BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1986/34

AUSTRALIA'S POTENTIAL FOR FURTHER PETROLEUM DISCOVERIES

(FROM MAY 1986)

BY

D. J. FORMAN

(PAPER PRESENTED AT BMR RESEARCH SYMPOSIUM, NOVEMBER 1986)

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BMR Research Symposium November 1986
Australia's potential for further petroleum discoveries
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D. J. Forman

Mr Chairman, ladies, and gentlemen,

As many of you will know, the Minister released the results of a new assessment of Australia's undiscovered petroleum resources last August. The purpose of this talk is to describe the new method by which this assessment was carried out and to give further details of the results.

Slides 1 and 2

Traditional methods of assessing undiscovered petroleum resources, such as the prospect by prospect method or the Canadian play method, use an equation like the one shown on the left hand slide. This equation is: the volume of oil equals the closure area of the trap, times the net pay thickness, times porosity, times one minus the water saturation, times percent trap fill, times recovery factor, divided by the oil shrinkage factor.

Because the value of each parameter is not known with any certainty before drilling, the range of possible values is input to a Monte Carlo type computer program as a probability distribution, as shown diagrammatically on the slide. A value for each parameter is selected at random from each distribution and the values are then multiplied throughout the equation to give a single value for the undiscovered resource. The process is repeated several thousand times and the assessment of the prospect or play is given as a cumulative probability distribution of resources.

We have called the new method that I will describe today the "trap by trap creaming method". The basic equation for the method is V equals A times V/A as shown on the right hand slide. V, once again, is the field size and A is the closure area of the trap. The ratio V/A is called the retention factor and one of my prime tasks today will be to explain its significance.

Another important difference between the trap by trap creaming method and the traditional methods is that instead of a simple distribution for each parameter, the new method uses a distribution that changes in a systematic manner from one prospect to the next as shown diagrammatically in the slide. This systematic change is attributed to the creaming phenomenon which is the diminishing effectiveness of exploration with exploration effort.

The new method has two main advantages over the traditional methods:
- firstly, it is simpler, involving fewer parameters;
- secondly, it relates the undiscovered resources to the new-field wildcat drilling required to discover them, and we expect to be able to use the method to estimate not only undiscovered resources but also future rates of annual crude oil production.

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The statistical basis for the new method is described in a paper by Alan Hinde and myself which was published in the American Association of Petroleum Geologists Studies in Geology No 21. During todays talk I will describe how we determine values for the retention factor (V/A) and the closure area (A) of each undrilled prospect. Then I will give the results of our latest assessment, in terms of the magnitude and the distribution of our undiscovered resources. I will conclude with comments about how we think the assessment can be improved.

Slides 3 and 4

We have assessed the petroleum potential of the Phanerozoic sedimentary rocks lying on the Australian continent, both onshore and offshore, except for Australia's remote offshore territories. The first step in the assessment was to divide these sedimentary rocks up into a number of fairly independent petroleum systems*.

The left hand slide is a section across an independent petroleum system, showing impermeable shale in green and porous sandstone in yellow. You will notice that a thick shale seal overlies the system and that lesser seals occur within it. Lateral barriers to migration are provided by faults or regional highs such as those that occur on the margins of sub-basins. Ideally, the barriers to migration are such that very little oil or gas escapes from one system to another.

The second step in the assessment was to identify the types of traps that occur in each independent petroleum system. The right hand slide shows the possible trap types simply divided into anticlines, faulted anticlines, palaeotopographic highs, faults, diapirs, reefs, and stratigraphic traps. Obviously, traps can form at different times and can receive and retain different amounts of hydrocarbons. Also, different degrees of exploration risk may be associated with different types of traps. For these reasons each trap type is assessed separately in the trap by trap creaming method.

Slides 5 and 6

The retention factor, V/A, is more than a ratio. The next three slides that I am going to show you will demonstrate that it is a measure of the richness of an independent petroleum system and that it can be estimated by quantitative geochemical and geological modelling.

This slide shows the amounts of oil and gas generated during progressive burial of about 200 metres of good quality non-marine source rock. The vertical axis shows the depth of burial in metres. The horizontal axis shows the cumulative amounts of oil and gas generated, expressed as a vertical height in metres, as though the oil and gas could be removed from the source rock and their thickness or height measured by a gauge at the surface. These amounts could be determined in the laboratory by chemical analysis of samples recovered during drilling.

*Ulmishek, G., & Harrison, W., 1984- Quantitative methods for assessment of petroleum resources of poorly known basins. International Union of Geological Sciences Publication 17, 80-94.

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The red curve shows the cumulative height of gas in metres of oil equivalent. The green curve shows the cumulative height of crude oil and the blue curve shows the cumulative height of crude oil and gas. The slide indicates that about 40 centimetres of oil and oil equivalent gas is generated at a depth of about 4000 metres.

Slides 7 and 8

This slide shows schematically what happens when the hydrocarbons migrate from their source rocks. Beginning with the 40 centimetres of oil and gas generated in the source rocks, we see that only about 10 centimetres will be expelled. Of this amount, some will be dissolved or dispersed along carrier beds and fractures, some will leak from the traps, and some may be lost to the surface, but a proportion, maybe about four centimetres, will be retained in the traps. This amount is called the retention height.

Slides 9 and 10

Suppose now that our hydrocarbons have migrated upwards into the drainage area of the fault trap shown in this slide. As you can see, there is a major fault in the southwest. The structure contours outline a syncline running parallel to the fault and a closed fault trap lying alongside the fault. The closure area of the trap is shown by the hachuring and the drainage area of the trap is outlined in red.

The amount of oil and gas that could be trapped in the prospect can be estimated either by multiplying the drainage area by the retention height of four centimetres or by multiplying the closure area by the retention factor. Nederlof, of Shell International, has stated that there is a fairly strong correlation between the drainage and closure areas of traps. It follows, therefore, that there should also be a strong correlation between the retention factors and the retention heights.

Hence the retention factor is a measure of the richness of an independent petroleum system and it can be estimated by quantitative geochemical and geological modelling, although we have not attempted this at BMR to date.

Slides 11 and 12

For our assessment, we have used projections of historic data to estimate the retention factor, wherever it has been possible. These two slides show the retention factors of the fields that have been discovered within the anticlines in two independent petroleum systems, onshore. In each slide, the ratio, V/A, for each field is plotted on a logarithmic scale in the order in which the field was discovered: that is the retention factor of the first field, then the second, and so on.

The straight lines fitted to the data have gentle slopes to the right. If we assume that future exploration will follow the same trends, we can extrapolate the data trends and use them to predict the retention factors of the undrilled anticlines in each system.

In summary, therefore, there are several ways of estimating the retention factors of the undiscovered fields. We can use quantitative geochemical and geological modelling or we can use projections of historic data. Where geochemical and historical data are lacking, we have to use data from an area with analogous geology.

Slides 13 and 14

Now let's leave consideration of the retention factor and instead have a look at how we can determine the closure areas of the undrilled traps. This slide shows the closure areas of the fault traps that have been drilled in an independent petroleum system, offshore. The closure area of each prospect is plotted on a logarithmic scale in the order in which it was drilled; that is the area of the first prospect, then the second, and so on. The straight line fitted to the data has a slope to the right, indicating a tendency for the explorer to drill the larger structures early.

If we assume that future exploration will follow the same trend, we can extrapolate the data trend and use this to indicate the closure areas of the undrilled fault traps and the order in which they are likely to be drilled. Another way of estimating the closure areas is to measure them directly from a seismic map. Where historical data and seismic maps are both lacking, we have to use data from an area with analogous structure.

We use a computer program to estimate the undiscovered petroleum resources of each trap type. The program simulates drilling the prospects within each trap type in each independent petroleum system, and when discoveries are simulated their size is estimated by multiplying together the predicted values for the retention factor and the closure area. This program also uses other types of information such as existence risk, success rate, the proportion of oil to gas, and a minimum cut-off for the field size.

Slides 15 and 16

We use another computer program to add up our estimates of the undiscovered petroleum resources in the various trap types. As you will see, this can be done several ways, so that we can obtain totals by region, by the age of the rocks, or by trap type.

These two slides show the assessments of Australia's undiscovered oil and gas resources. The oil assessment on the left indicates that Australia has the potential to find somewhere between about 1000 and 5000 million barrels of crude oil, with an average of about 2400 million barrels, which is comparable to the 2600 million barrels of our previous assessment. The gas assessment on the right indicates the potential to find between 10 and 45 trillion cubic feet of sales gas with an average of about 23 TCF.

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It should be realised that these figures refer only to conventional oil and gas accumulations contained in structures or stratigraphic traps that are not presently known to contain oil or gas. More oil will, of course be proved up in identified fields and there are undiscovered condensate resources that have yet to be assessed. Of the totals shown only a proportion will occur in fields that would be economic to produce at todays prices.

Slides 17 and 18

The slide on the left shows eight of Australia's most prospective sedimentary areas ranked in order of the average estimate of their undiscovered oil resources, in millions of barrels. According to the assessment, the most prospective areas are the offshore parts of the Bonaparte and Carnarvon Basins.

The slide on the right shows six of Australia's most prospective sedimentary basins ranked in order of the average estimate of their undiscovered gas resources, in trillions of cubic feet. According to this assessment, the most prospective areas are the northwest shelf, offshore, and the Cooper Basin, onshore.

Slides 19 and 20

These two slides show the distribution of our undiscovered petroleum resources according to the age of the sedimentary rocks within which they occur. Again crude oil is shown on the left and sales gas is shown on the right. Each slide shows: a low value corresponding to the 95 percent probability shown in green, an average value shown at the top of the pale green, and a high value corresponding to the 5 percent probability shown at the top of the yellow. According to the assessment, the Jurassic to Recent sequence has the greatest potential for further oil discoveries and the Permian and Triassic sequence has the greatest potential for further gas discoveries.

