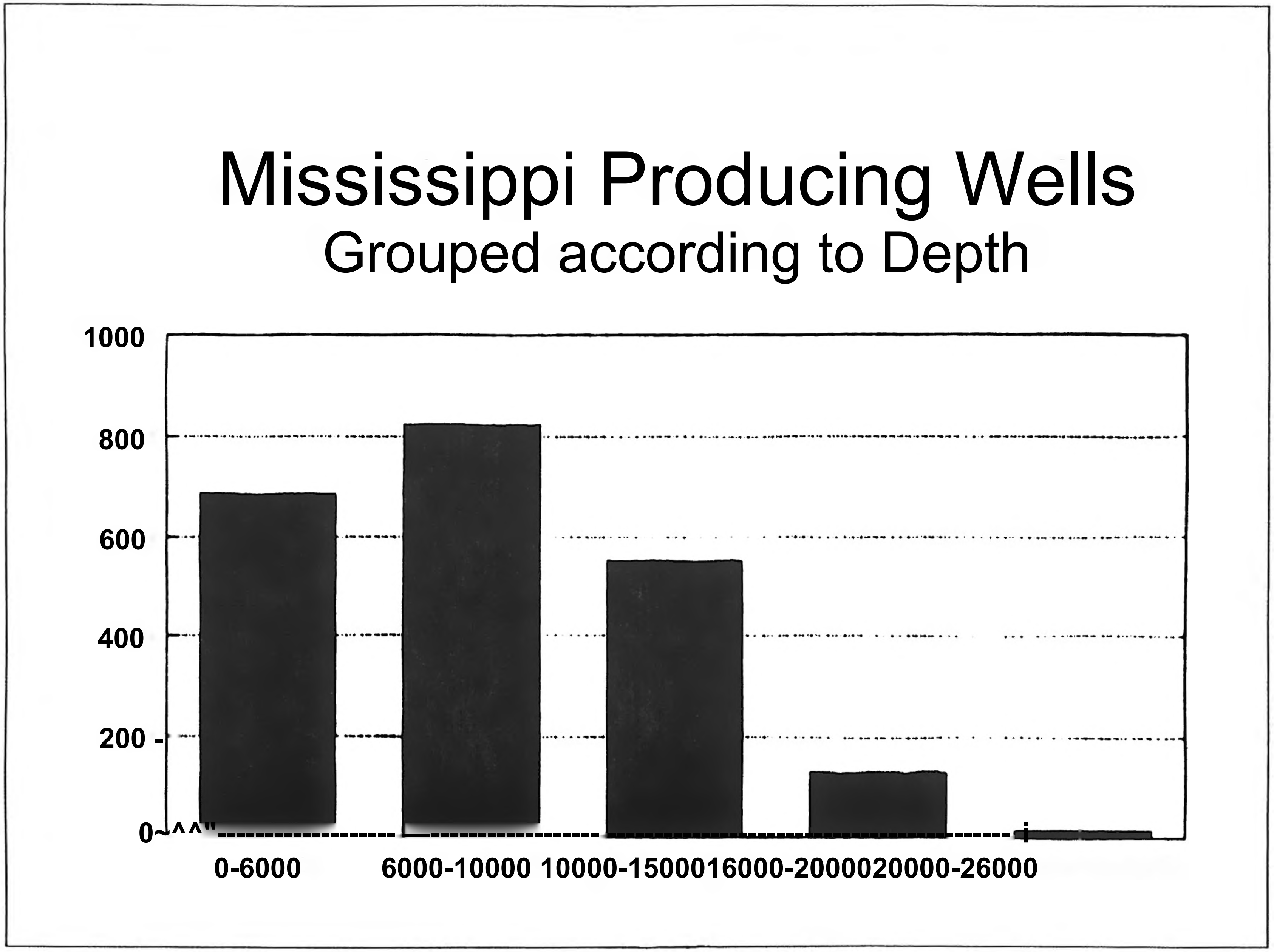


Figure 3

Figure 4


Mississippi Producing Wells
Grouped according to Depth
1000
800
600
400
200
0
0-6000
6000-10000 10000-1500016000-2000020000-26000

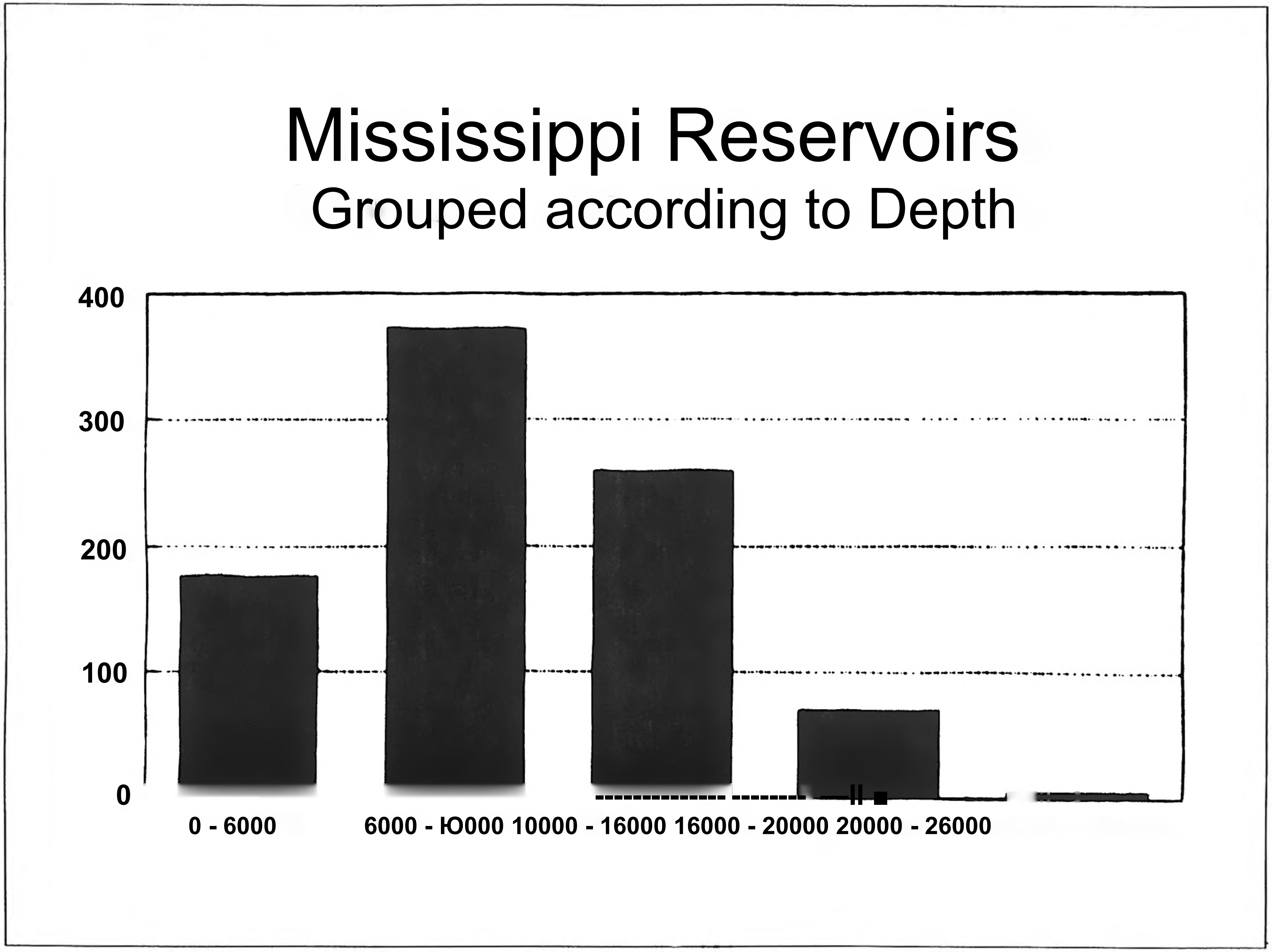

Mississippi Reservoirs
Grouped according to Depth
400
300
200
100
0
0 - 6000
6000 - Ю000
10000 - 16000
16000 - 20000
20000 - 26000

Figure 5

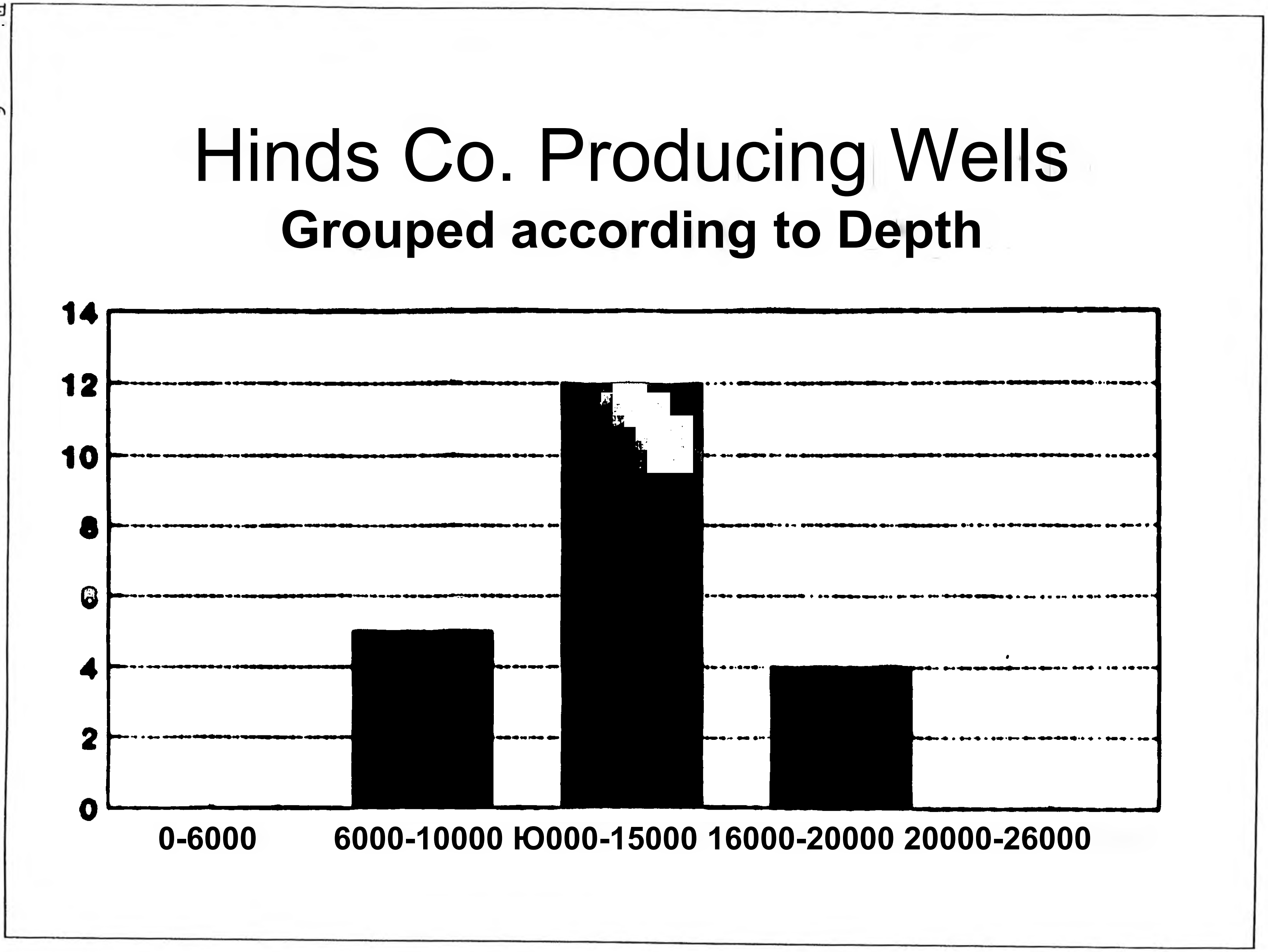

Hinds Co. Producing Wells
Grouped according to Depth
14
12
10
8
6
4
2
0
0-6000
6000-10000
10000-15000
16000-20000
20000-26000

