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GEOPHYSICAL EXPLORATION IN THE SEARCH FOR OIL IN AUSTRALIA

by

R.F. THYER

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INTRODUCTION

Although geophysical methods of prospecting have proved indispendsable in the search for oil deposits elsewhere, it is only in recent years that they have been used to any significant extent in Australia. The increase in their use has been quite remarkable over the past two or three years, due in no small measure to the encouragement given by means of Commonwealth subsidy. There is no doubt that the use of geophysical methods will continue to increase and this increase could be greatly accelerated as and when oil is discovered in commercial quantities.

This review of their use in Australia and the remarks and statistics are confined to work on the mainland. There has been a substantial amount of geophysical work in Papua, but as operating conditions are so very different to the mainland Papua has been regarded as a separate province.

HISTORICAL REVIEW

The first geophysical survey for oil in Australia was made by the German Company, Elbof, in the Roma area in 1928-29. About 200 gravity torsion balance stations were established in the Hunterton and Gubberamunda areas northwest of Roma and some rather primitive refraction seismic work using Mintrop mechanical seismographs was done.

It was not until 1940 that any further geophysical work was done in Queensland. Between June 1940 and June 1942, Shell (Queensland) Development Pty. Ltd. carried out a regional gravity survey extending over 190,000 square miles of the Great Artesian Basin in southern Queensland. Two parties operated using Thyssen gravity meters and Holweck-Lejay pendulums.

During the period 1947 to 1949 an extensive gravity reconnaissance was done by the Frome Broken Hill Company Pty. Ltd., in the Lake Frome Embayment where some experimental aeromagnetic traverses were also flown.

Very little work was done before 1948 and apart from the surveys mentioned above only a small amount of gravity work was done by the Bureau of Mineral Resources Geology and Geophysics in the Lake Frome Embayment and the Roma areas.

The next ten year period 1948 to 1959 saw the establishment of seismic and aeromagnetic methods. The first reflection seismic survey in Australia was carried out by the Bureau in the Roma area in 1949-1950, followed in successive years by work in the Carnarvon Basin, East Gippsland, Kimberleys, Roma, Perth Basin, Bonaparte Gulf Basin, Surat Basin and the Bowen Basin.

The first contract seismic crew in Australia was brought into the Carnarvon Basin by West Australian Petroleum Company (WAPET) in 1952, following initial work by the Bureau. This contract crew worked during most of 1952 and 1953 on various surface structures in the northern part of the Carnarvon Basin (including Rough Range), and in the Kimberleys. During 1954 and most of 1955 the Bureau's seismic crew was the only one operating but WAPET resumed work in its West Australian permits late in 1955 and has continued practically without interruption up to the present; at one time employing three crews simultaneously.

In 1957 the South Australian Mines Department put a seismic crew into the field for work on the sedimentary basins in that State and will add a second crew. Two additional contractors came into the field in 1958 and work respectively in the Otway Basin, Victoria, and the Maryborough Basin, Queensland.

Since the beginning of 1959 there has been a steady increase in the use of seismic methods and at the present time there are approximately 20 crews working; three of these are run by government agencies and the rest by contractors.

Figure 1 shows the amount of seismic work in total party months per year from 1948 to 1961 by Government agencies and private companies. There are already signs that the total for 1962 will be substantially greater in 1961 and may even be double.

Figure 2 shows the yearly variatinns in gravity surveys from 1946 to 1961. The diagram shows no significant trend over the past ten years except for the peaks between 1947-8 and 1954-7 corresponding respectively to the work carried out by Frome-Broken Hill Company Pty. Ltd., in the Frome Embayment and by WAPET in the Perth, Carnarvon and Canning Basins.

Steady progress has been made since 1950 in covering the major sedimentary basins with aeromagnetic surveys in which the Bureau has played a major role. The Bureau has covered the Perth, Carnarvon, Bonaparte Gulf and East Gippsland Basins and a part of the Bowen Basin. Reconnaissance surveys have been made in the Canning, Eucla, Great Artesian and Murray Basins. A large part of the Murray Basin has also been surveyed by the South Australian Mines Department and private companies. Since 1959 there has been a significant increase in the use of the aeromagnetic method by private companies. Figure 3 shows the distribution of aeromagnetic surveys in total party months per year from 1950 to 1961.

This brief review shows quite clearly that there has been a substantial increase in geophysical work over the past two years. There is no doubt that this is due very largely to the support given to the companies through Commonwealth subsidy for prospecting. However, in view of the enormous extent of our sedimentary basins and lack of fundamental knowledge of their geology, there is clearly need for a further considerable expansion. One factor which beyond all others would accelerate this increase is the

discovery of commercial petroleum deposits. Although the Moonie discovery has yet to be proved there is no doubt that the encouraging results to date have given a boost to geophysical work.

PREDICTION OF FUTURE ACTIVITY

If the statistics given above are considered only as a record of what has happened in the past few will be interested in them. What really counts is "What do they portend for the future?" The upward trend in seismic activities which is apparent over the last two years will continue at least for the next few years and if early success is achieved there may, in fact, be a boom as there was in Canada after the discovery of the Le duc oilfield in Alberta in 1946.