Slides 21 and 22

The last two slides show the distribution of our petroleum resources by trap type. Crude oil is shown on the left and sales gas on the right. In each slide, the amount of our identified resources is shown below, in purple, and the average amount of our undiscovered resources is shown above, in blue.

Whereas most of our identified oil occurs in anticlines and palaeotopographic highs, most of our undiscovered oil is expected to occur in faulted anticlines and fault traps. Most of our identified gas occurs in faulted anticlines and fault traps and most of our undiscovered gas is expected to occur in the same trap types.

How can we improve the assessments carried out by the trap by trap creaming method? In this assessment we have had to rely heavily on projections of historic data and on analogue data to obtain estimates for the retention factor and the closure area of each prospect. We hope in the future to obtain independent estimates of the retention factor by quantitative modelling of 6 the generation, migration, and entrapment of petroleum. We also wish to obtain independent estimates of the closure areas of the prospects by actually measuring them on the seismic maps.

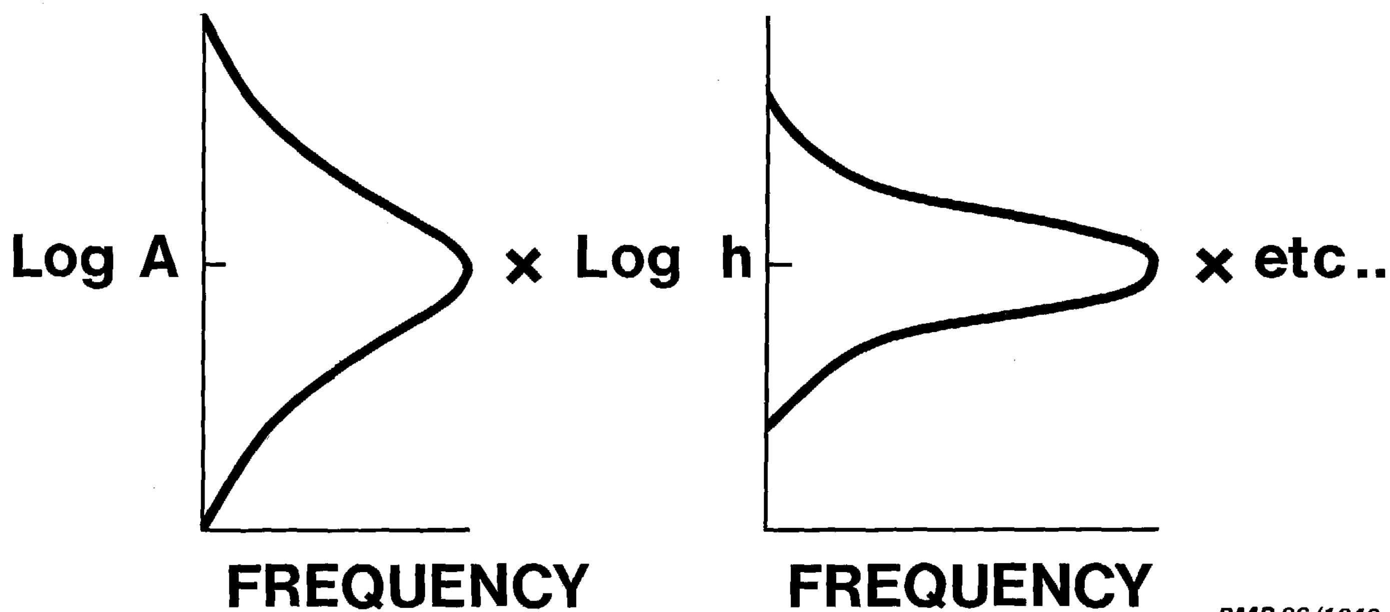
In summary, BMR has developed and adopted a new method for the assessment of Australia's undiscovered petroleum resources, which we have called the trap by trap creaming method. The computer program that we use simulates drilling the prospects in each trap type in each independent petroleum system and when discoveries are simulated their size is estimated by multiplying together the predicted values for the retention factor and the closure area. The program also uses other types of information such as existence risk, success rate, the proportion of oil to gas, and a minimum cut-off for the field size.

Estimates of the amount and distribution of Australia's undiscovered petroleum resources by the new method give similar results to those obtained in our previous assessment.

In conclusion, I wish to acknowledge the assistance of a large number of people in the preparation of the assessment, and in the preparation of this talk, particularly:
Alan Hinde who wrote the computer programs,
Shige Miyazaki, Murray Jones, and Lyndelle Darke, who helped compile the historic data and run the computer programs,
The geoscientists from throughout BMR who provided the input for assessments of individual areas,
A number of private companies and State mines departments who provided data for use in the assessment,
Trevor Powell, Colin Robertson, and Lee Ranford for criticising the text of this talk,
Steve Cadman for assistance with one of the slides,
and Ken Barrett and Rosa Fabbo for drafting the slides.