Figure 6

Hinds Co. Reservoirs

Grouped according to Depth

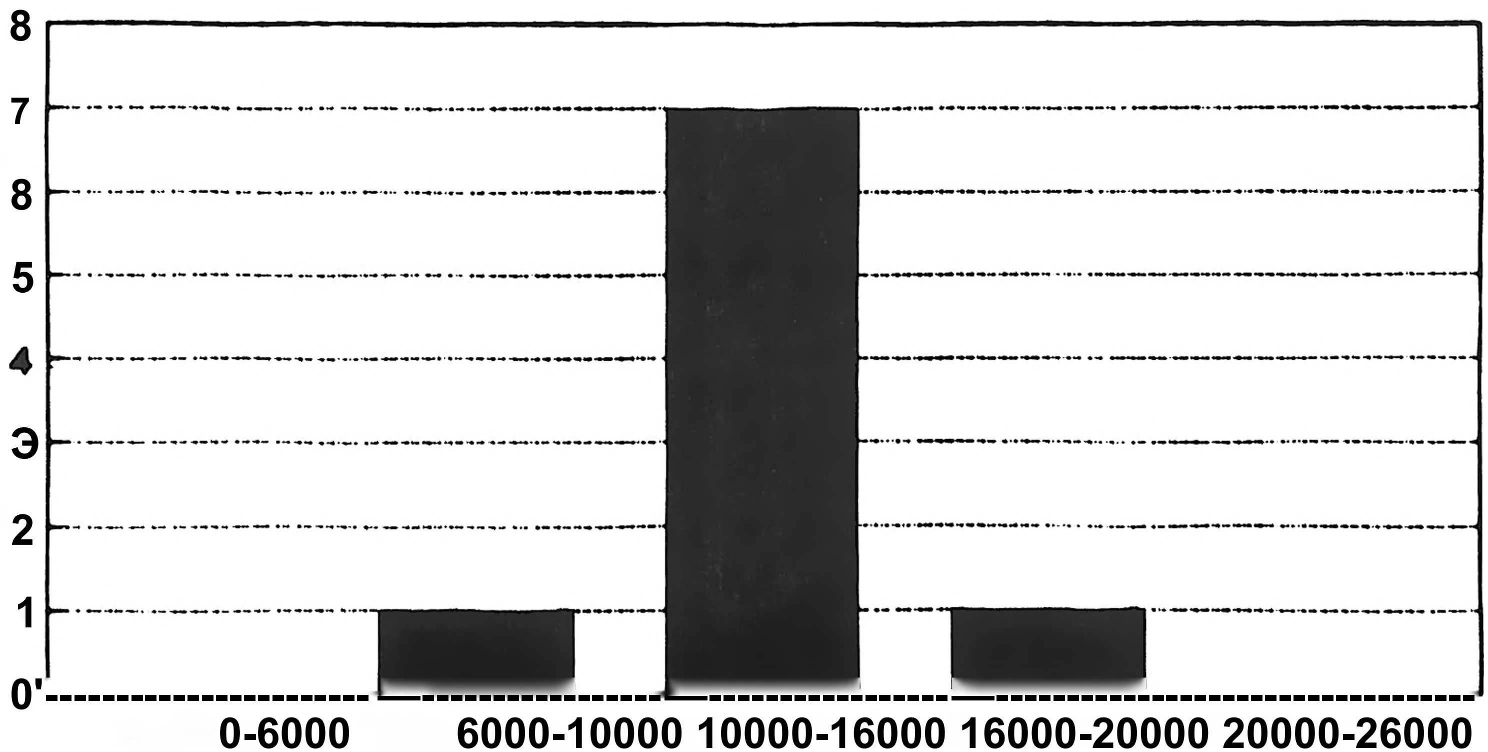
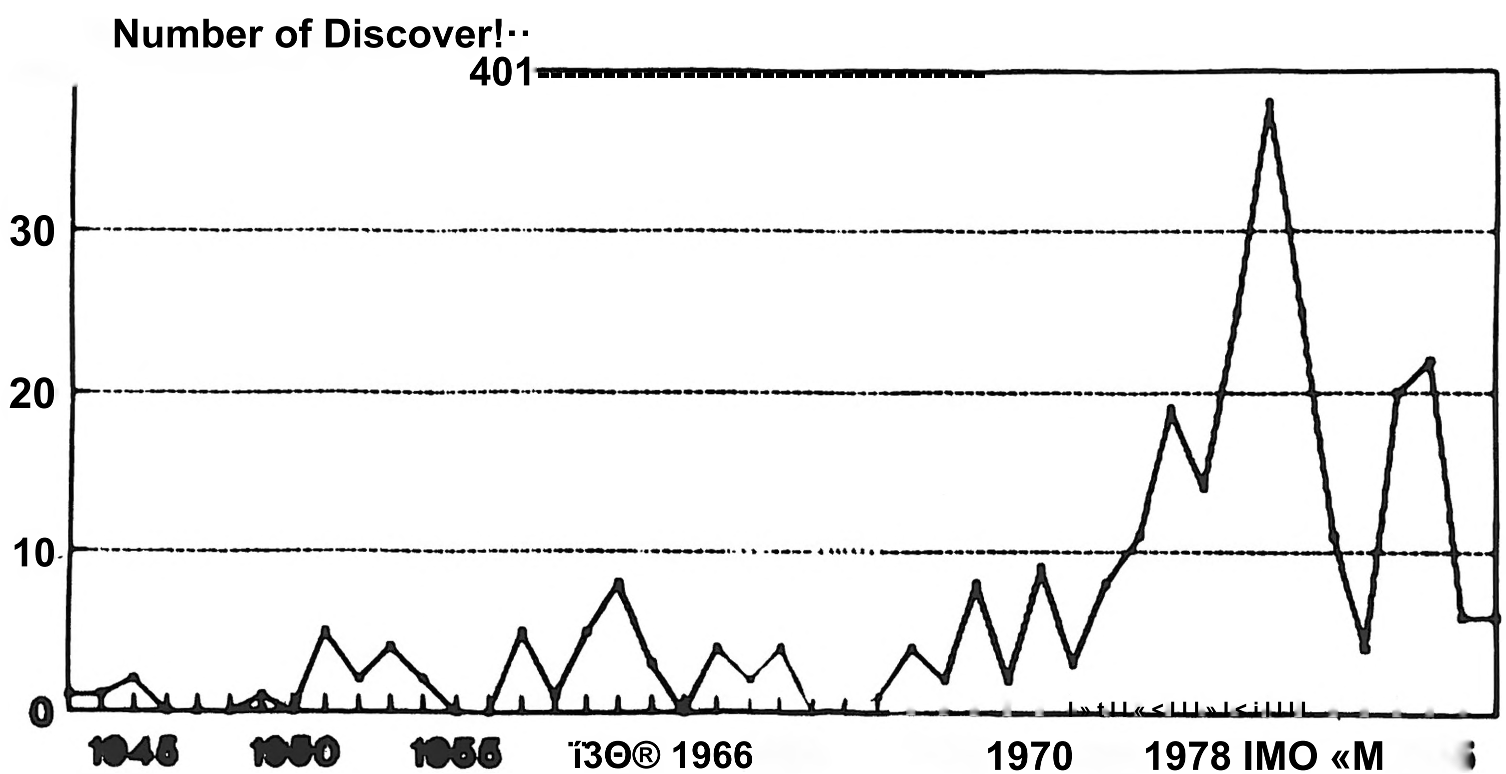


Figure 7

Figure 8

Gas Reservoir Discoveries

(still producing 11/30/89)



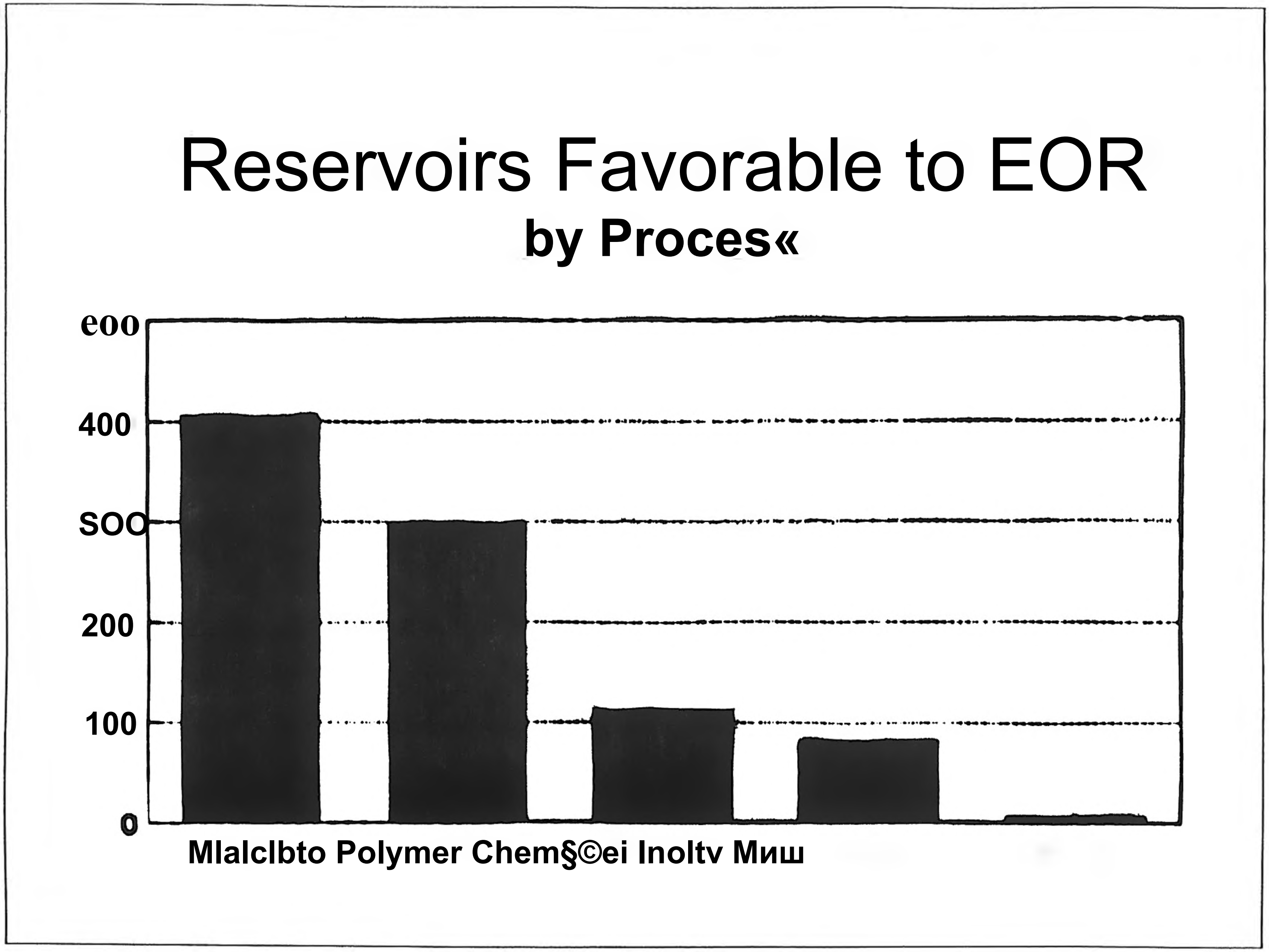


Figure 9

co
co

Figure 10

Incremental Oil Production
by CO2 Flooding

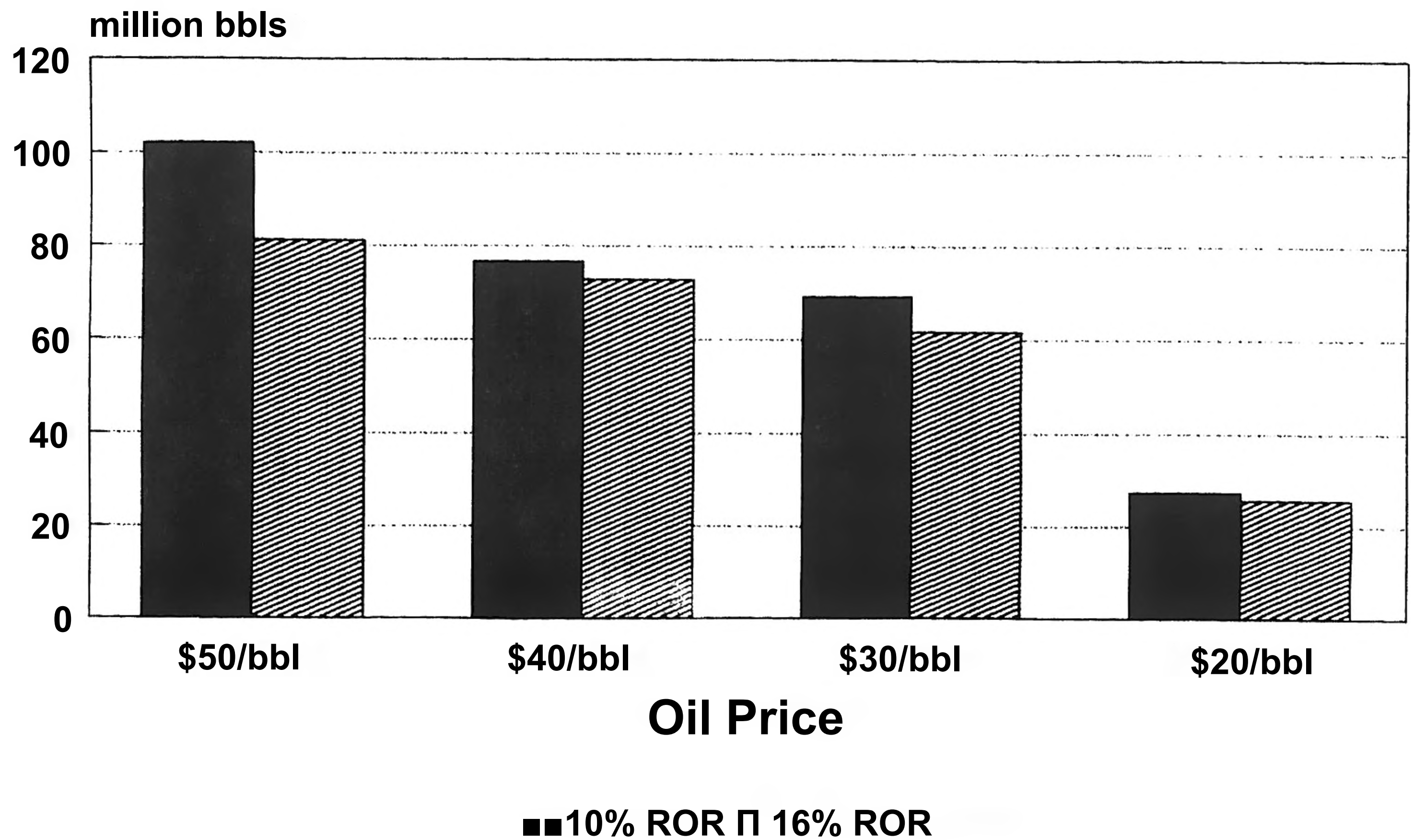


Figure 11

Incremental Gross Oil Production

(10% required rate of return)