If we are to make long range plans to accommodate such an increase we must attempt to predict its magnitude even though this does involve rather tenuous assumptions.

In the discussion that follows remarks will be confined to the seismic method which is by far the most important and extensively used geophysical method. It has also proved elsewhere to be a good yardstick with which to measure total exploration activity.

To arrive at an order of magnitude for the likely increase in seismic activities use has been made of data from the United States and Canada relating seismic activity to Petroleum discoveries.

It is assumed that Australia contains hidden petroleum resources which can be found and developed over the next 20 years to make us self-sufficient. This, of course, involves the build-up of reserves while at the same time providing for a yearly increase in production. The seismic effort needed for such a programme will be regarded as the maximum required although a more rapid development might in fact be achieved.

Our present consumption of liquid petroleum products is roughly 90 million barrels a year and this will probably treble over the next 20 years. For comparison it might be noted that Canada's actual consumption trebled over the period 1948 to 1960.

To achieve a production of 270 million barrels a year by 1983 it would be necessary to build up reserves to at least thirteen times this figure and to maintain it at this rate. (The average ratio of total reserves to production in U.S.A. is roughly 13; some authorities claim however that the "safe" ratio is 15). On these figures Australia to be self-sufficient in 20 years would need to build up reserves to approximately 3600 million barrels, an average net gain of approximately 180 million barrels per year. Naturally the gross gain in reserves per year must be substantially higher than this to provide for progressively increasing production. For the purpose of this prediction it will be assumed that the gross reserves added each year or "discovery rate" will increase linearly over the first 10 years and remain constant thereafter at 420 million barrels per year.

Figure 4 shows the yearly increase in total reserves based on the above "discovery" rate and allowing for a maximum yearly production ("productive capacity") at a rate of one-thirteenth of the year by year reserves. As mentioned above this ratio of 13 for production to reserves is based on U.S.A. practice; if a ratio of 15 is used the yearly "discovery rate" would need to be somewhat higher.

Actual production would of course lag behind the "productive capacity" because of the time required to instal equipment. In Canada this lag was initially about three years (see Figure 5). The curve shown on Figure 4 for "production" takes this lag into account. On Figure 4 is also shown

the curve for "consumption" of liquid petroleum products. This is based on estimates provided by the Fuel Division of the Bureau and takes into account present trends in consumption.

On the basis of the assumptions used it is seen that Australia would become self-sufficient by about 1984.

It is interesting to note that in the similar curves for Canada (Figure 5) actual production is only about 60% of "productive capacity" due to economic and political factors.

To find sufficient petroleum to build up reserves to "self-sufficiency" would of course involve a considerable exploration programme. Seismic surveys will have to be carried out to locate suitable drilling targets. It has been found in North America (and no doubt elsewhere) that the amount of seismic work required is roughly proportional to the discovery rate.

Figure 6 shows a year by year comparison of discoveries in terms of number of reserves added and seismic activities in the United States in 1932-1960. Figure 7 is a similar comparison for Canada from 1946-1960. The rapid growth in Canada from 1947 onwards was initiated by the discovery of Devonian reef oil at Le duc, Alberta, in 1946. It will be seen from these figures that petroleum reserves discovered in one year are roughly proportional to the number of seismic crews operating. During the period 1946-1960 in U.S.A. the average is 6.0 million barrels per crew year and in Canada from 1950-1960 4.0 million barrels per crew year. These figures therefore, give some basis, although very tenuous, for estimating the seismic activity that might be needed to sustain a given discovery rate. One factor that should be noted in the Canadian curves (Figure 7) is that the peak in discoveries lags the peak in seismic activities by about 5 years.

On this basis and assuming that the Canadian figure is more likely to represent Australian conditions than the U.S. figure, it would require 900 crew years of work to build up reserves of 3600 million barrels, that is an average of 45 crews per year for 20 years. Additional seismic work, of course, would be needed to sustain production at a yearly rate increasing from 0 to 270 million barrels per year after 20 years. This would require a systematic increase from 0 to 68 crews per year and a gradual increase thereafter to keep pace with growing consumption. It will be noted that in Canada the effort was somewhat more concentrated than suggested above. In effect Canada became self-sufficient in petroleum in a period of about 15 years, helped, of course, by the early discovery of some major fields. Another trend that can be seen in the Canadian curves (Figure 5) is that actual production lags the theoretical productive capacity by about 3 years.

Figure 8 shows prediction curves for seismic activity for a 20-year period to self-sufficiency. The Canadian curves are shown for comparison.

ACTIVITY vs. DISCOVERY RATE

Curve I is the assumed discovery rate i.e. the yearly added gross reserves rising from zero at the end of 1963 to 420 million barrels per year by 1973 and thence remaining constant.

Curve II is the predicted seismic activity needed to maintain this discovery rate. It rises rapidly over the first five-year period to 105 crews per year and then remains constant at this value - note that the maximum value is reached 5 years before the maximum discovery rate. These curves correspond to performance shown in Figure 4 in which actual production reached "consumption" after 20 years. It should be noted, however, from the respective trends of the consumption and production curves that if a constant discovery rate of only 420 million barrels per year is maintained, production will thereafter fall below consumption by an

increasing amount. In order to maintain production at the constantly increasing consumption rate it would be necessary to gradually increase the discovery rate and this would require a gradual increase in the number of seismic crews. Curve III is a modification of Curve II to make allowance for this gradual increase.