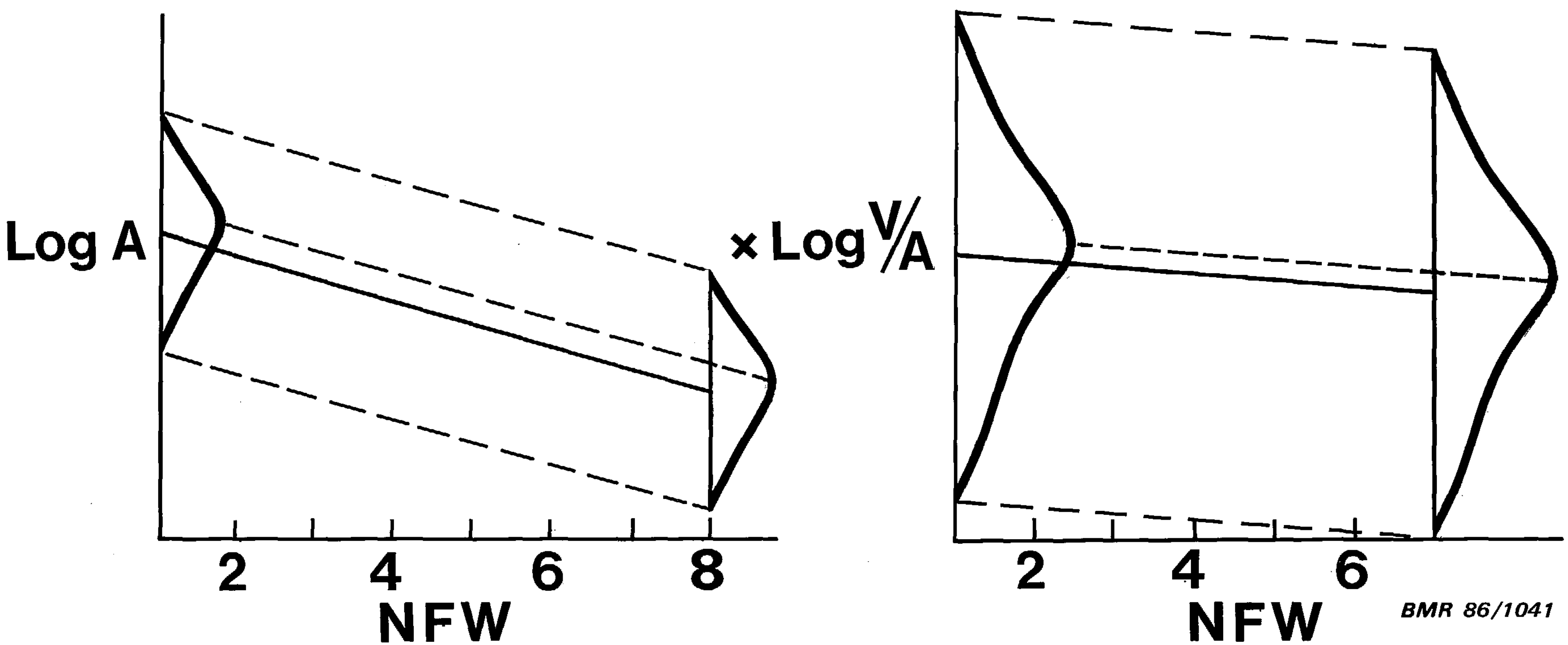
SLIDE 1

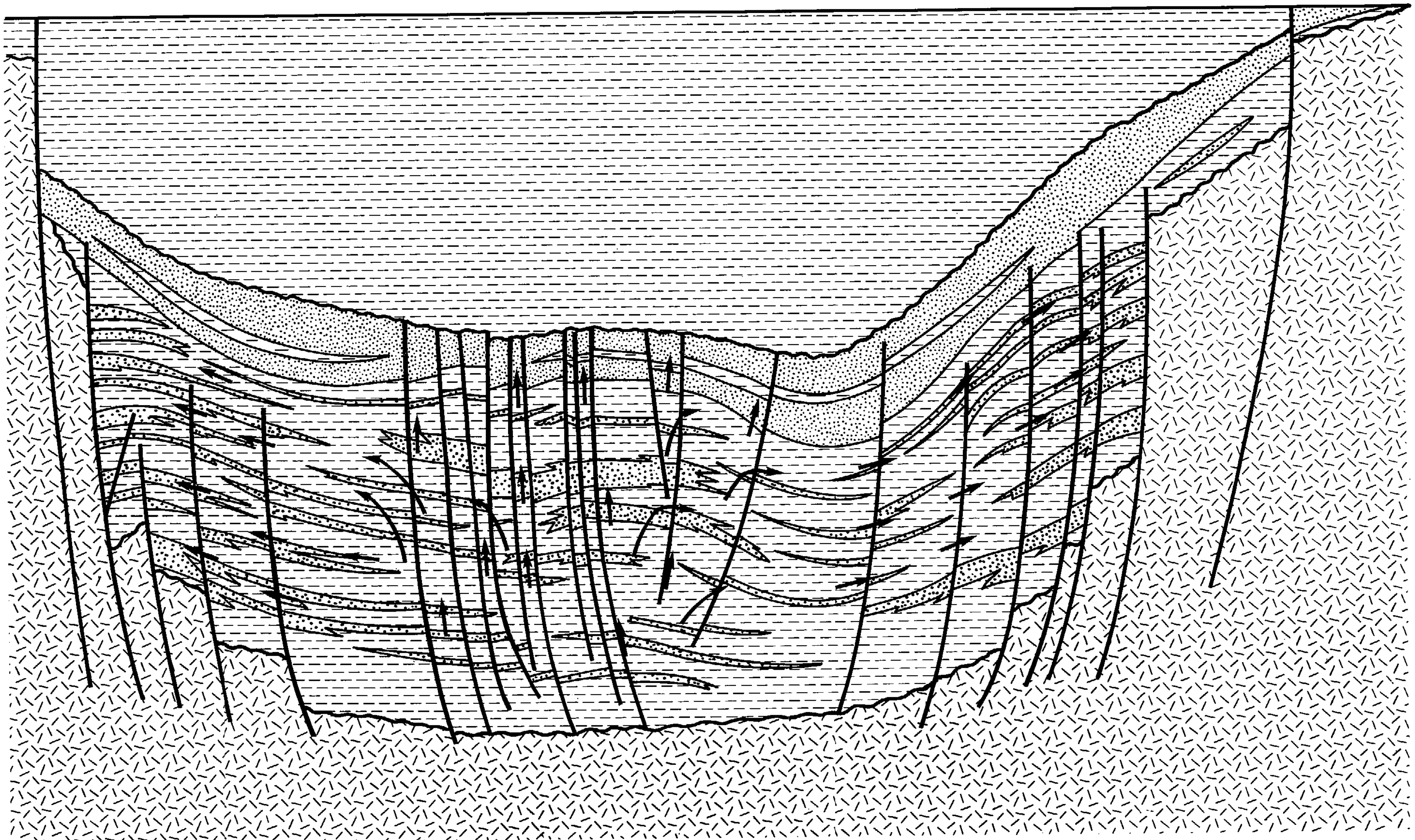
$$V = \frac{A \times h \times \phi \times (1 - S_W) \times \%TF \times RF}{B_O}$$



BMR 86/1040

$$V = A \times V/A$$





MIGRATION PATH

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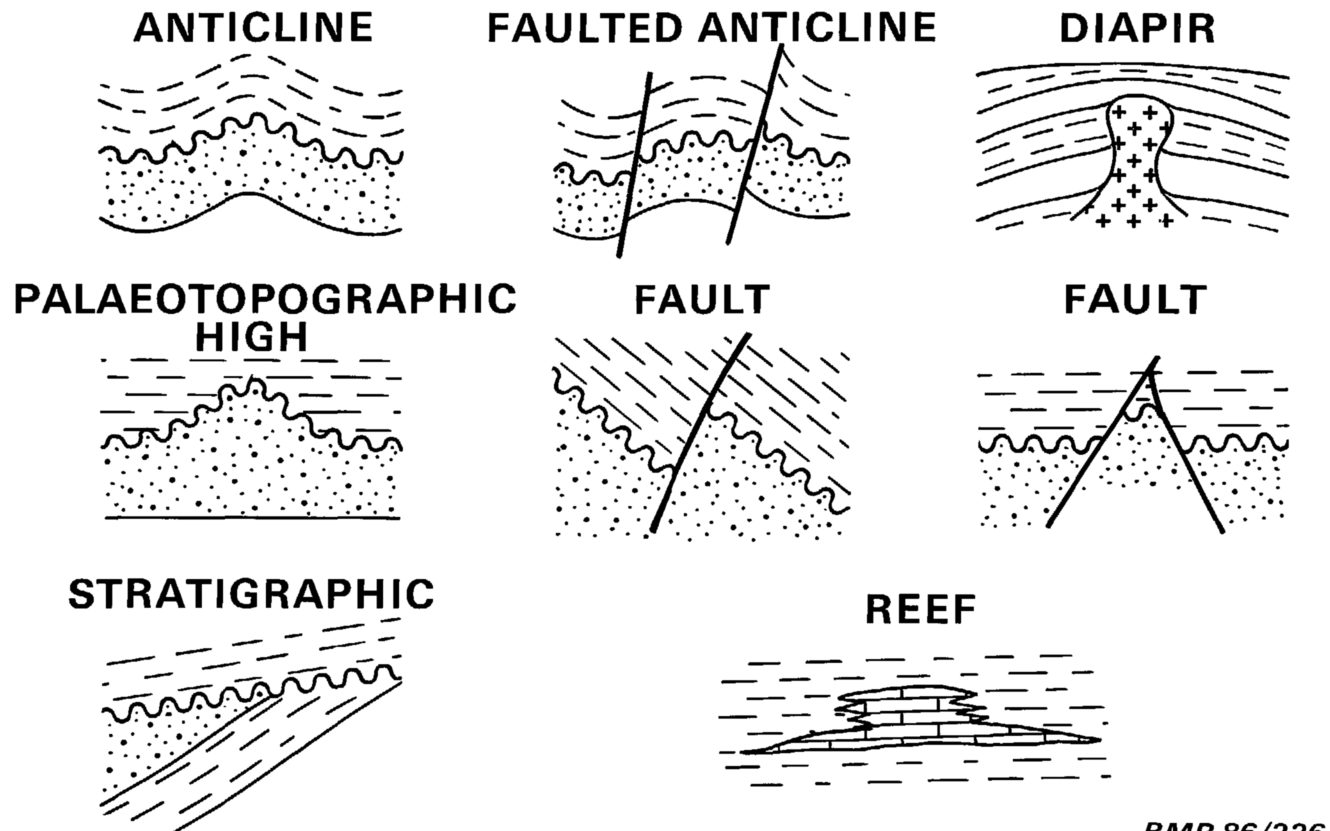
SLIDE 4



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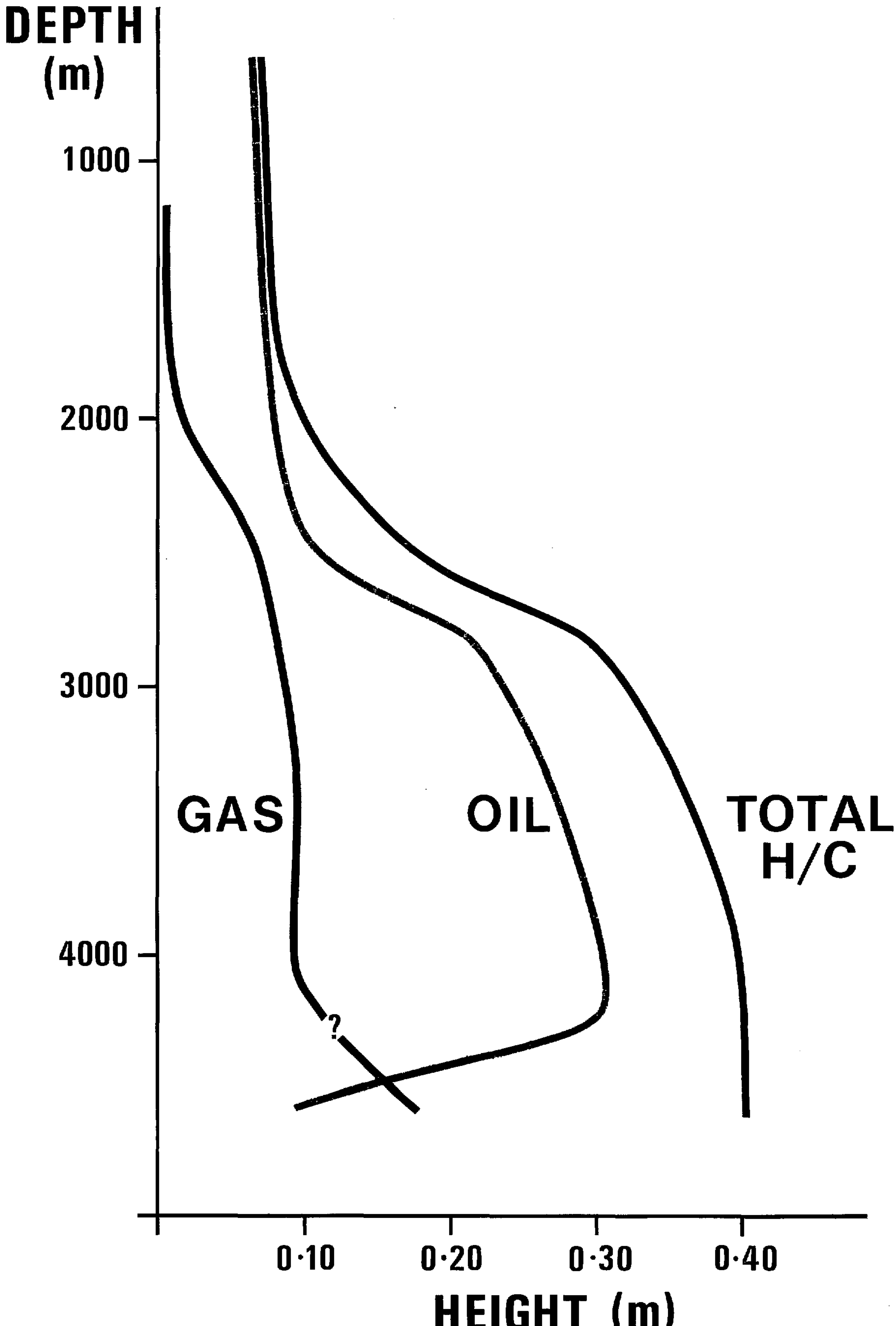
SLIDE 5