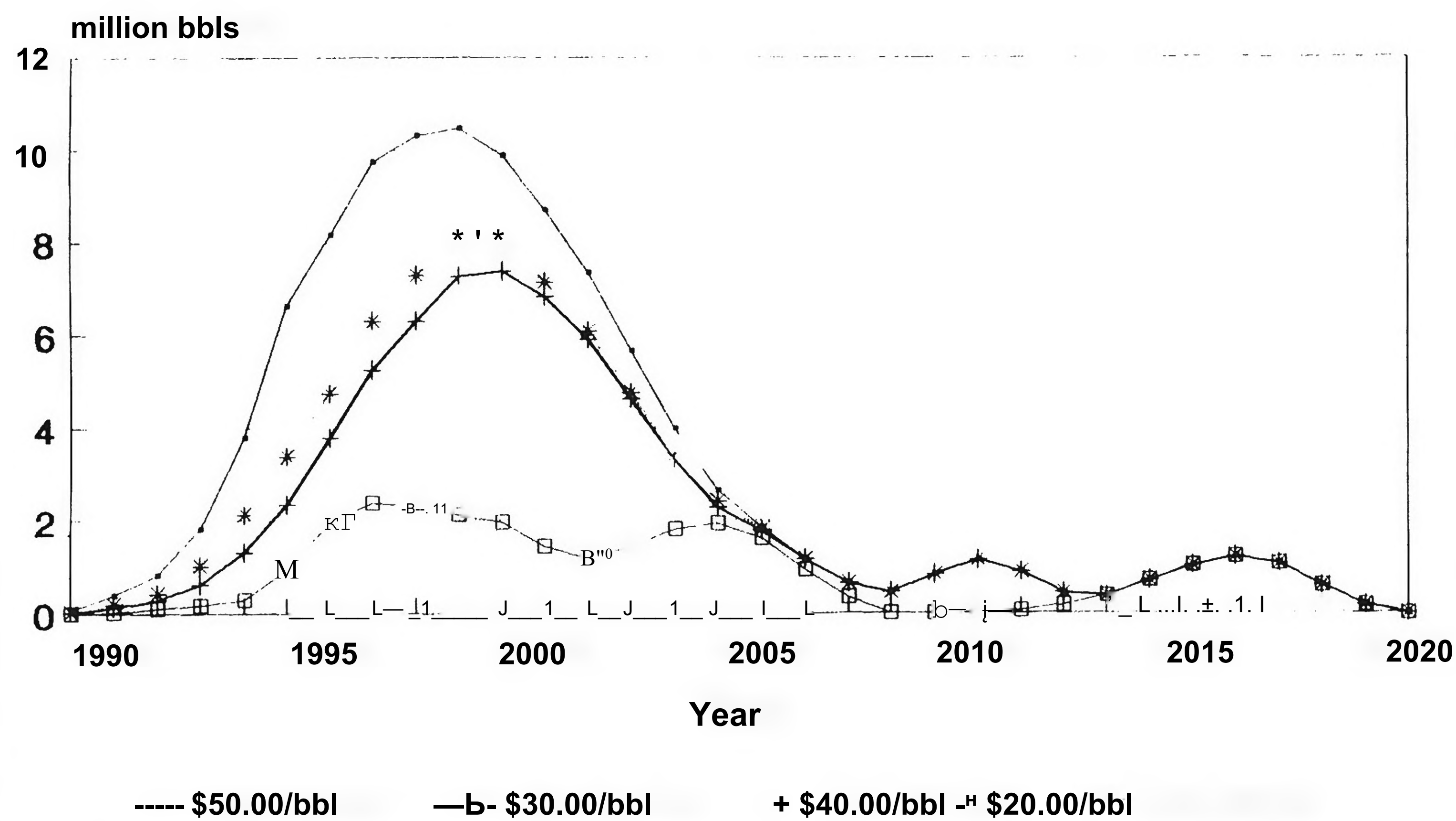
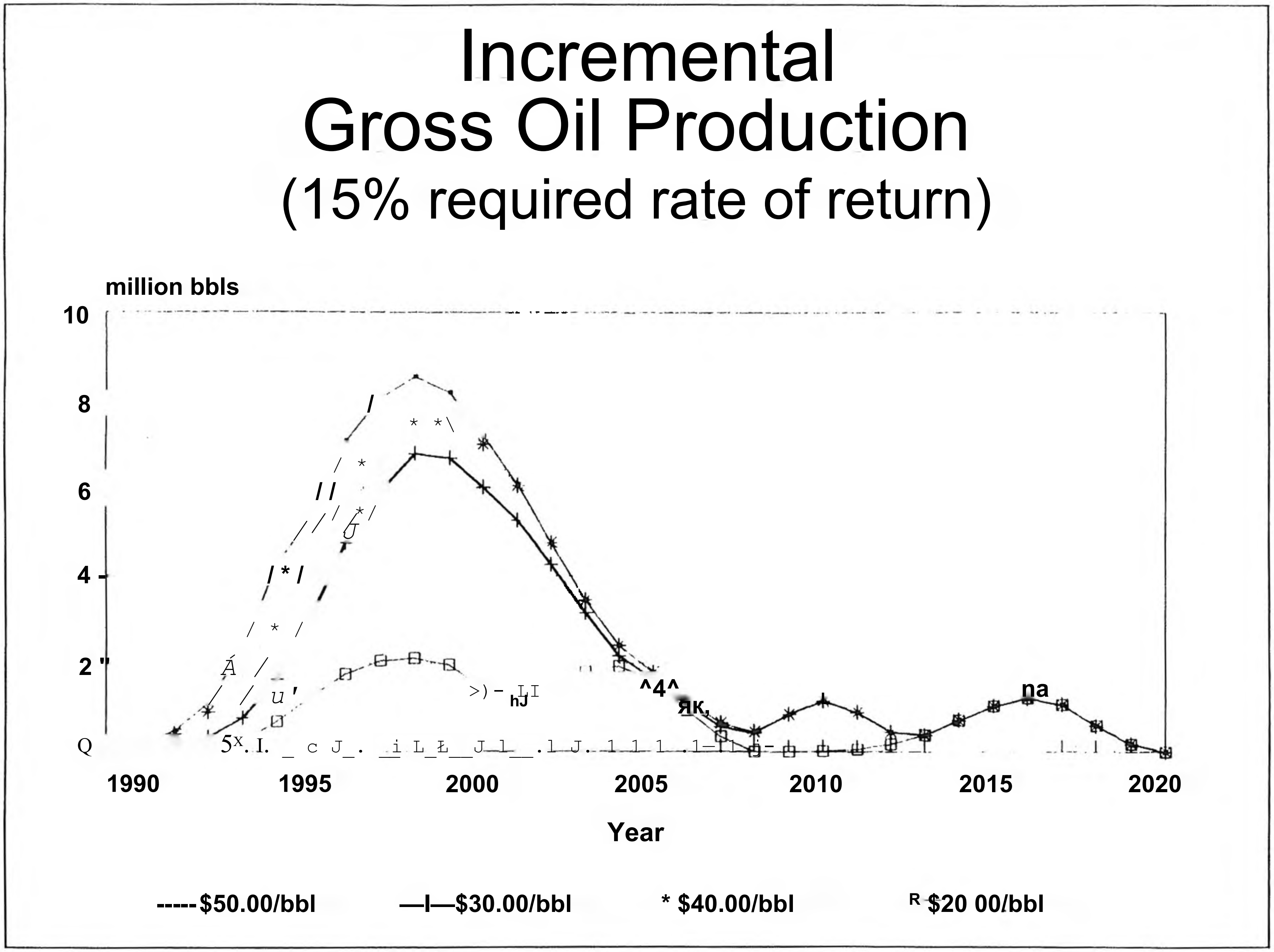


Figure 12



Incremental
Gross Oil Production
(15% required rate of return)
million bbls
10
8
6
4
2
0
1990
1995
2000
2005
2010
2015
2020
Year
$50.00/bbl
$30.00/bbl
$40.00/bbl
$20 00/bbl

Figure 13

Incrementai Oil Production

at varying rates of return

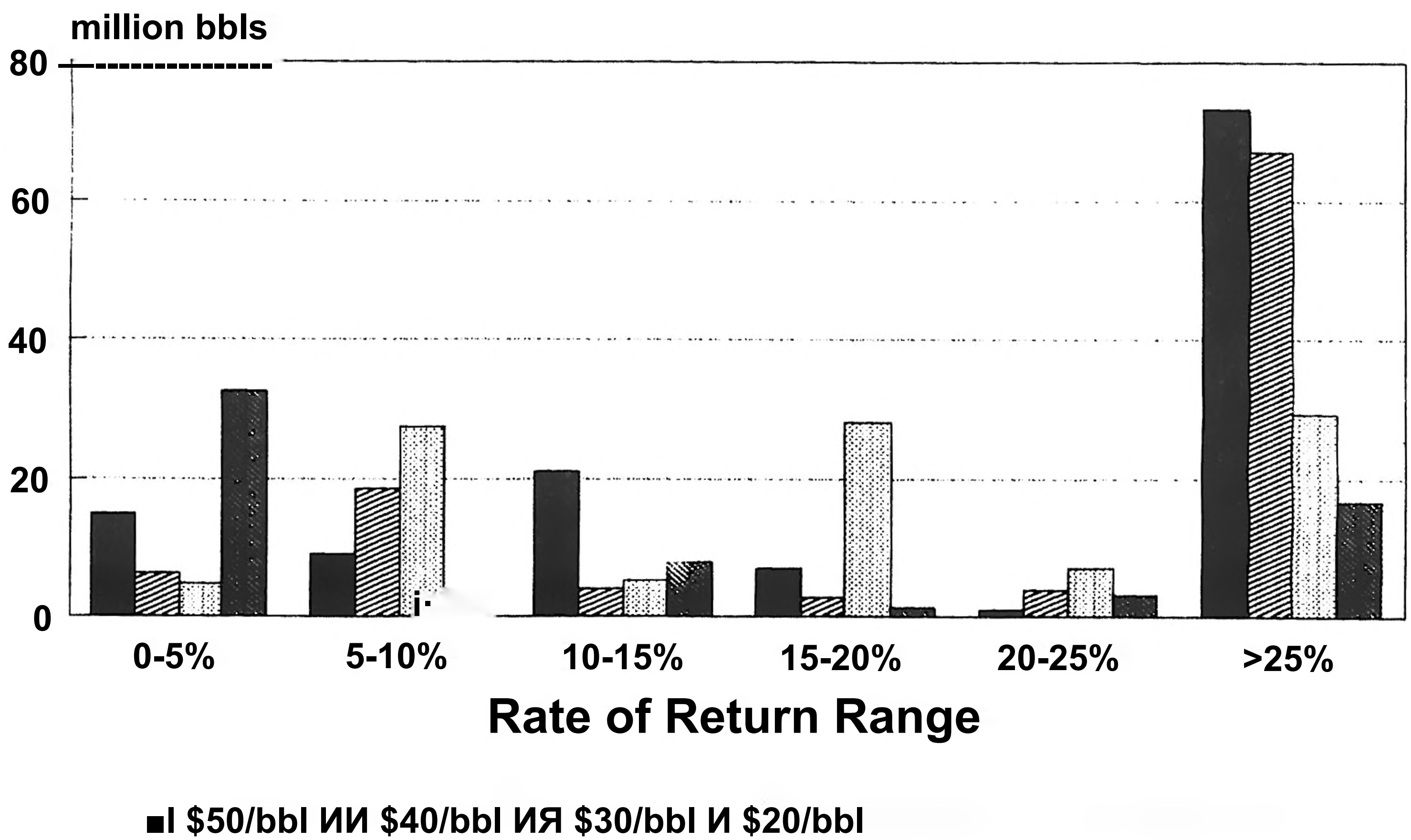


Figure 14

Incremental Gross Oil Sales

(10% required rate of return)