Curves III and IV are respectively the average yearly discovery rate and seismic crews for Canada over the 15-year period (1945-1960).

Curve V is a "gloomy prediction" based on the assumption that prospecting over the next few years will be unfavourable; it is of course no more than an informed guess.

Curves IIa and V can be considered as extreme cases and a moderately successful prospecting campaign might result in seismic activity somewhere between these extremes. However, in the Canadian data there is some suggestion that seismic activity reached a peak that was greater than necessary and that the subsequent decline may have been the result of this.

If a major discovery is made here within the next year or so it seems likely that the initial rise in crews may be greater than in Curve II - perhaps to 120 crews. On these somewhat tenuous grounds and taking the most optimistic view I predict that seismic work will build up over the next 5 years from the present level of 20 crews to some figure between 50 and 120 crews, depending on the degree of early successes achieved. Assuming that somewhat less than my most optimistic prediction will be achieved, we should, perhaps, plan on the basis of 100 crews operating 5 years hence and consider what problems this will bring.

EXPANSION PROBLEMS

One major problem, of course, is finance. The cost of running a seismic crew in Australia is approximately £200,000 a year so that 100 crews would require approximately £20,000,000 per year. On North American experience it is known that the cost of seismic exploration is only about 10 per cent of the total cost, so that this scale of activities envisages a total annual expenditure of approximately £200 million per year. Whether or not money of this order would be available I leave to the financial experts to guess.

As far as seismic operations are concerned one of the biggest problems is likely to be manpower. The effectiveness of any seismic operation depends to a large degree on sound technical experience and training. This, of course, is not obtained overnight, and if we are to think in terms of local manpower the problem is with us right now. Quite clearly we in Australia are not equipped to do more than make a token contribution at present and our only hope is to import the geophysicists we need. Practically all the professional staff used by contractors working here now has been brought from overseas. This has been made relatively easy by a marked recession over the past few years in the use of seismic methods particularly in North and South America and the Middle East. Canada, of course, faced a similar problem in 1946 but the growth of seismic work from 1947-1951 almost exactly matched the decline in the United States over the same period. The inference is obvious; it was handled simply by a transfer of U.S. crews to Canada. After 1951, however, seismic work increased in both Canada and the U.S. and an increasing number of Canadian University graduates were absorbed into the industry. Canada was fortunate in having this breathing space in which to do something about training her own geophysicists and she made good use of it.

In order to make some assessment of our likely needs for geophysicists in the immediate future Table I shows the number of professional geophysicists (University graduates) at present employed in Australia in all types of geophysical prospecting and in geomagnetics and seismology.

TABLE I

Geophysics - Australia - Professional Manpower

1962

	GRADUATES							
	Petroleum Prospecting			Other Geophysical			Totals	
	Local	O/seas	Total	Local	O/seas	Total	Local	O/seas
Private companies	10	37	47	3	2	5	13	39
Government organizations	24	14	38	38	23	61	62	37
Universities				7	7	14	7	7
	34	51		48	32		82	83
Totals			85			80		165

1968 (Estimate based on 100 seismic crews)

Private companies	270	15	
Government organisations	50	85	
Universities	-	25	
Totals:	320	125	445

Increase in five year period (445 - 165) = 280

Certain classes of Geophysicists such a meteorologists, oceanographers and the like, have been excluded although these will be needed in increasing numbers in the years to come. Also shown on the table is an estimate of the number that will be required 5 years hence if seismic work builds up to the 100 crew level. It will be noted that the petroleum industry employs at present about 50 per cent of the total. It should be noted also that 60 per cent of these are graduates from overseas universities.

Within the Bureau which is by far the largest single employer of geophysicists at present 40 per cent of the geophysicists have been recruited from overseas, mostly from the United Kingdom. Over the past 5 years more than half the Bureau's new recruits have been from overseas. In the lower part of Table I an attempt to product the likely numbers in 1968 has been made. It will be realised at best this is an informed guess but it is not an improbable estimate. It is influenced to a marked degree by the assumed increase to 100 seismic crews. It also takes into account probable increases in the use of other geophysical methods.

On these figures it is seen that a three-fold increase is not beyond the realms of possibility.

Where will we get all these extra men? Quite clearly we will have to rely in the immediate future on imported manpower while we build up our own potential, but this necessarily must be a short term view. If we succeed in becoming self-sufficient or in producing a substantial part of our needs then there will be a continuing need for geophysical prospecting crews to maintain reserves at the safe level. An indigenous petroleum industry cannot be maintained by continually importing the manpower needed. For the purposes of planning we have to take the optimistic view and make provision for eventual supply of relatively large numbers of geophysicists. The development of a petroleum industry will of course require vast numbers of professional people in other categories.

LACK OF TRAINING FACILITIES

In the author's view it is a most unfortunate thing that the Universities with few exceptions appear to be quite oblivious to the present and potential need for geophysicists. One University alone provides what might approximate to an Undergraduate Course. Most of them give courses of lectures in geophysics which for the most part are no more than an introduction to the subject and generally designed to teach geologists the rudiments of the subject. In the Bureau we have relied on recruiting Science and Engineering graduates with basic training in physics, maths and preferably geology. In geophysical prospecting a sound knowledge of electronics is of advantage but few if any of our new appointees have this - even those who have majored in physics.