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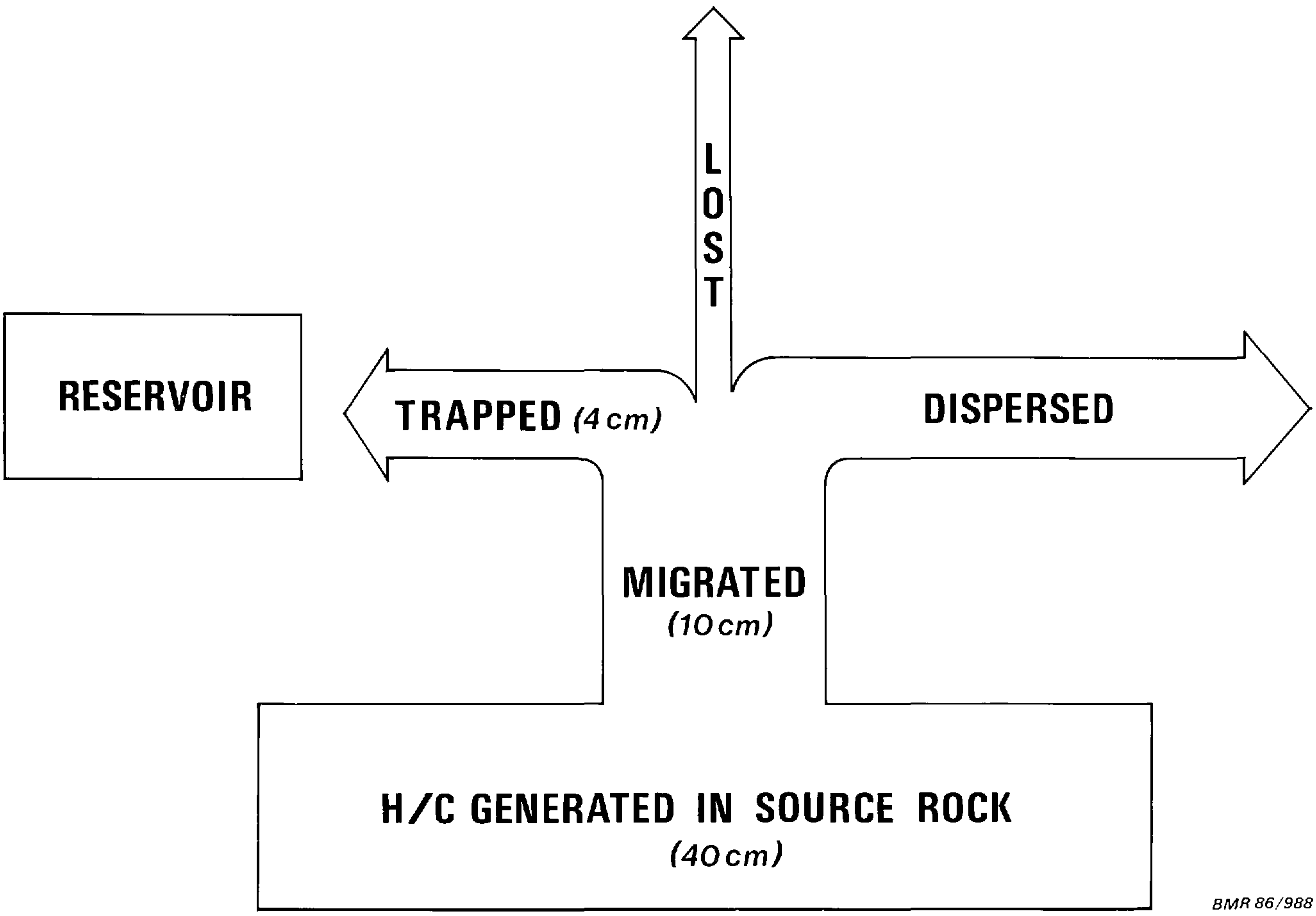
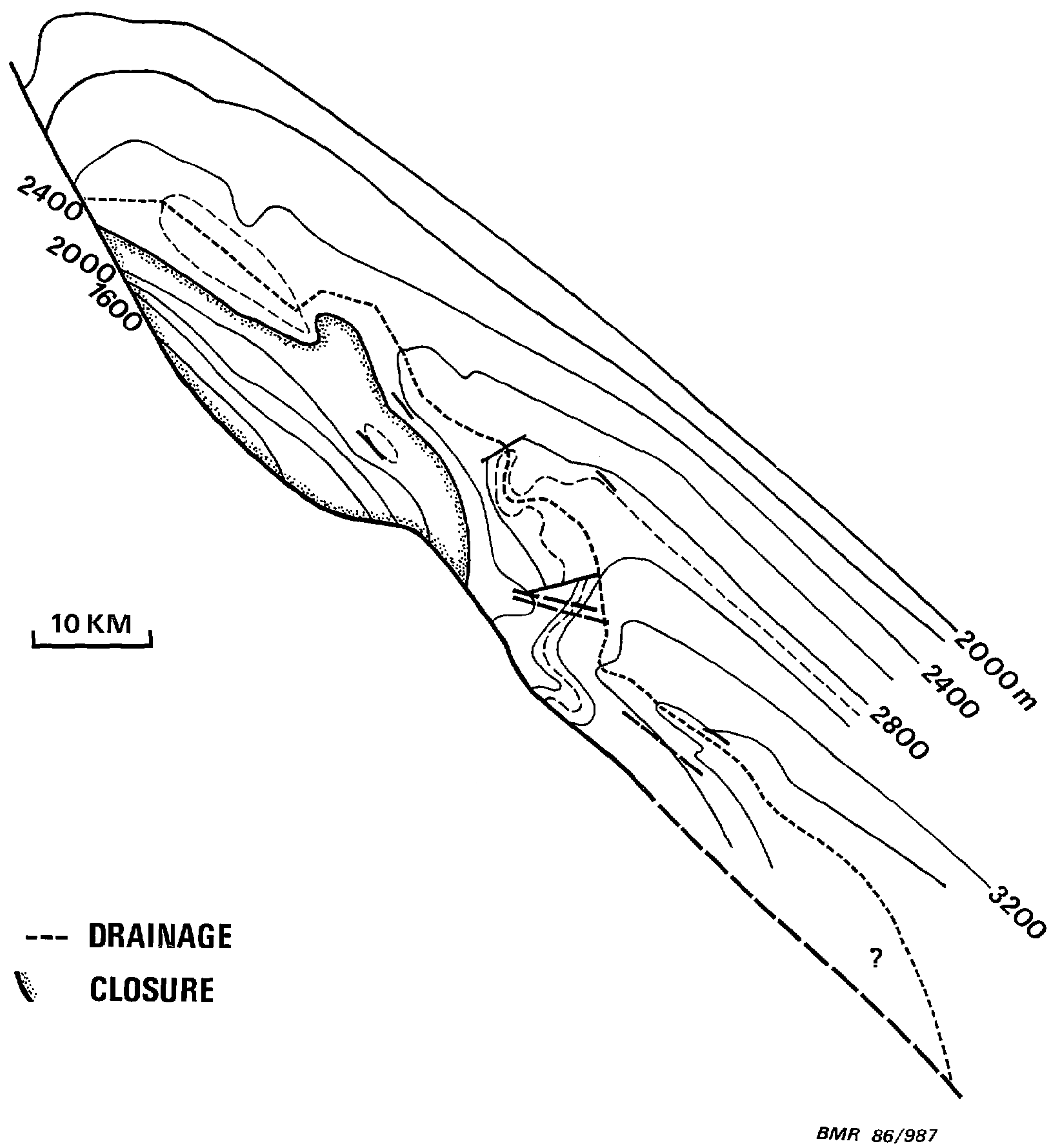
SLIDE 7



Modified after McDowell, 1975,
Oil and Gas Journal, June 9, Fig.1

SLIDE 9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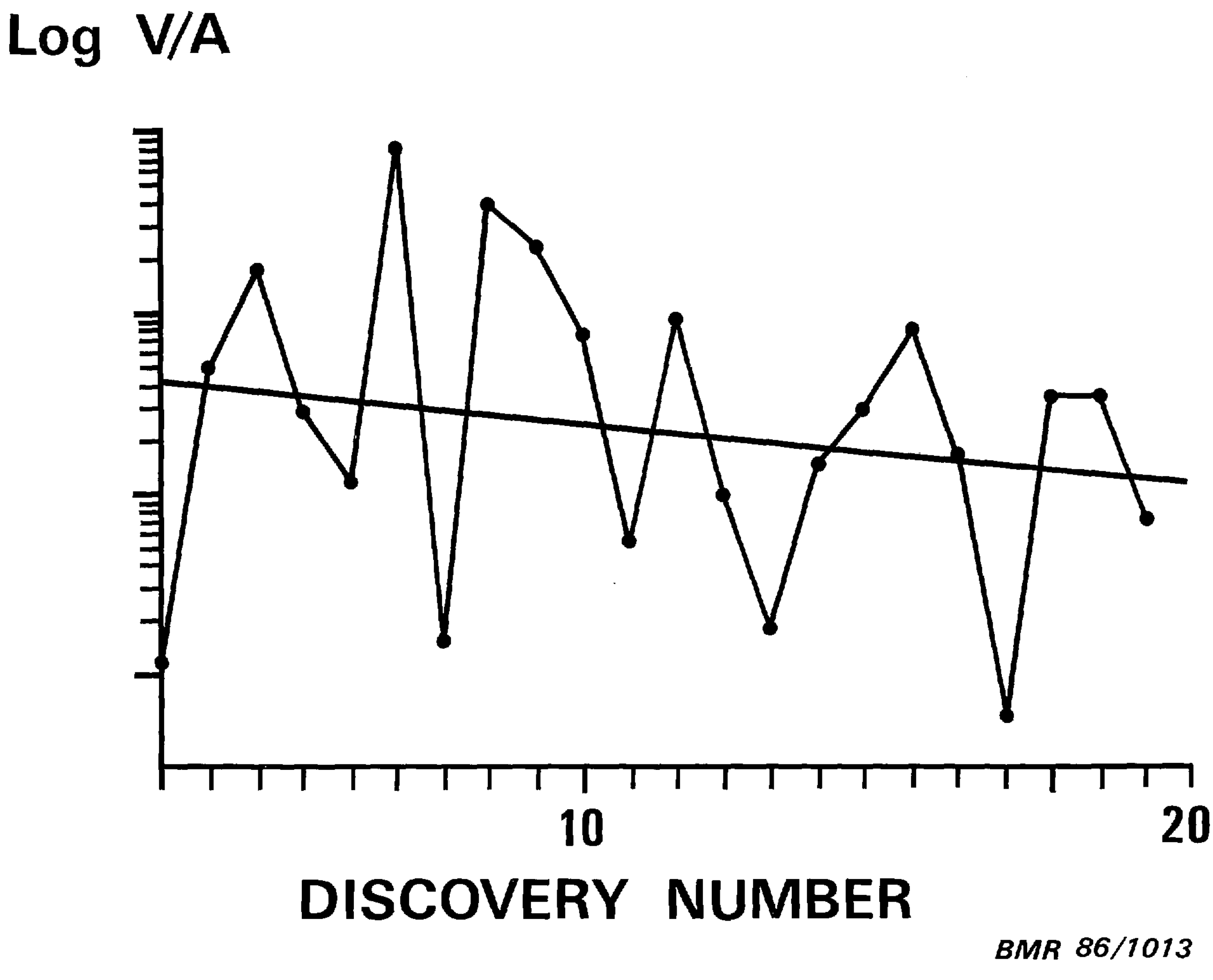
BMR 86/987