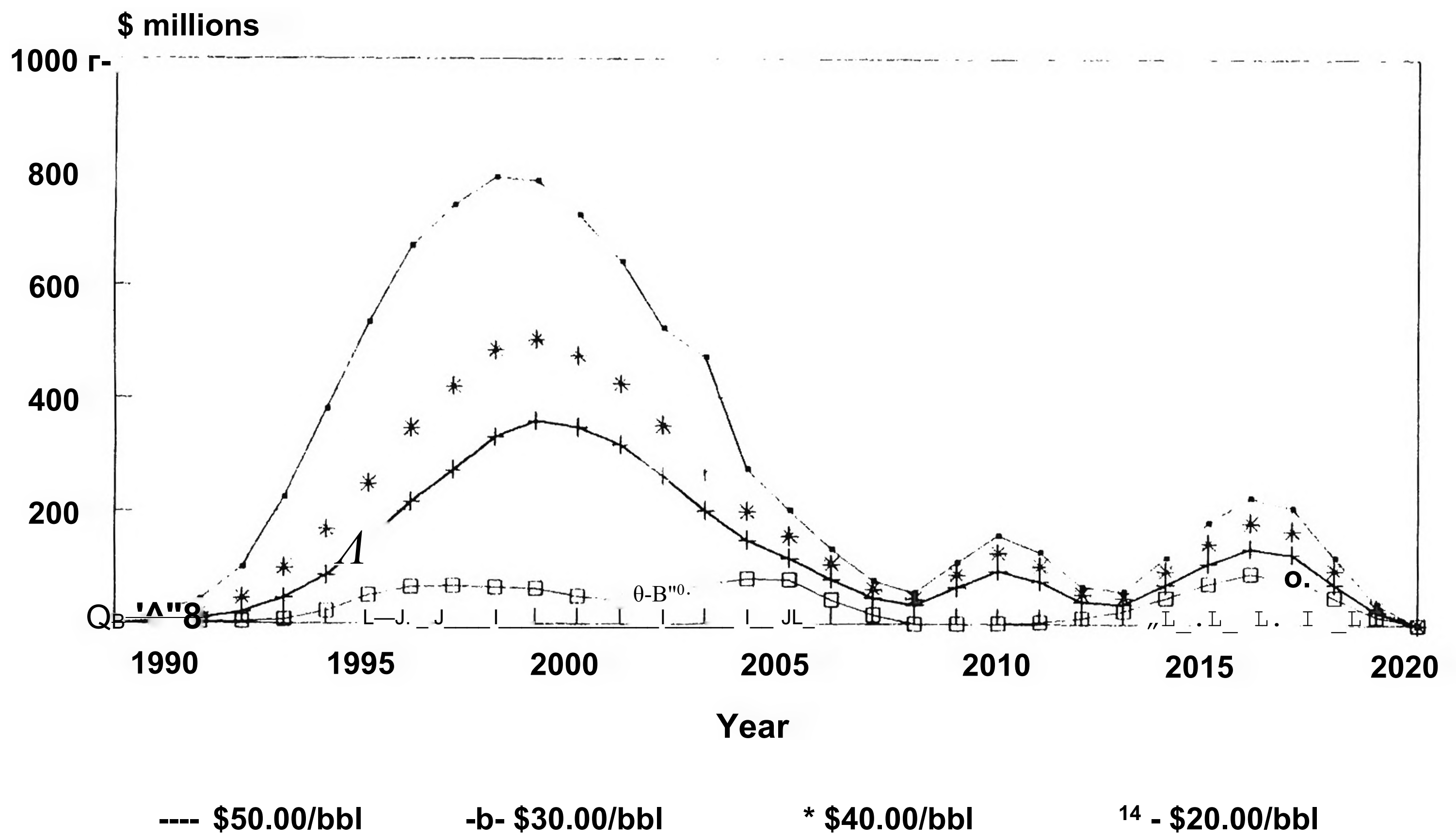
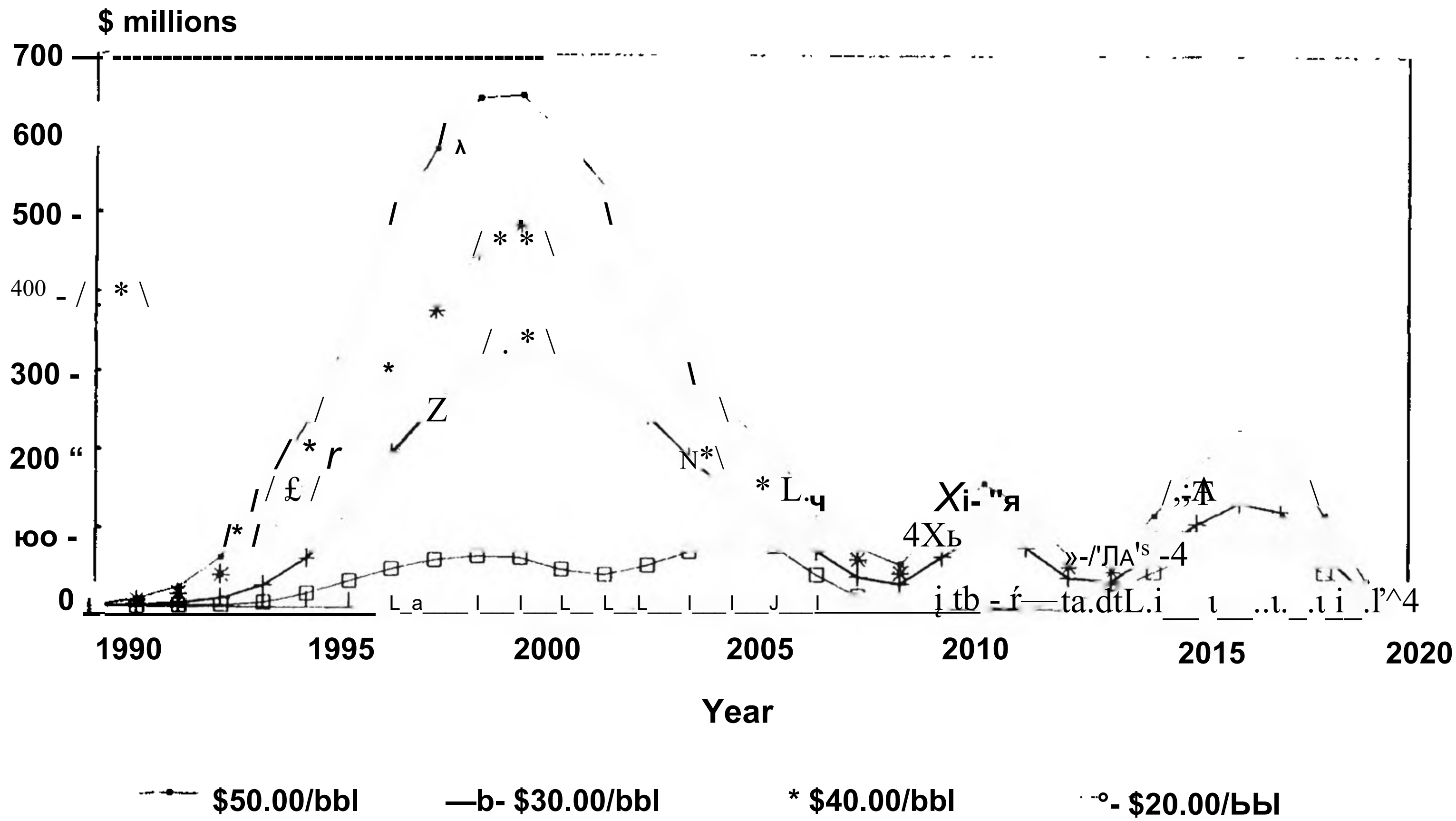


Figure 15

Incremental Gross Oil Sales
(15% required rate of return)



Incremental Gross Oil Sales
(net present value)