If the prediction on which Table I is based is fulfilled, Australia will need during the next 5 years not less than 280 geophysicists of whom 235 will be employed in the petroleum industry. These numbers may not seem high but their true significance will be apparent when they are considered in relation to the relatively small numbers of students who graduate in Australia. The number who graduated in science in all disciplines in 1962 was only about 800 of whom no more than 200 have the basic qualifications needed for geophysics. About half this number will enter the teaching profession at University or secondary school level, so that employers of geophysicists will have to compete with all the other potential employers of this class of graduates for something like 100 graduates. When it is realised that there are at present insufficient graduates to fill existing demands, the likely need for 280 geophysicists over the next 5 years can be viewed in better perspective.

Although the potential employers of geophysicists can and, in fact, do employ graduates majoring in physics, mathematics or geology and undertake their further training in geophysics, they would undoubtedly prefer to engage graduates who have received appropriate training in geophysics at the University.

It is the author's firm conviction that the present and likely future demand for geophysicists warrants the establishment of special courses at the Universities. The smaller Universities are, I believe, for various reasons better able to do this than the larger Universities like Melbourne and Sydney. The next five years will be a critical period in the recruitment of geophysicists, but it is quite clear that very few Australian graduates will be available. Even if schools in geophysics were started in 1963 it would be four years before any graduates were available.

Even though the geophysical contractors will have to bring most of their geophysicists from overseas I am sure that they will seek every opportunity of employing and training local graduates and will, in fact, prefer to do so if only to reduce their operating costs.

After the initial build-up period there will, of course, be a steady demand for geophysicists. If employment remains at the level of about 500 the continuing yearly demand will probably be not less than 20 per year and may even be substantially higher because of the relatively high wastage rate in this profession.

In this brief review the present trend in geophysical prospecting for petroleum has been illustrated and an attempt to predict how they may increase in the years to come has been made. No doubt geophysical prospecting will increase very substantially over the next five years and with reasonable success in our petroleum ventures will continue at a level of at least three times the present. For years to come there will be a continuing demand for University trained geophysicists and it is up to the industry which has most to gain to make its voice heard in encouraging the Universities to do something about it.