SLIDE 11



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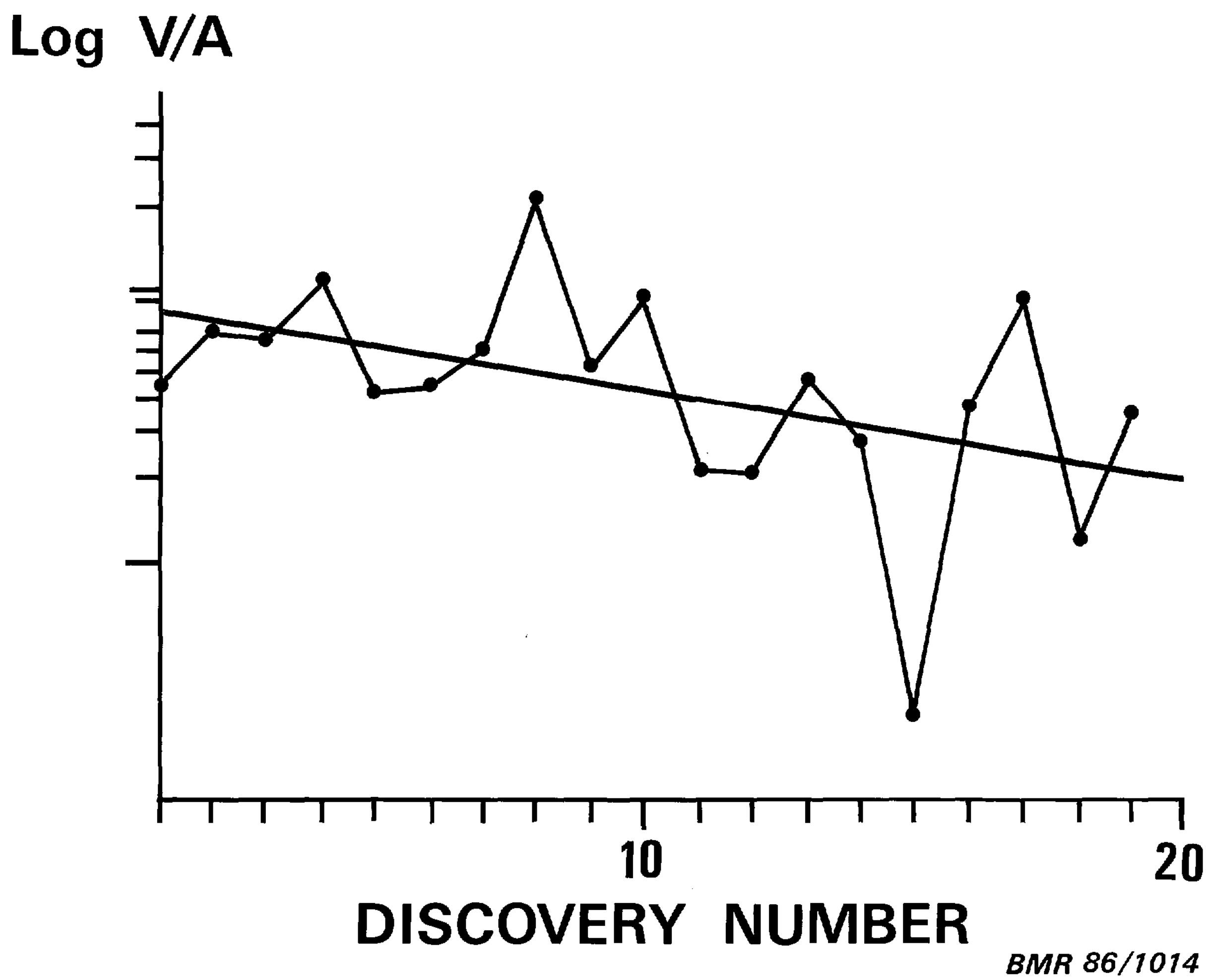
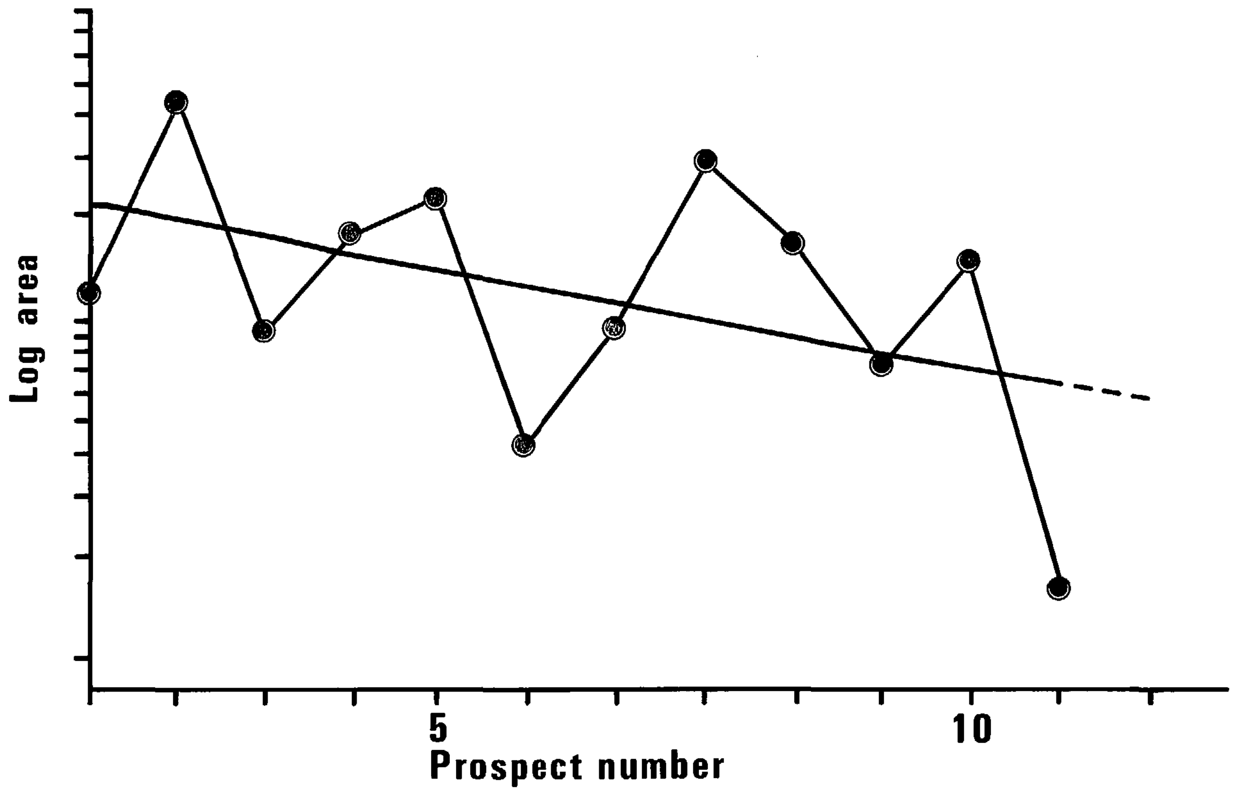
SLIDE 12