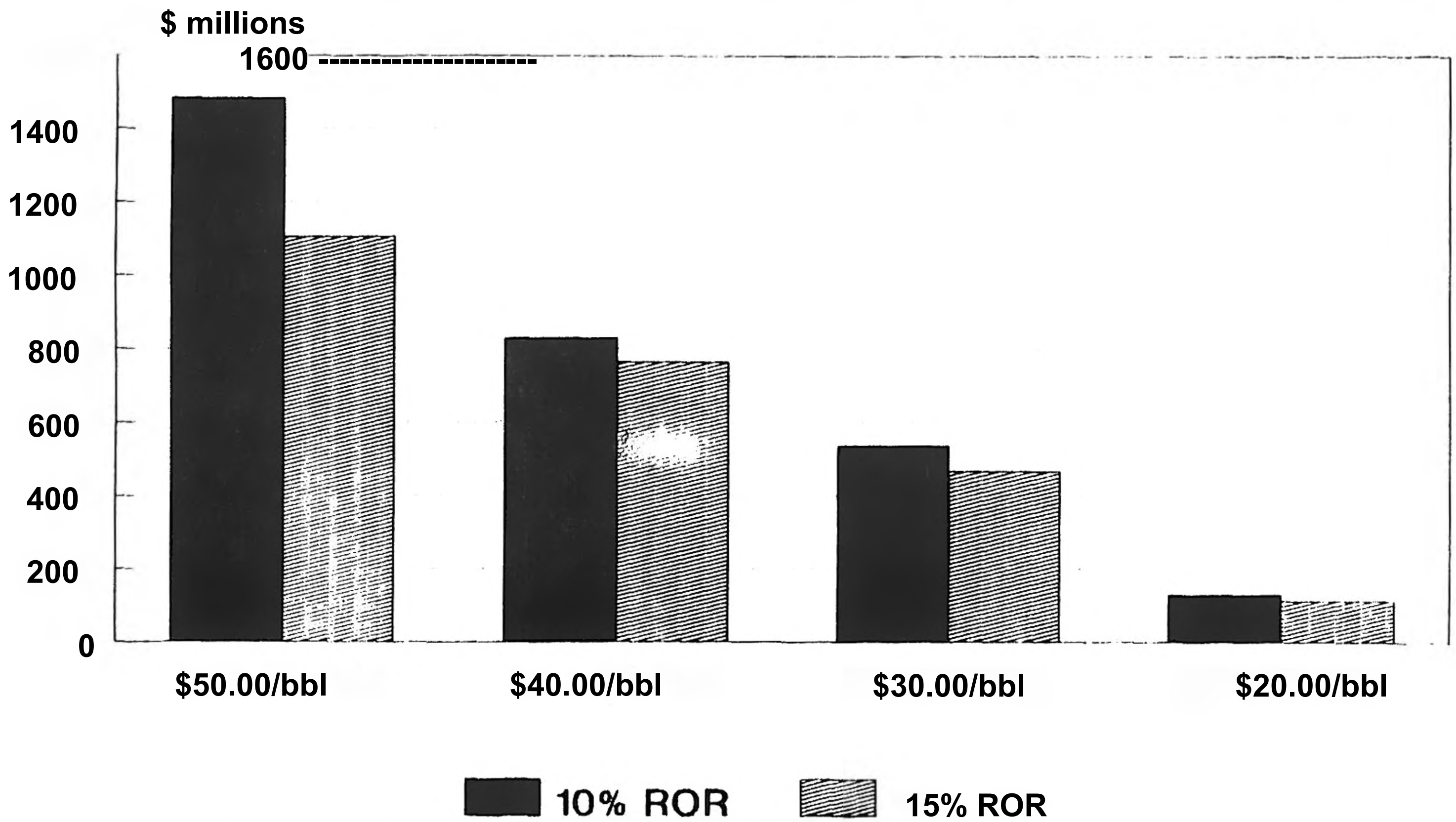


Figure 17

Incremental Severance Taxes
by CO2 Flooding

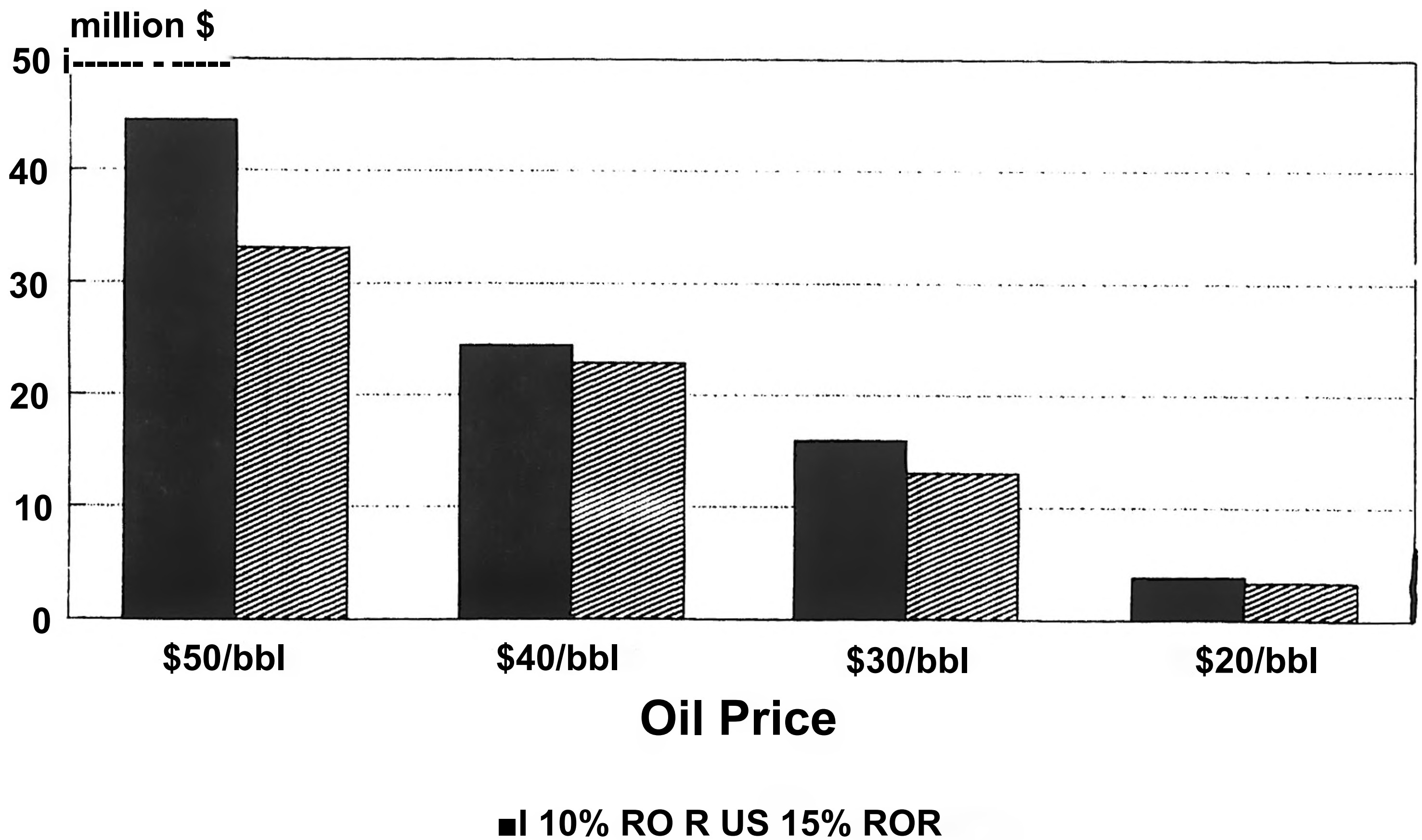


Figure 18

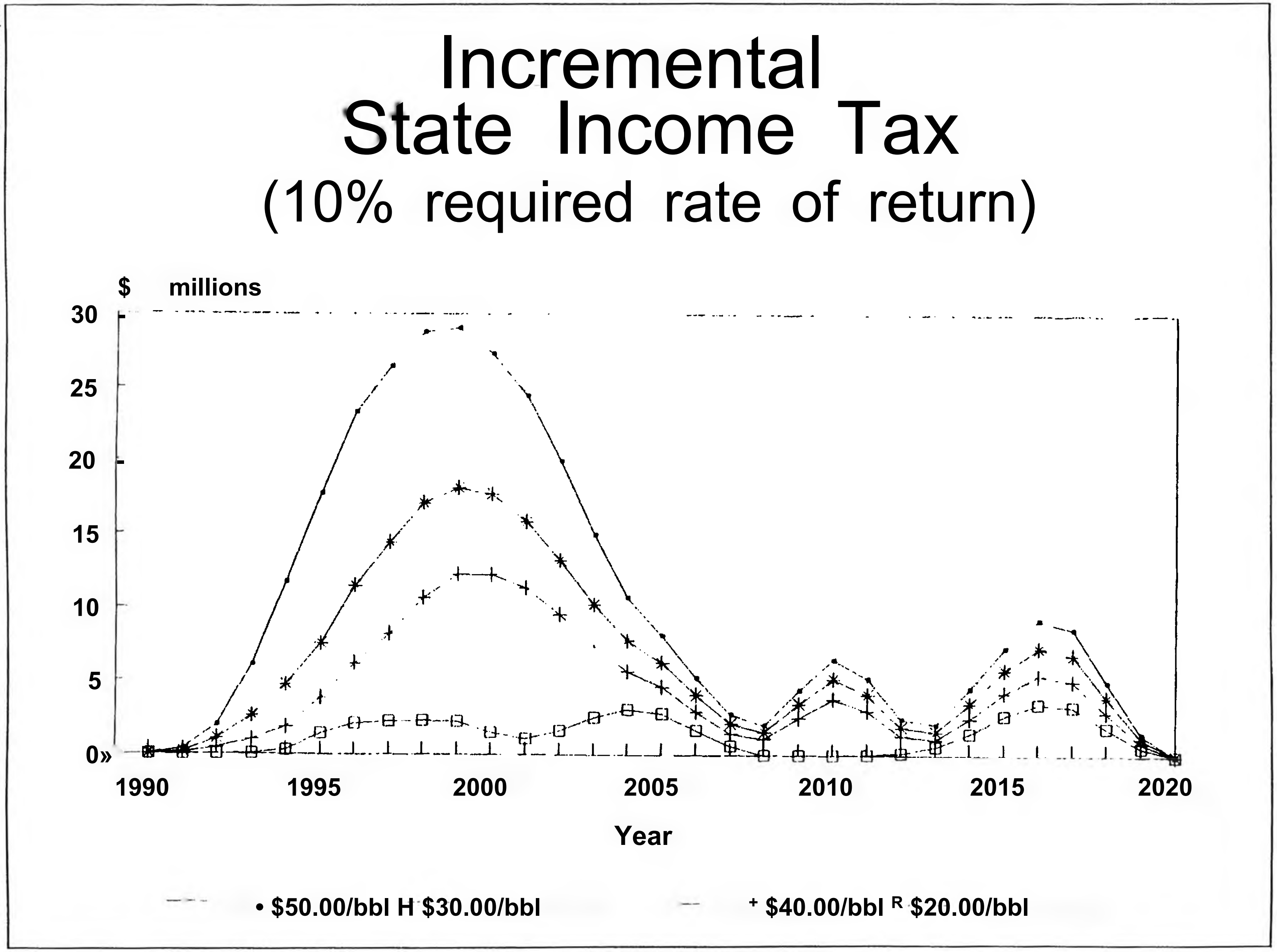

Incremental
State Income Tax
(10% required rate of return)
$ millions
30
25
20
15
10
5
0»
1990
1995
2000
2005
2010
2015
2020
Year
• $50.00/bbl H $30.00/bbl
+ $40.00/bbl R $20.00/bbl

Figure 19

Incremental State Income Tax
(15% required rate of return)

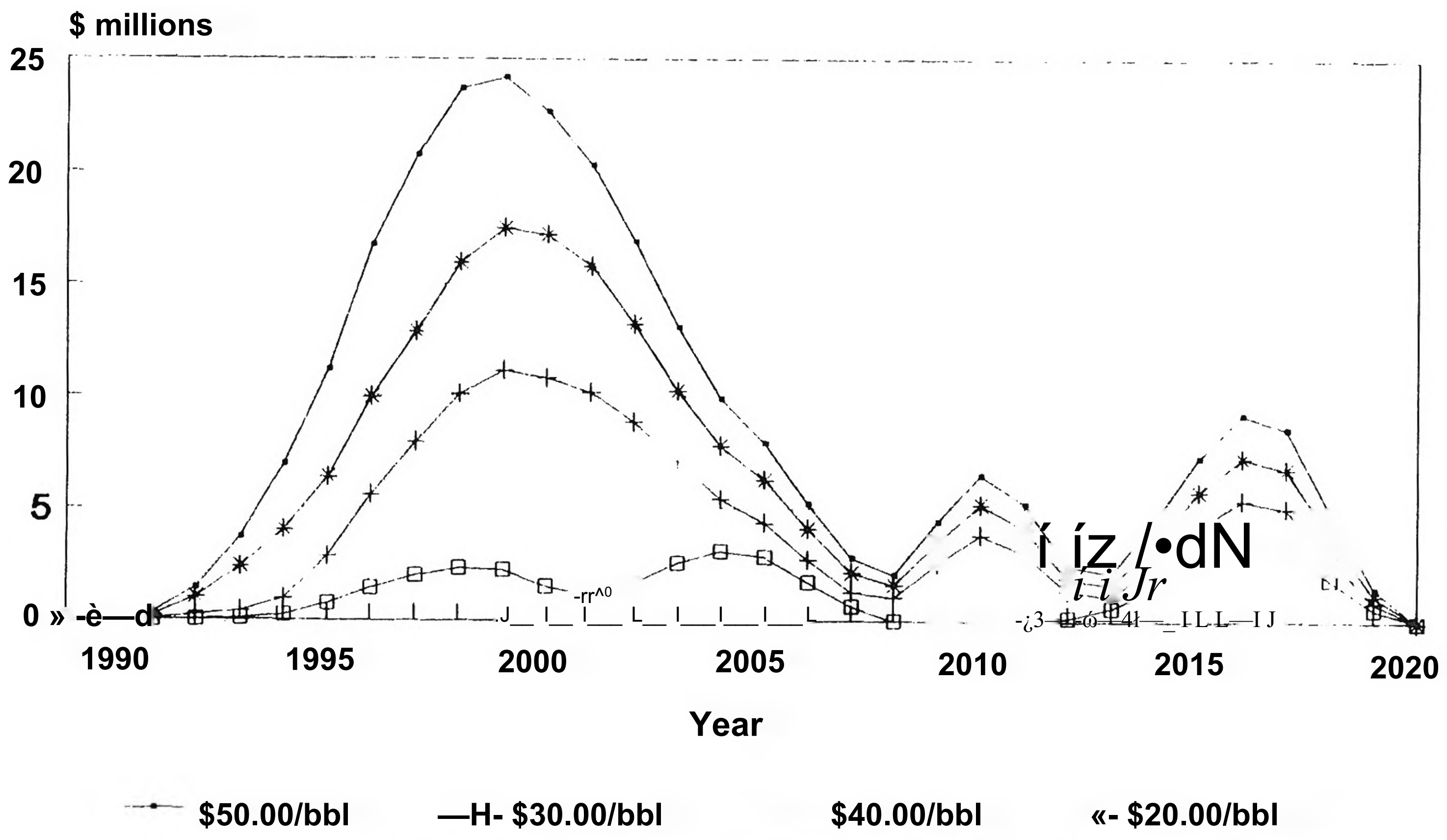


Figure 20

Incremental State Income Taxes

(net present value)

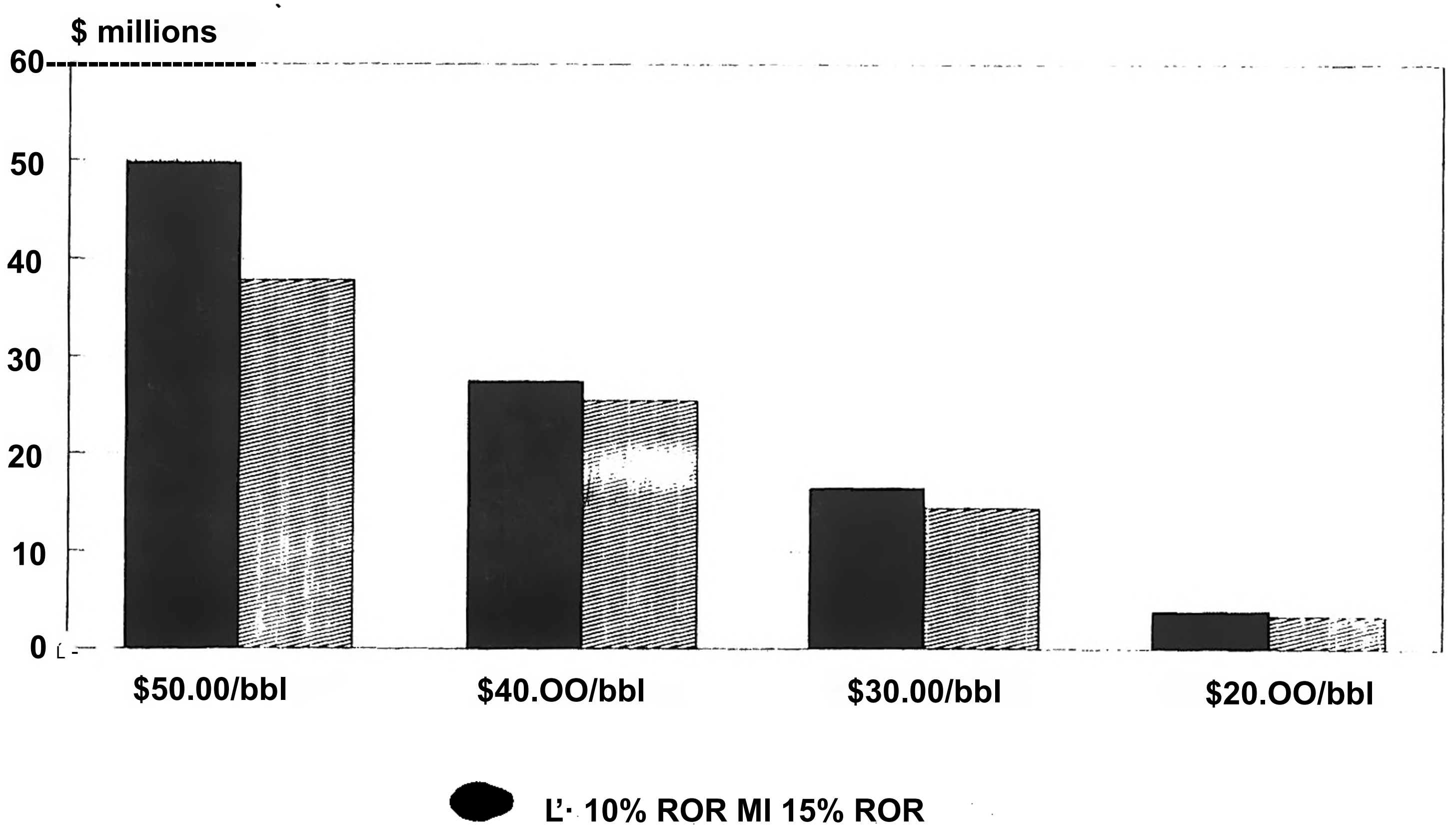


Figure 21

Incremental Tangible Capital Costs

(10% required rate of return)