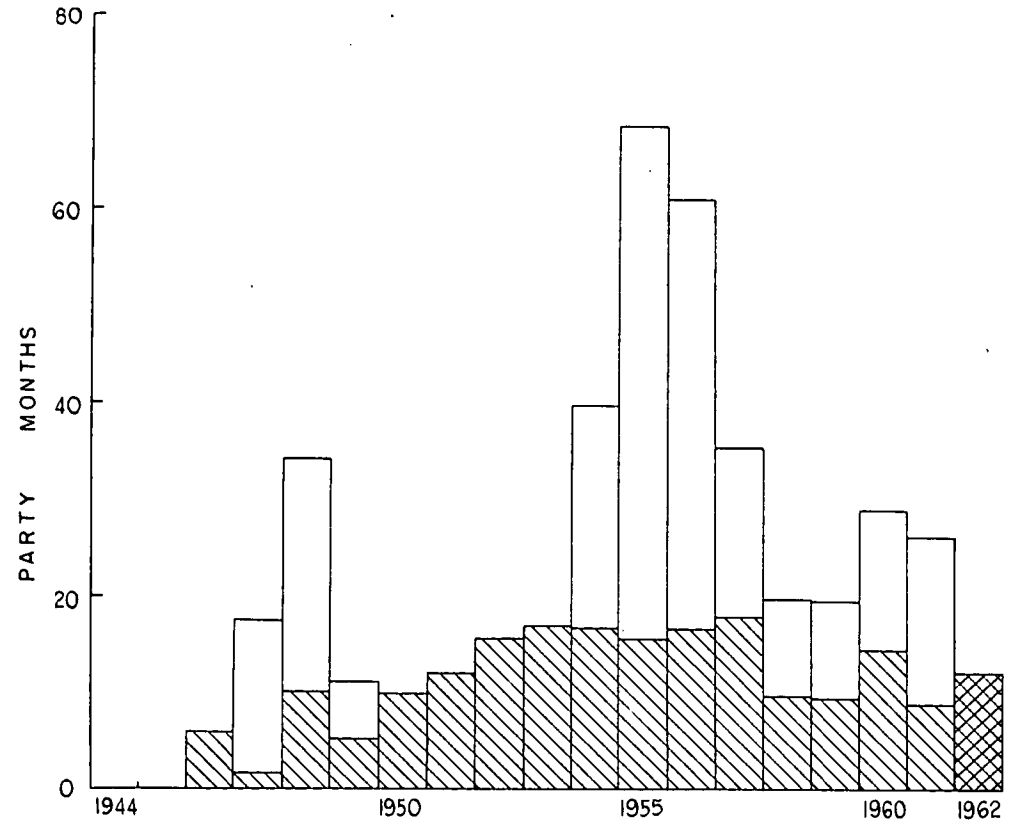

Fig. 2.
GRAVITY SURVEYS
Total Party Months/Year

Private Company Surveys
Government Surveys
B.M.R. Proposed Programme

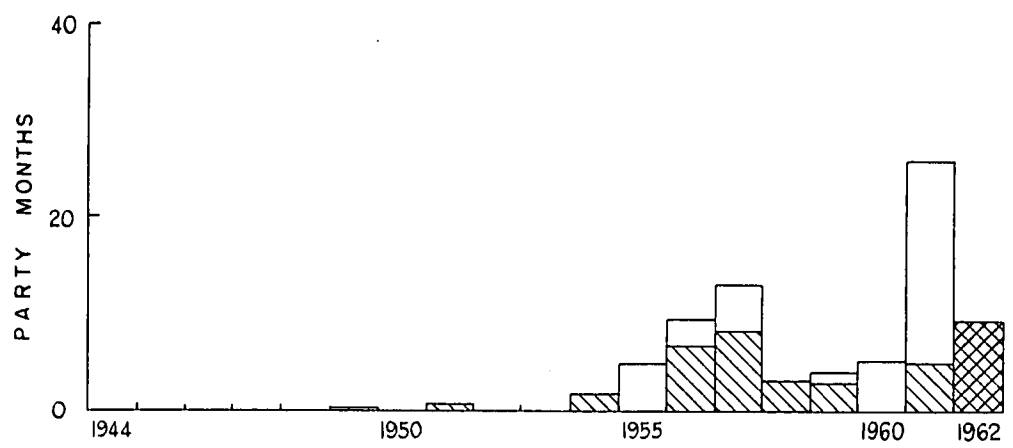

Fig. 3
AEROMAGNETIC SURVEYS