SLIDE 13



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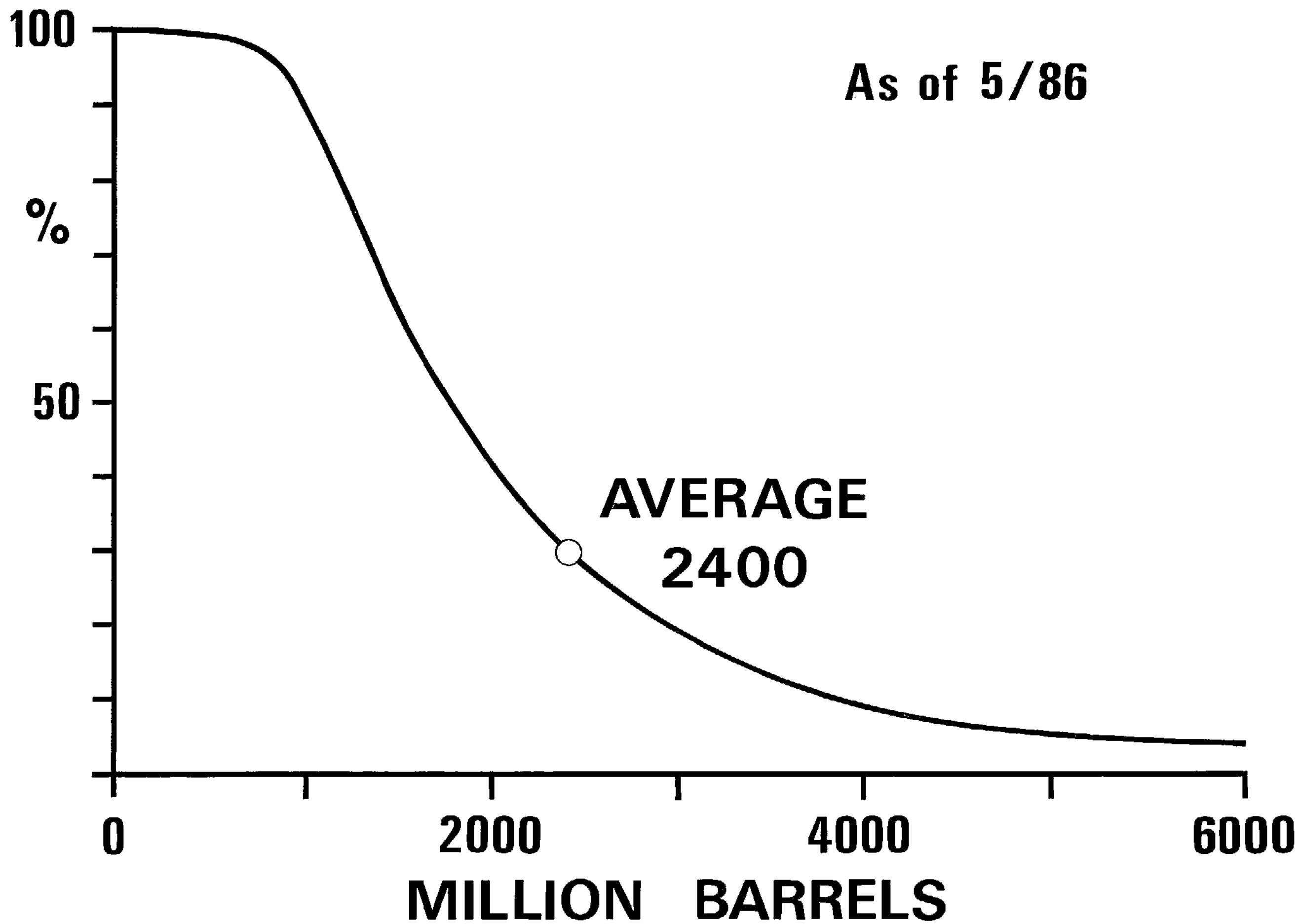
SLIDE 15



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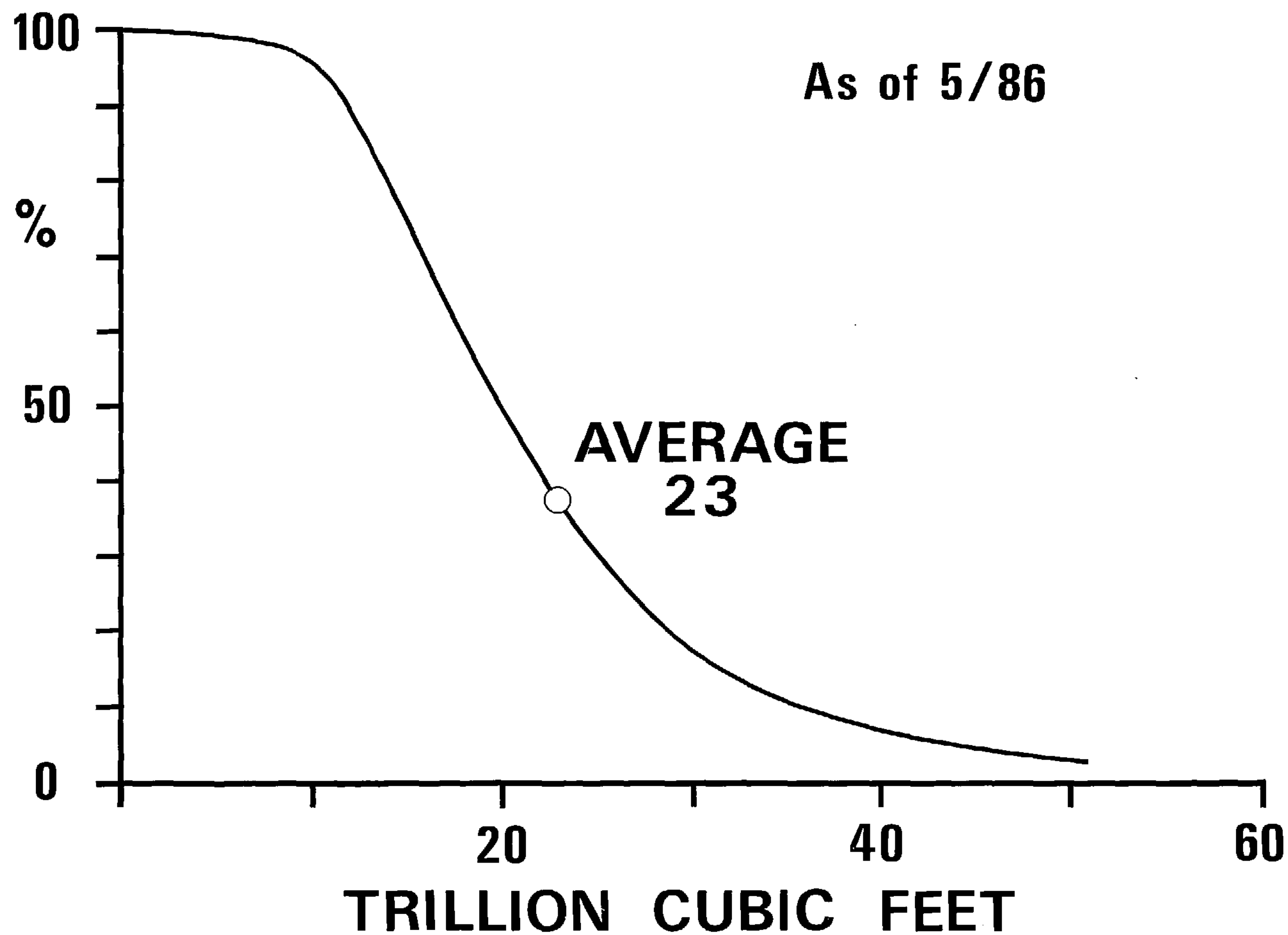
SLIDE 16



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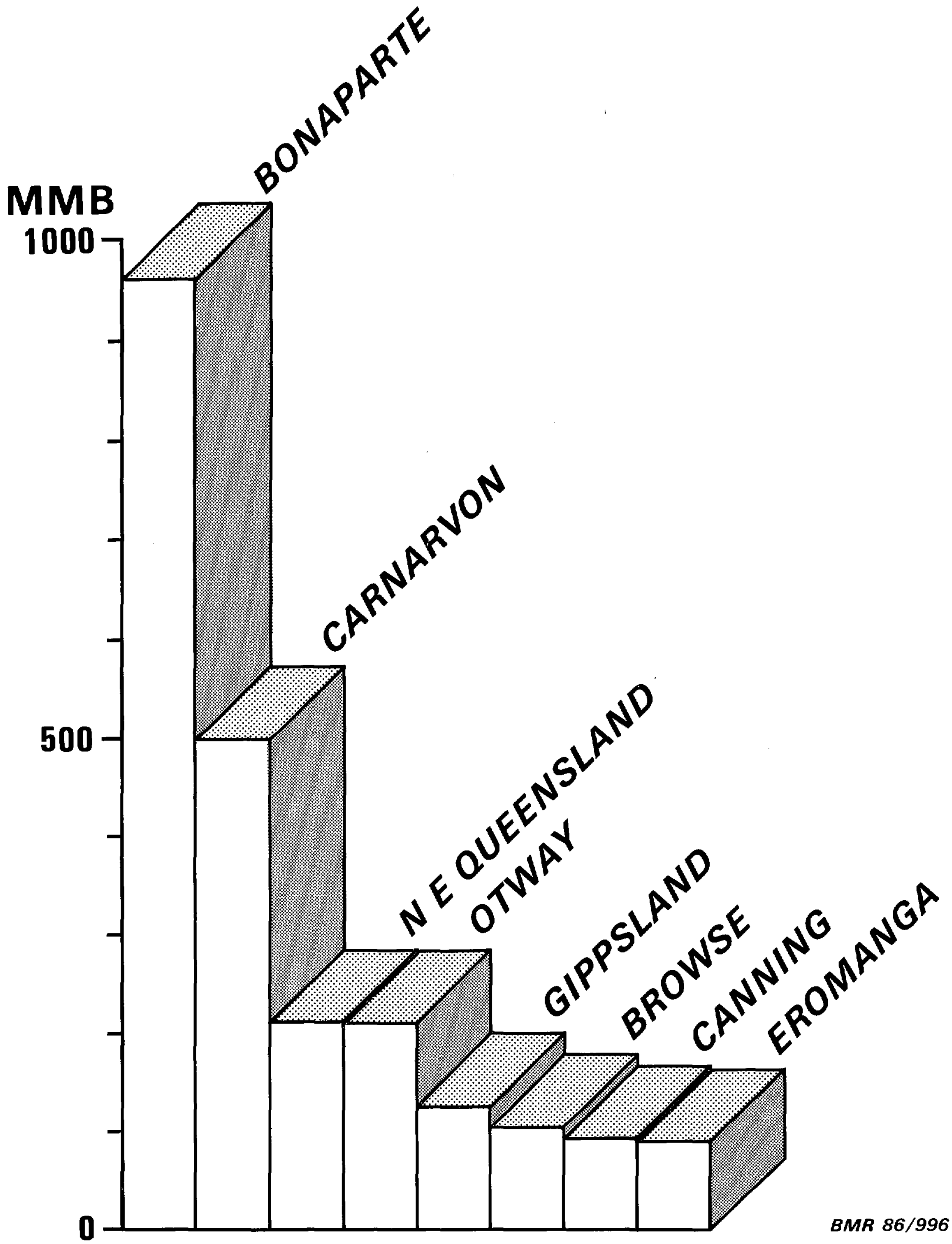
SLIDE 17