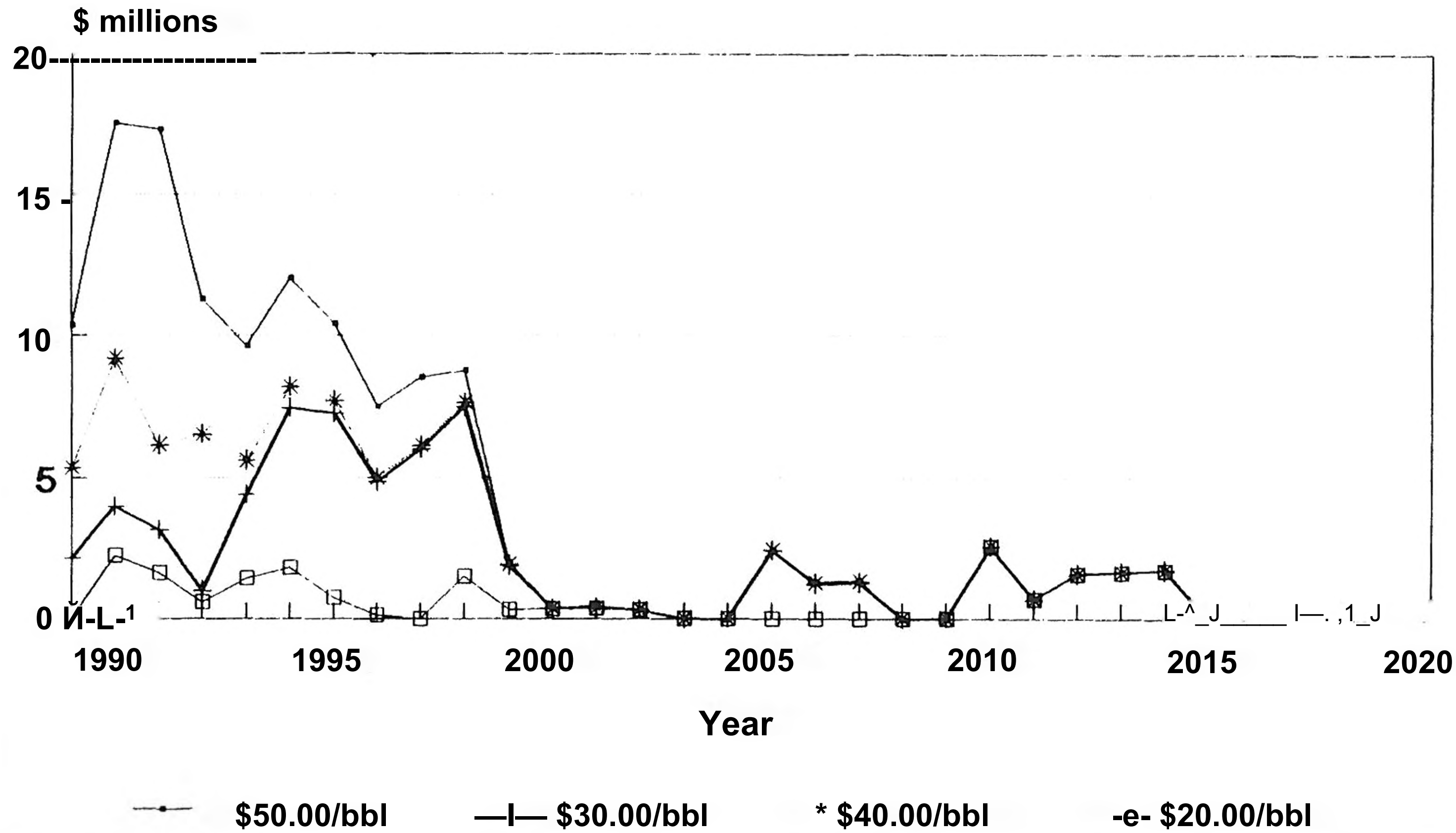
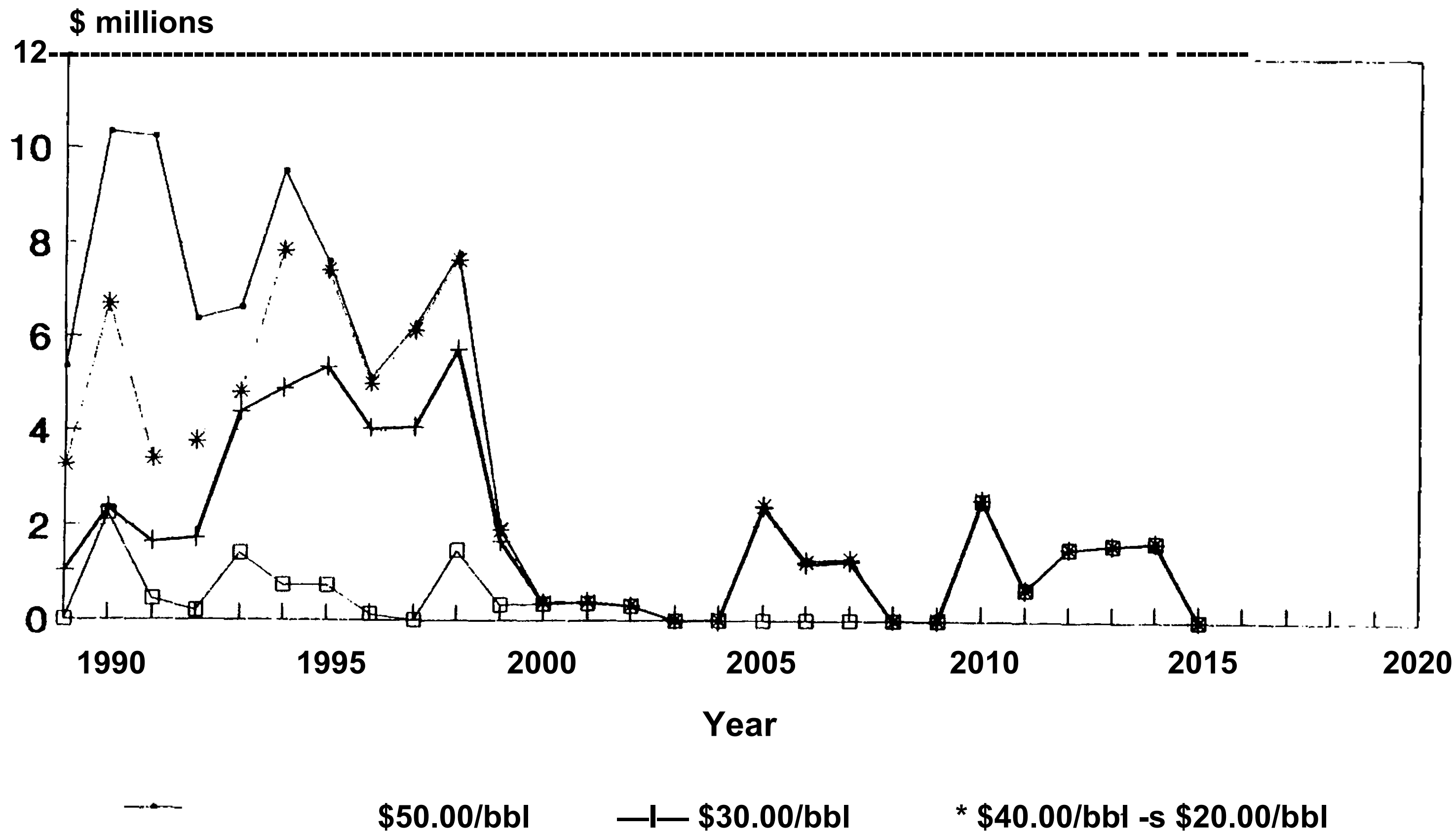


Figure 22

Incremental Tangible Capital Costs

(15% required rate of return)



4
en

Figure 23

Incrementai
Intangible Capital Costs
(10% required rate of return)

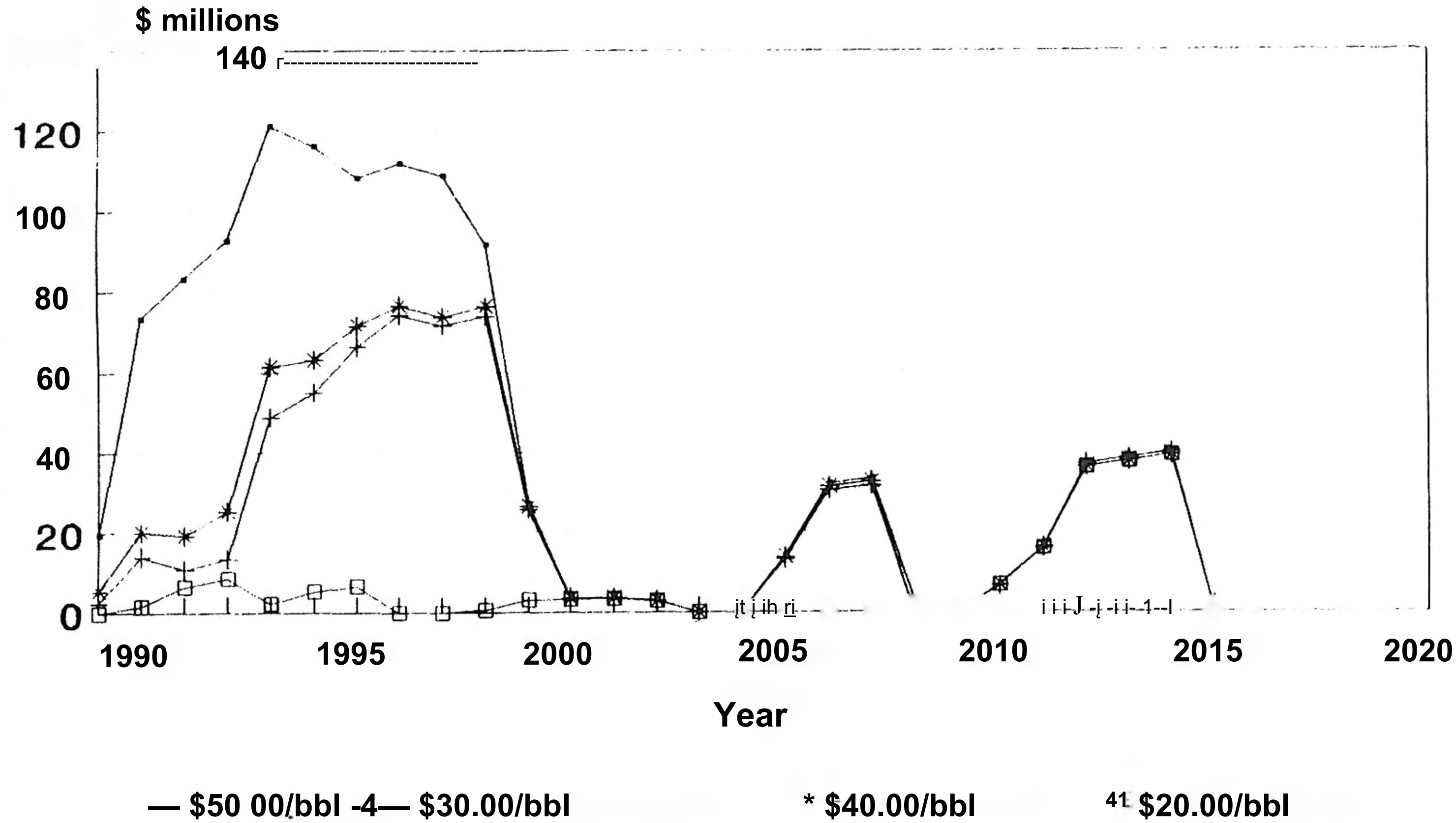


Figure 24

Incremental Intangible Capital Costs
(15% required rate of return)

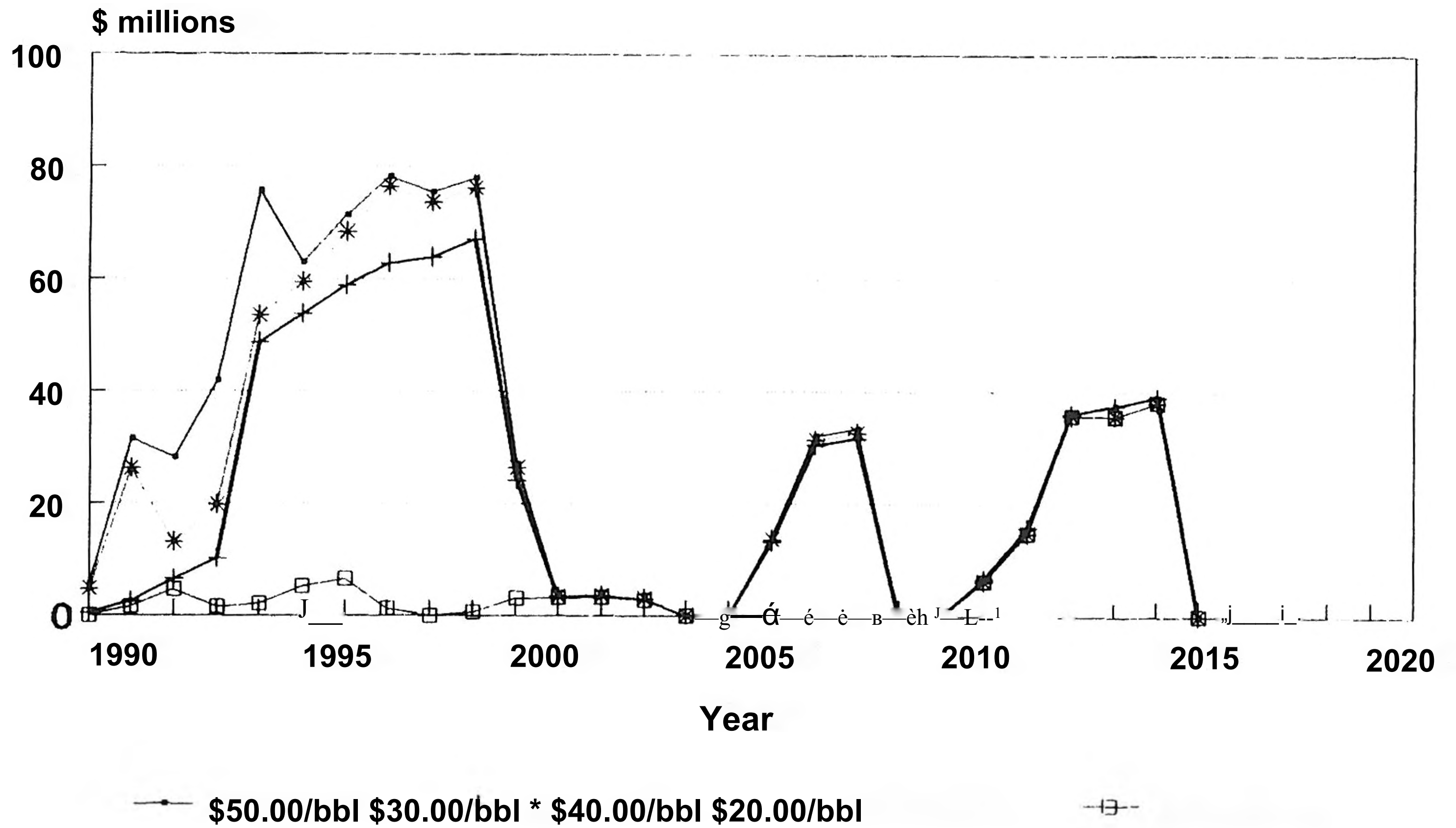
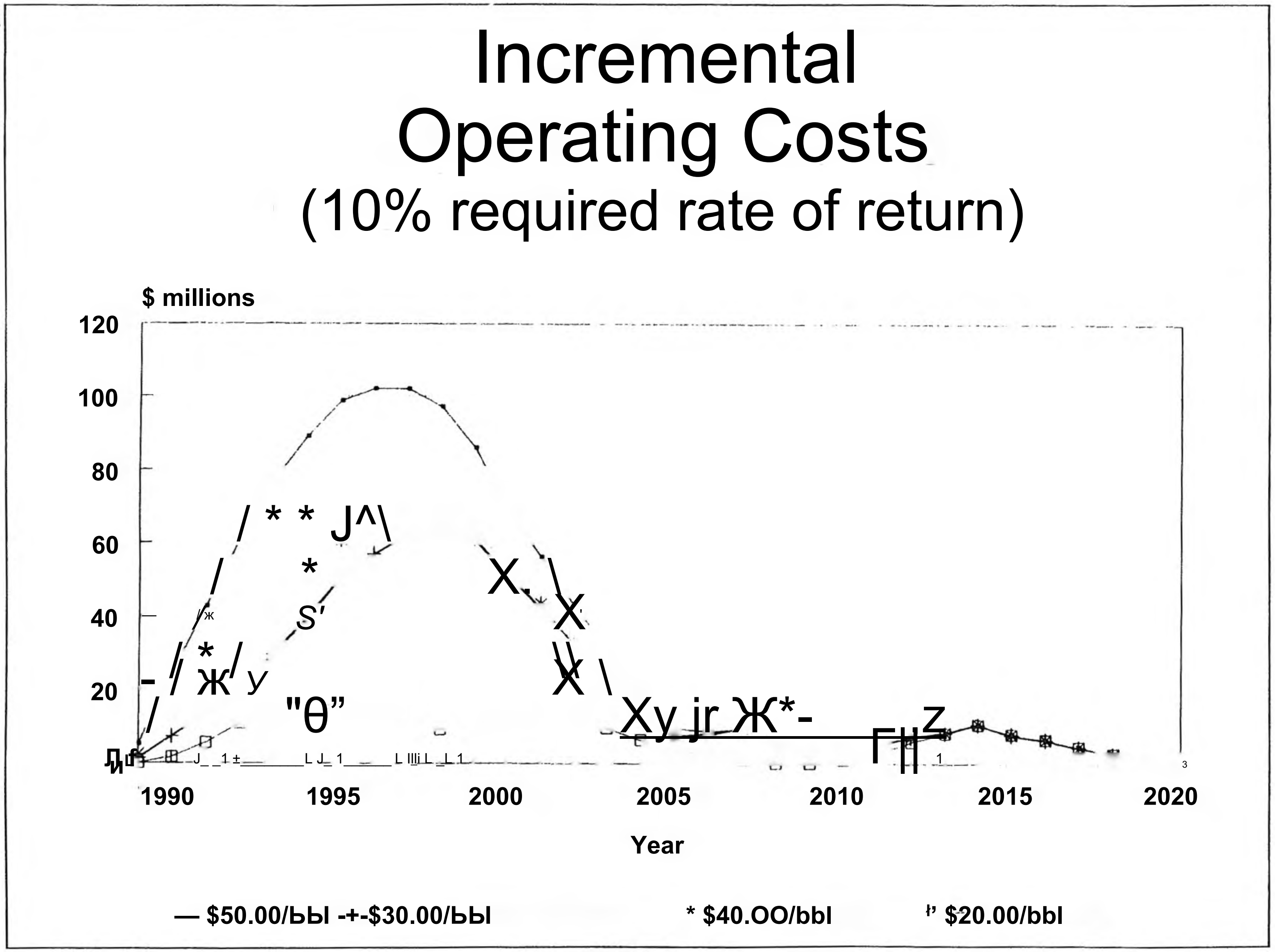