Total Party Months/Year

Private Company Surveys
Government Surveys
B.M.R. Proposed Programme

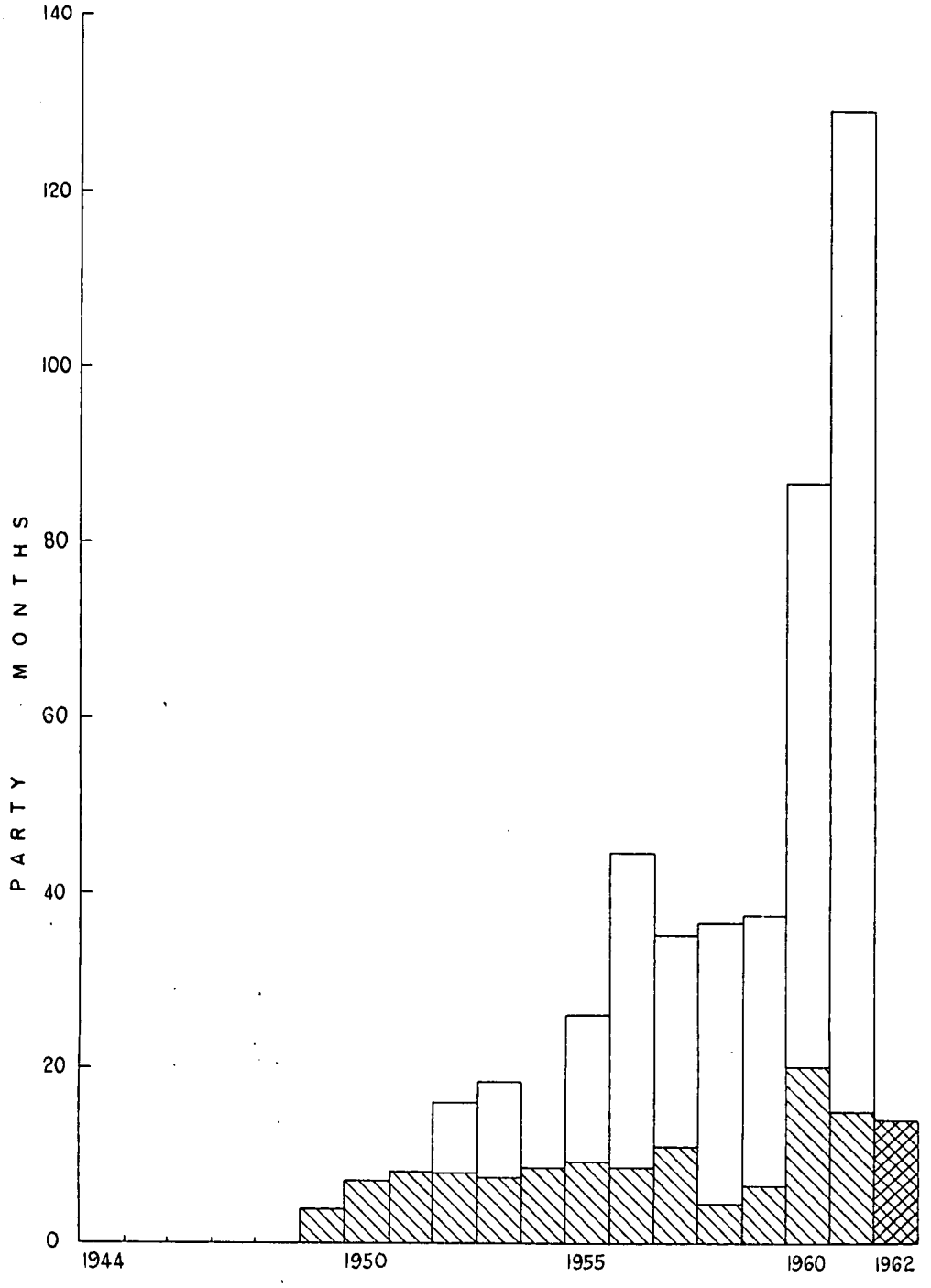

Fig. I
SEISMIC SURVEYS
Total Party Months/Year

Private Company Surveys
Government Surveys