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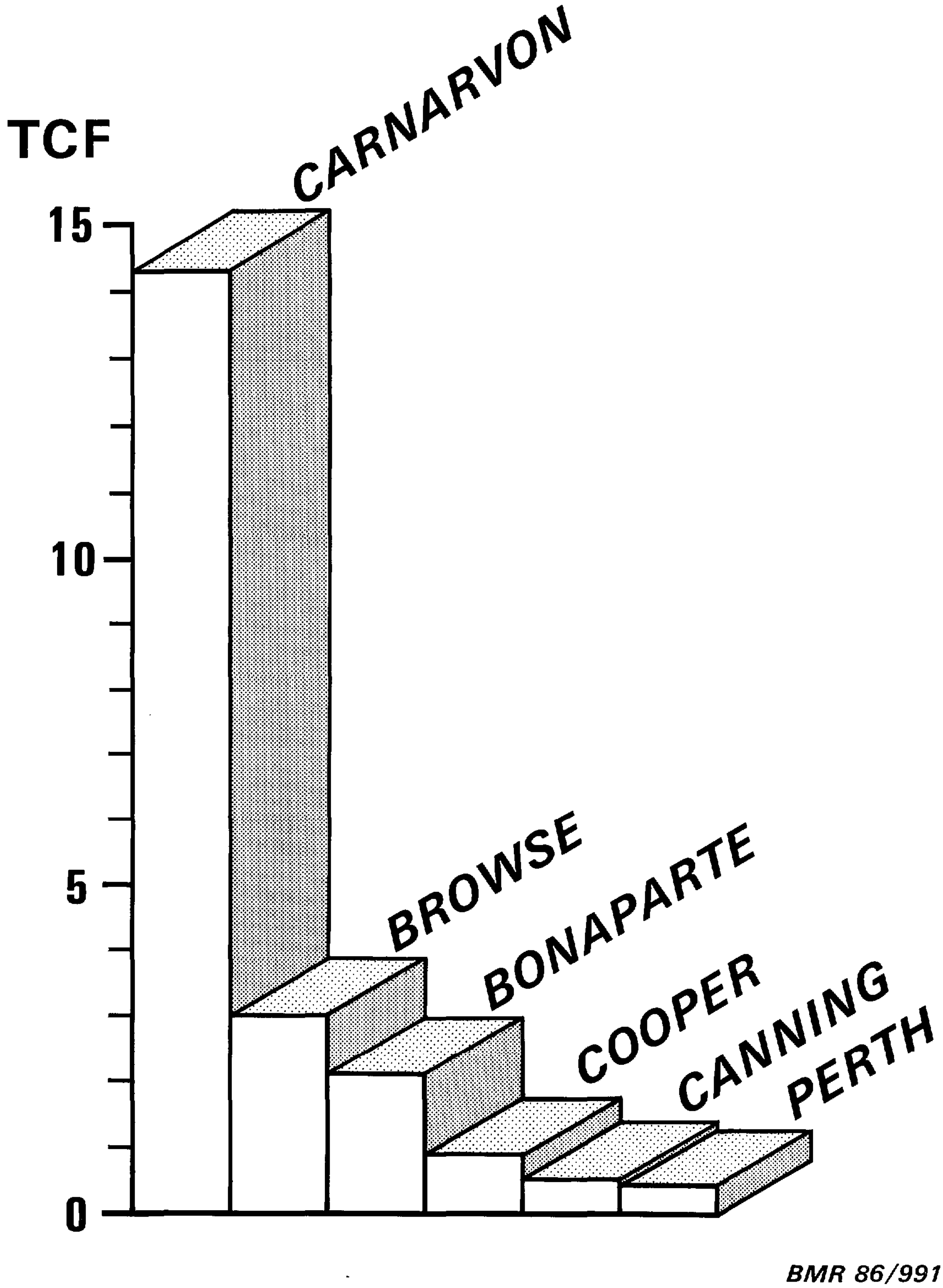
SLIDE 18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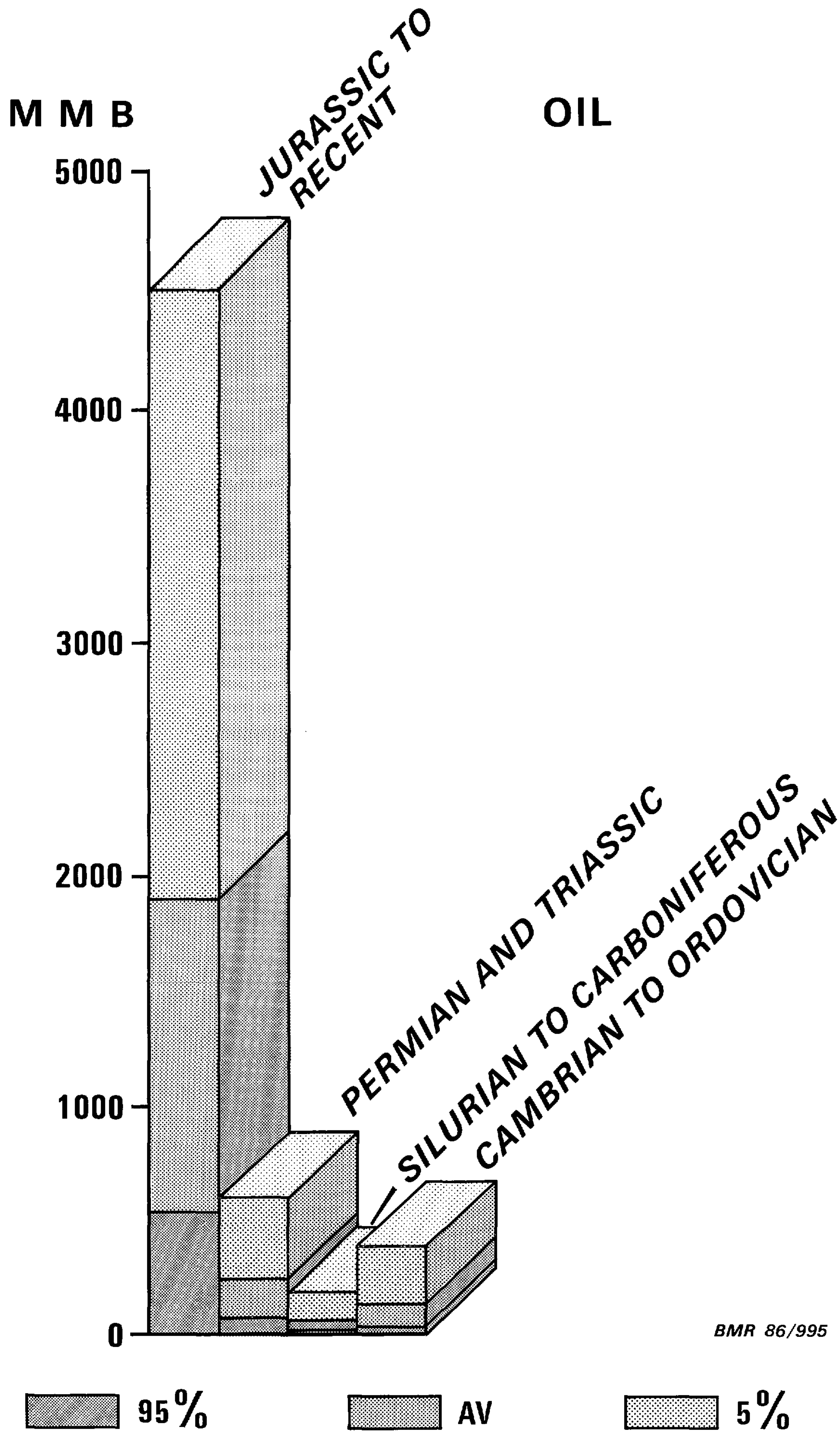
SLIDE 19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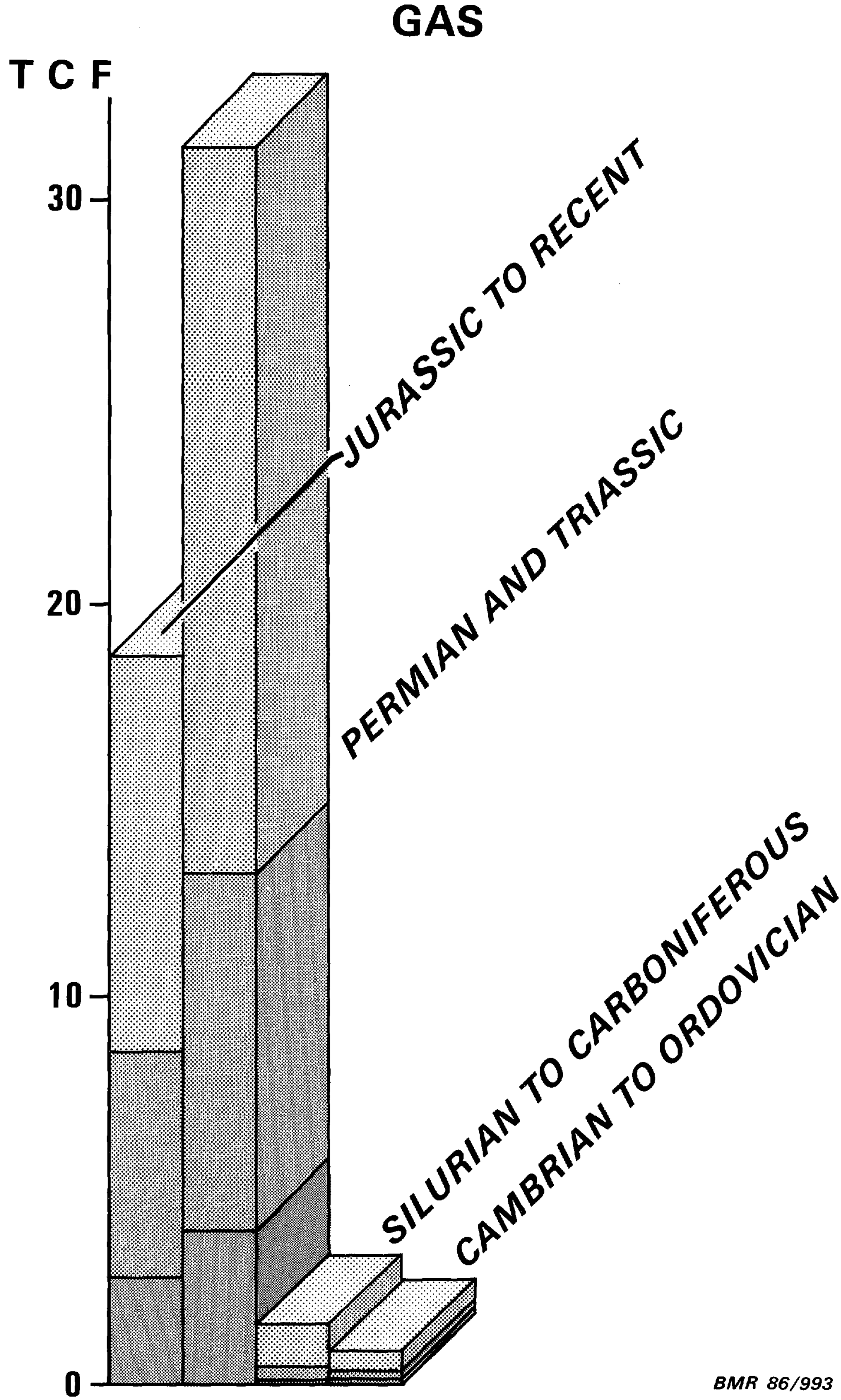
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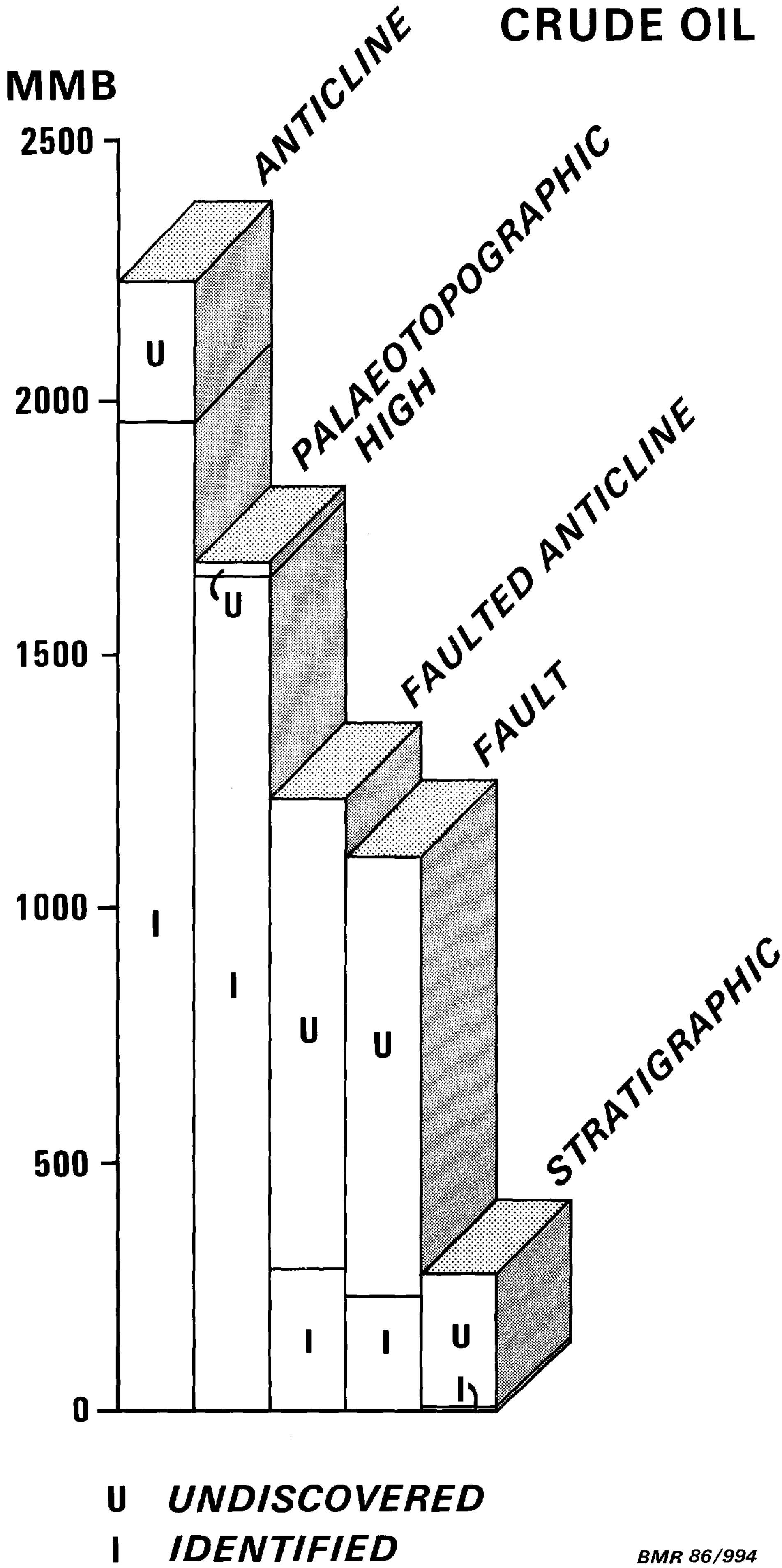
SLIDE 21