Figure 25



Incremental
Operating Costs
(10% required rate of return)
$ millions
120
100
80
60
40
20
1990
1995
2000
2005
2010
2015
2020
Year
— $50.00/bbl
-+-$30.00/bbl
* $40.00/bbl
$20.00/bbl

Figure 26

Incremental Operating Costs

(15% required rate of return)

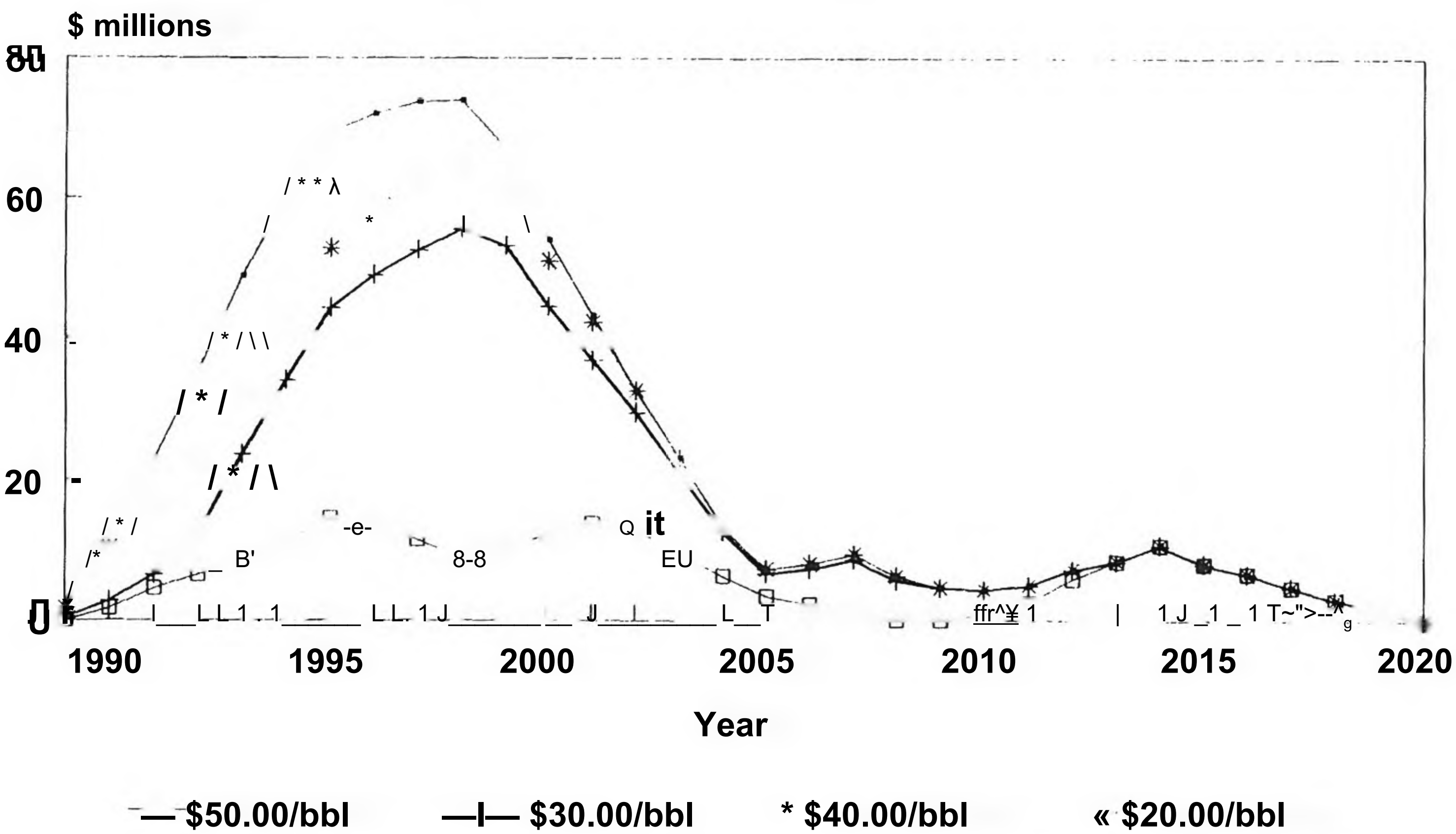


Figure 27

Incremental Operating Costs
(net present value)

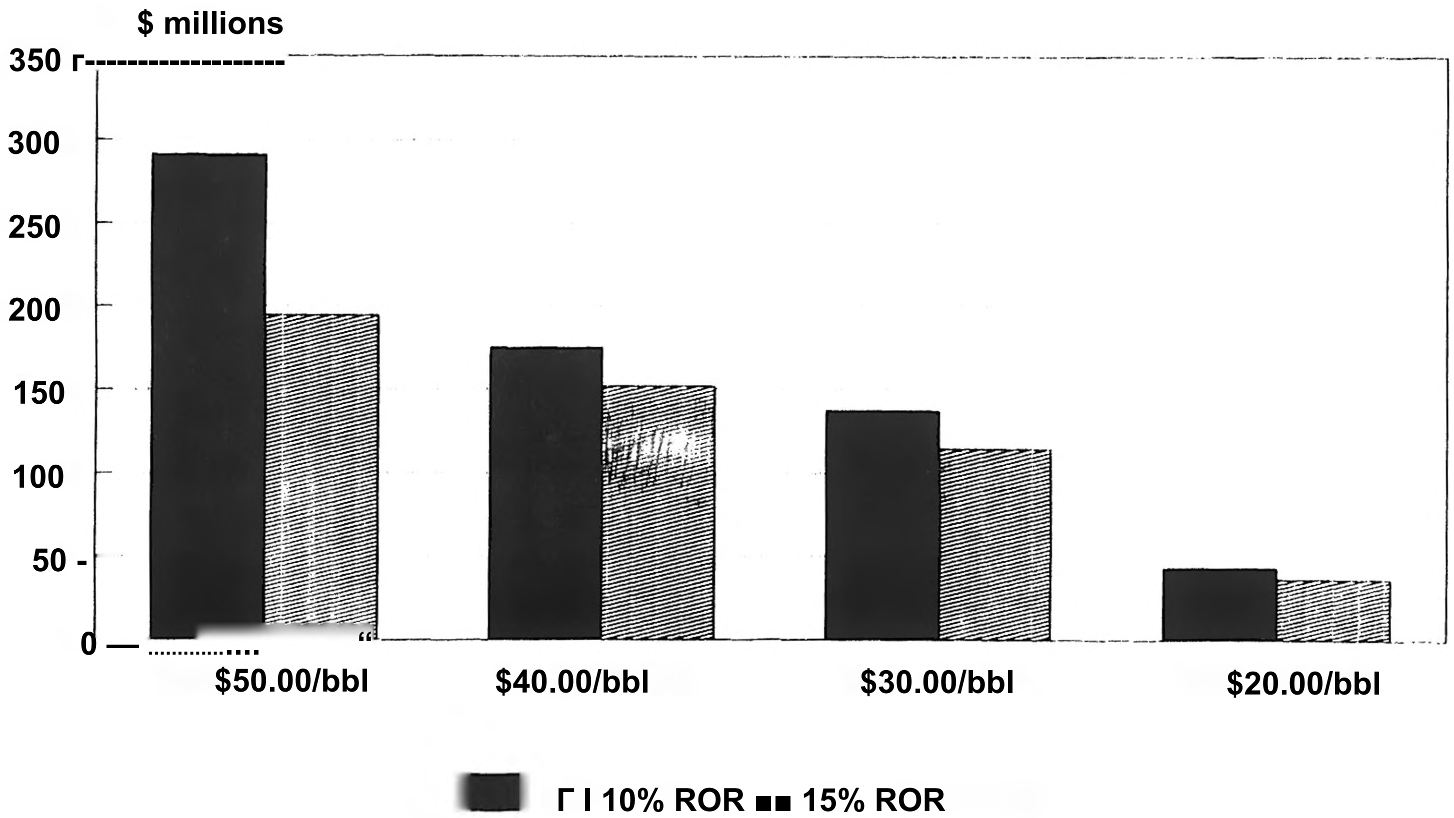
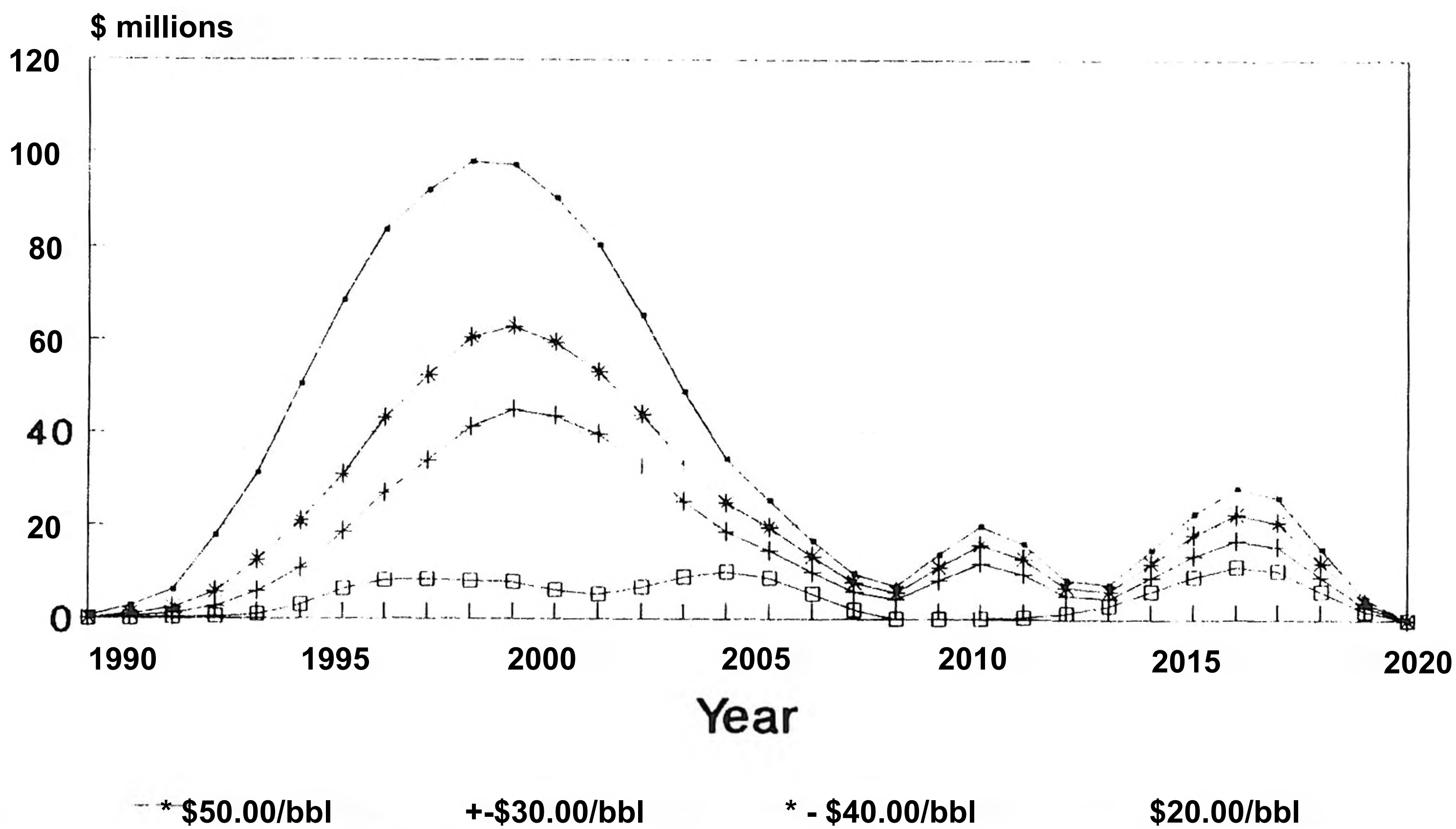