B.M.R. Proposed Programme

AUSTRALIAN PETROLEUM EXPLORATION
GEOPHYSICAL ACTIVITIES
IN TOTAL PARTY MONTHS PER YEAR

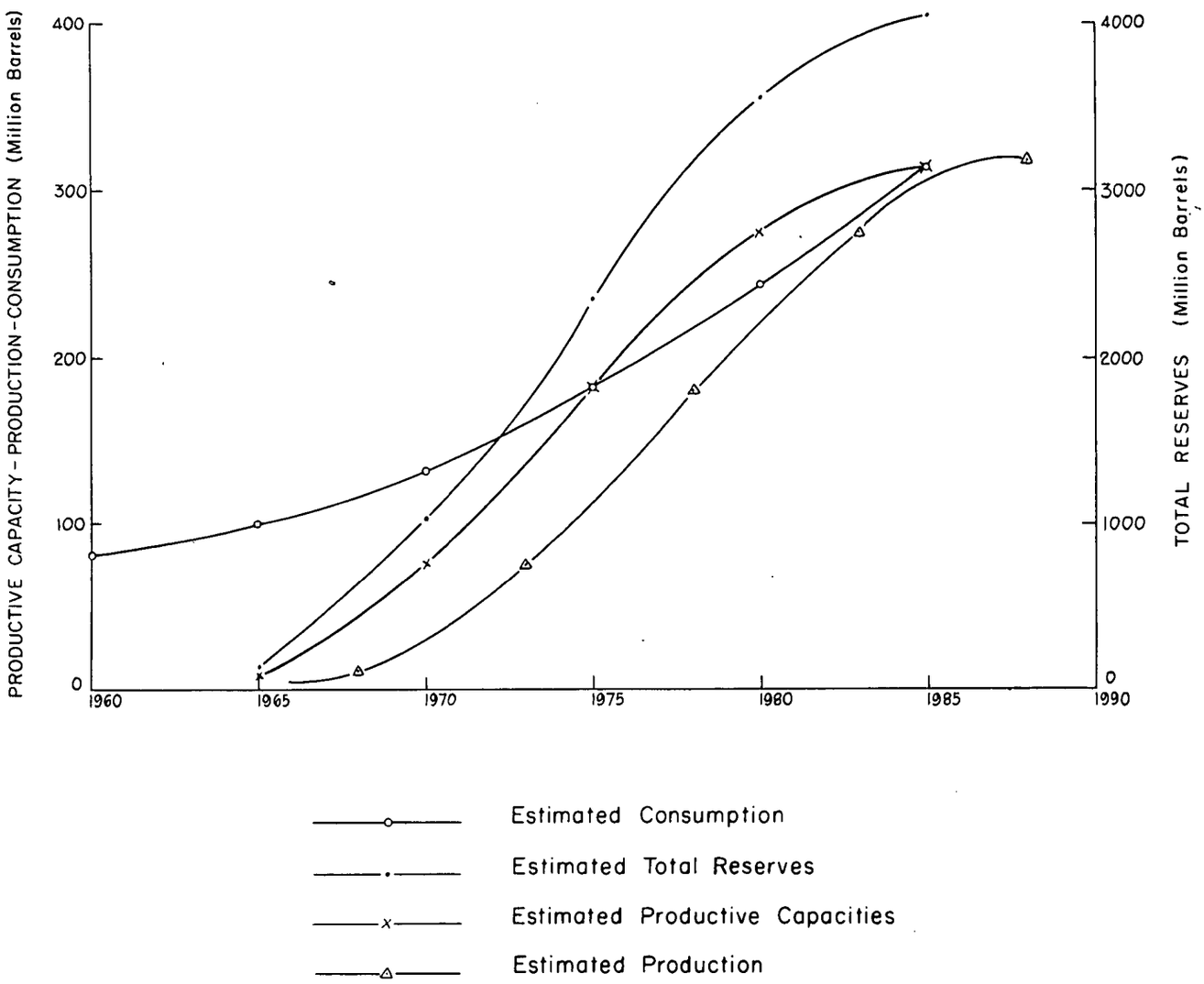

Fig. 4

AUSTRALIA 1960 - 1985

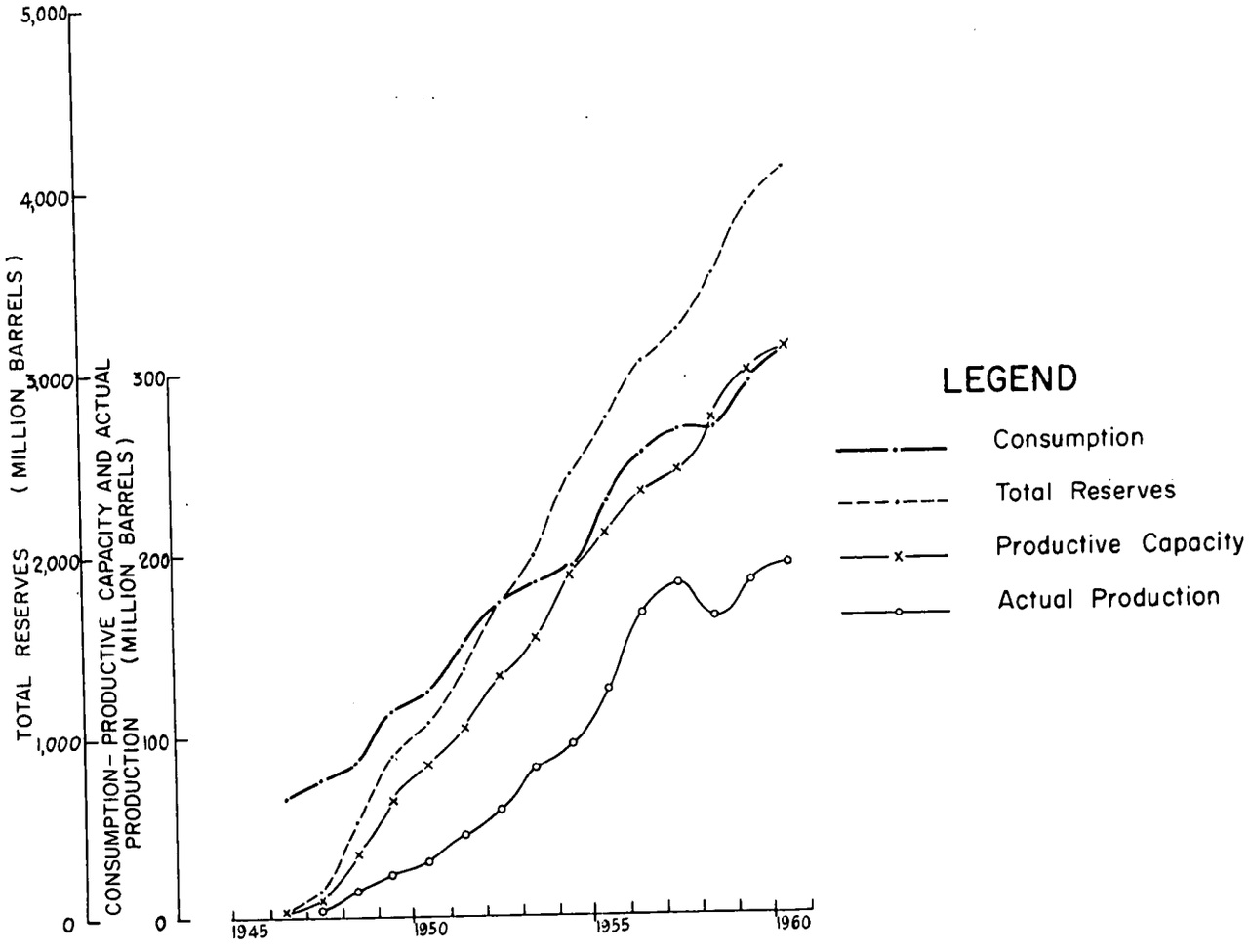

Fig. 5