CRUDE OIL



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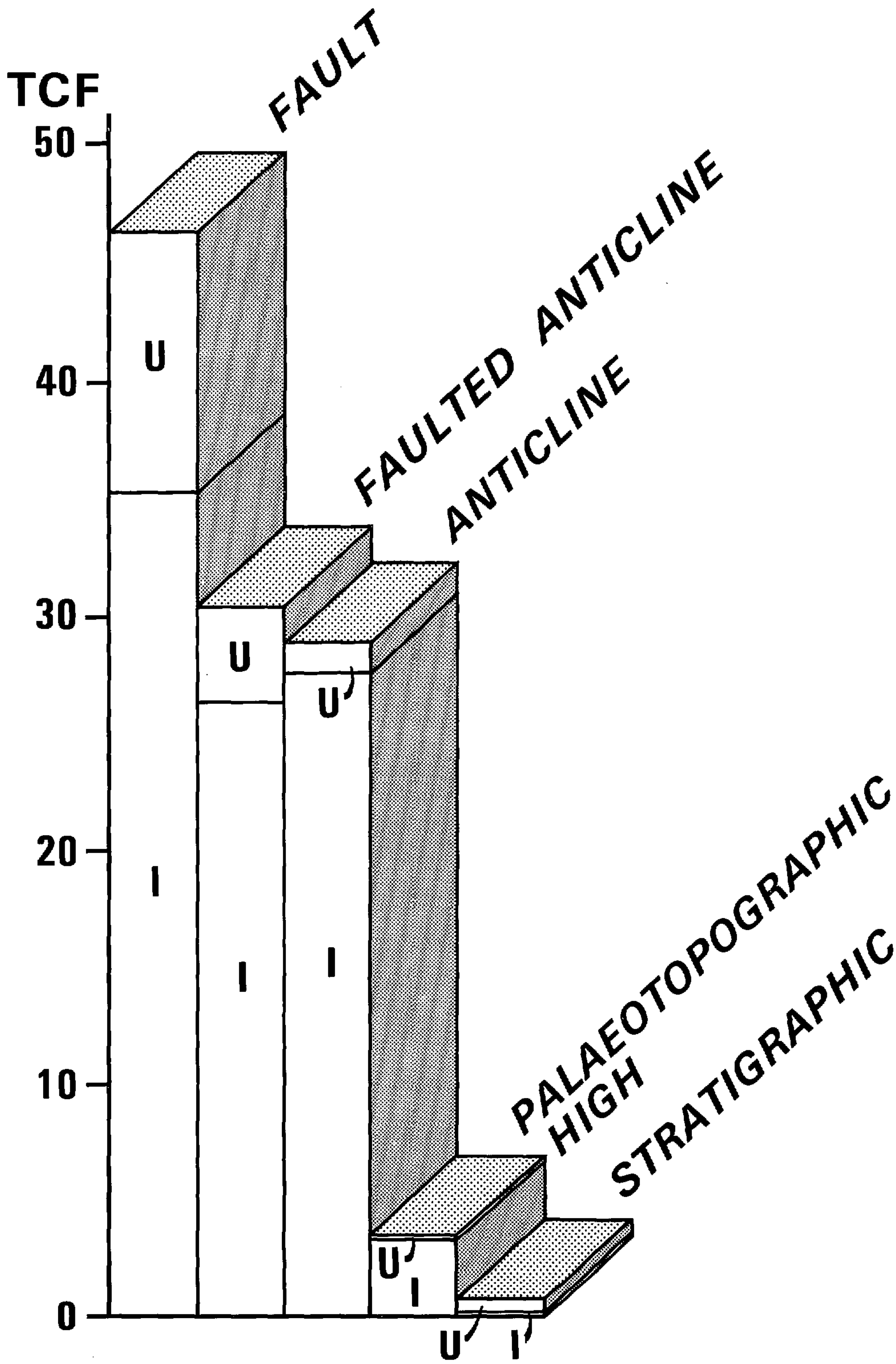
SLIDE 22

SALES GAS



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