Figure 28

Incremental Royalties

(10% required rate of return)



in
to

Figure 29

Incremental Royalties
(15% required rate of return)

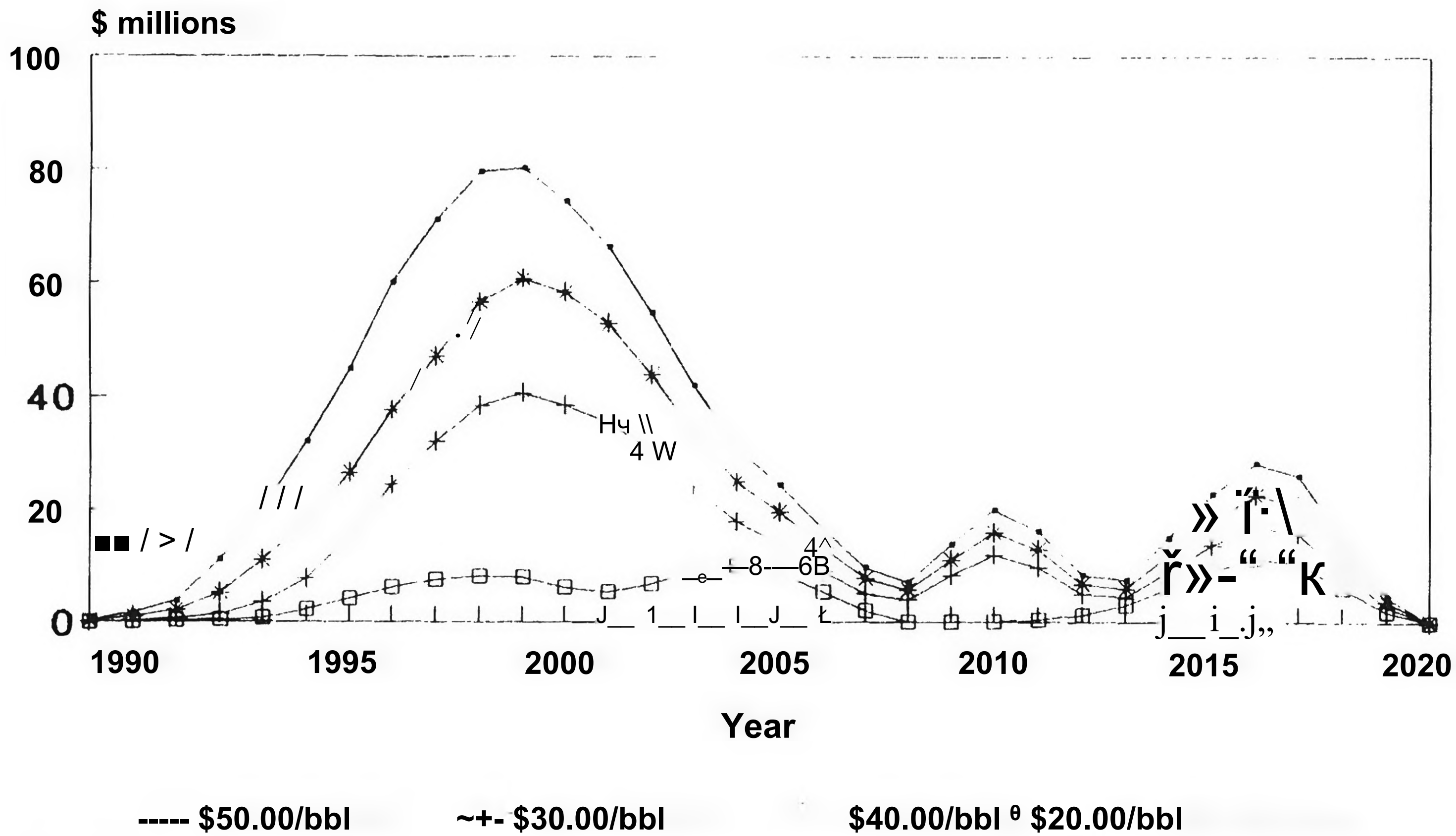


Figure 30

Incremental Royalties
(net present value)

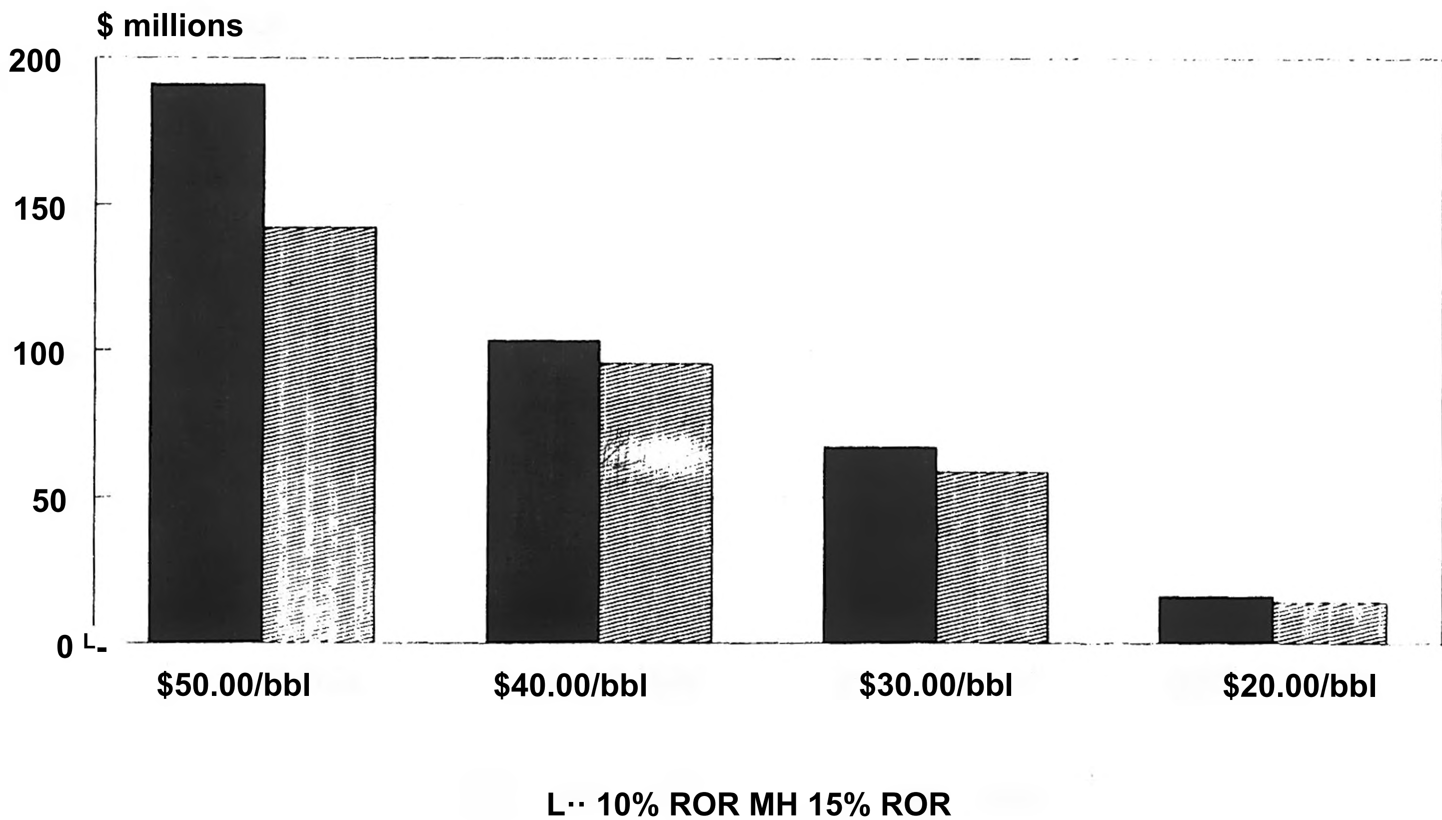
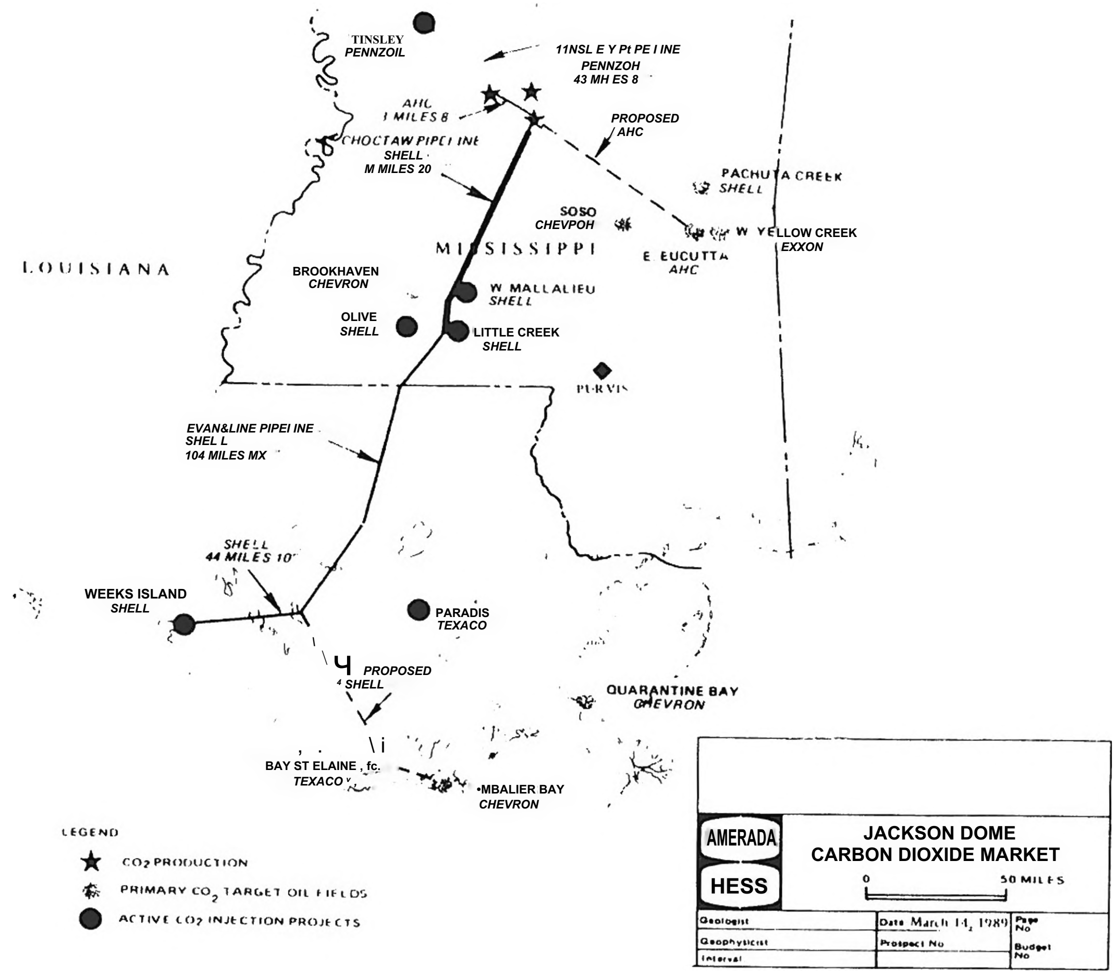


Figure 31


TINSLEY
PENNZOIL
11NSL E Y Pt PE I INE
PENNZOH
43 MH ES 8
AHC
I MILES 8
PROPOSED
AHC
CHOCTAW PIPEI INE
SHELL
M MILES 20
PACHUTA CREEK
SHELL
SOSO
CHEVPOH
W. YELLOW CREEK
EXXON
MISSISSIPPI
E EUCUTTA
AHC
LOUISIANA
BROOKHAVEN
CHEVRON
W MALLALIEU
SHELL
OLIVE
SHELL
LITTLE CREEK
SHELL
PURVIS
EVAN&LINE PIPEI INE
SHEL L
104 MILES MX
SHELL
44 MILES 10"
WEEKS ISLAND
SHELL
PARADIS
TEXACO
PROPOSED
SHELL
QUARANTINE BAY
CHEVRON
BAY ST ELAINE
TEXACO
MBALIER BAY
CHEVRON
LEGEND
CO_2 PRODUCTION
PRIMARY CO_2 TARGET OIL FIELDS
ACTIVE CO_2 INJECTION PROJECTS
AMERADA
HESS
JACKSON DOME
CARBON DIOXIDE MARKET
0
50 MILES
Geologist
Geophysicist
Interval
Date March 14, 1989
Prospect No
Page No
Budget No