CANADA – 1945-1960

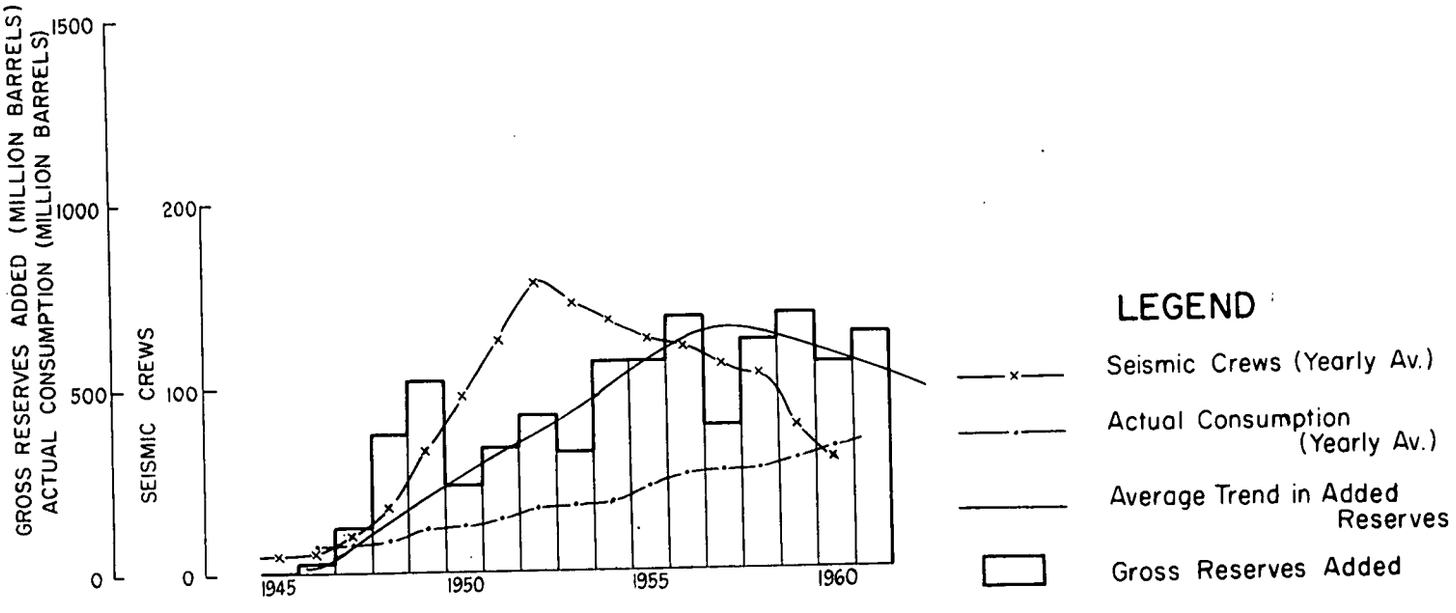

Fig. 7

CANADA – 1945-1961

SEISMIC ACTIVITY v RESERVES ADDED

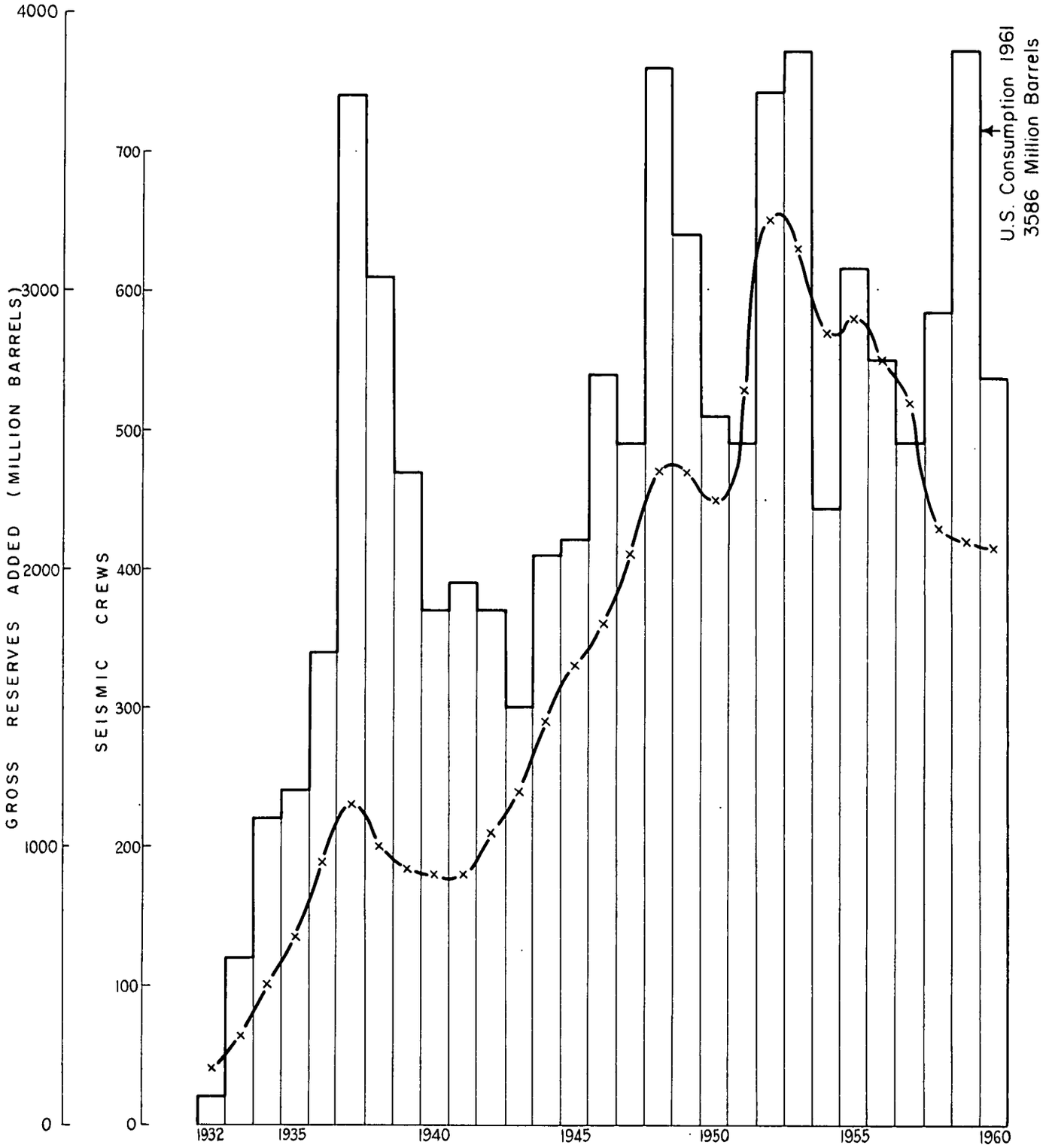

Fig. 6

U.S.A - 1932 – 1960

SEISMIC ACTIVITY v RESERVES ADDED

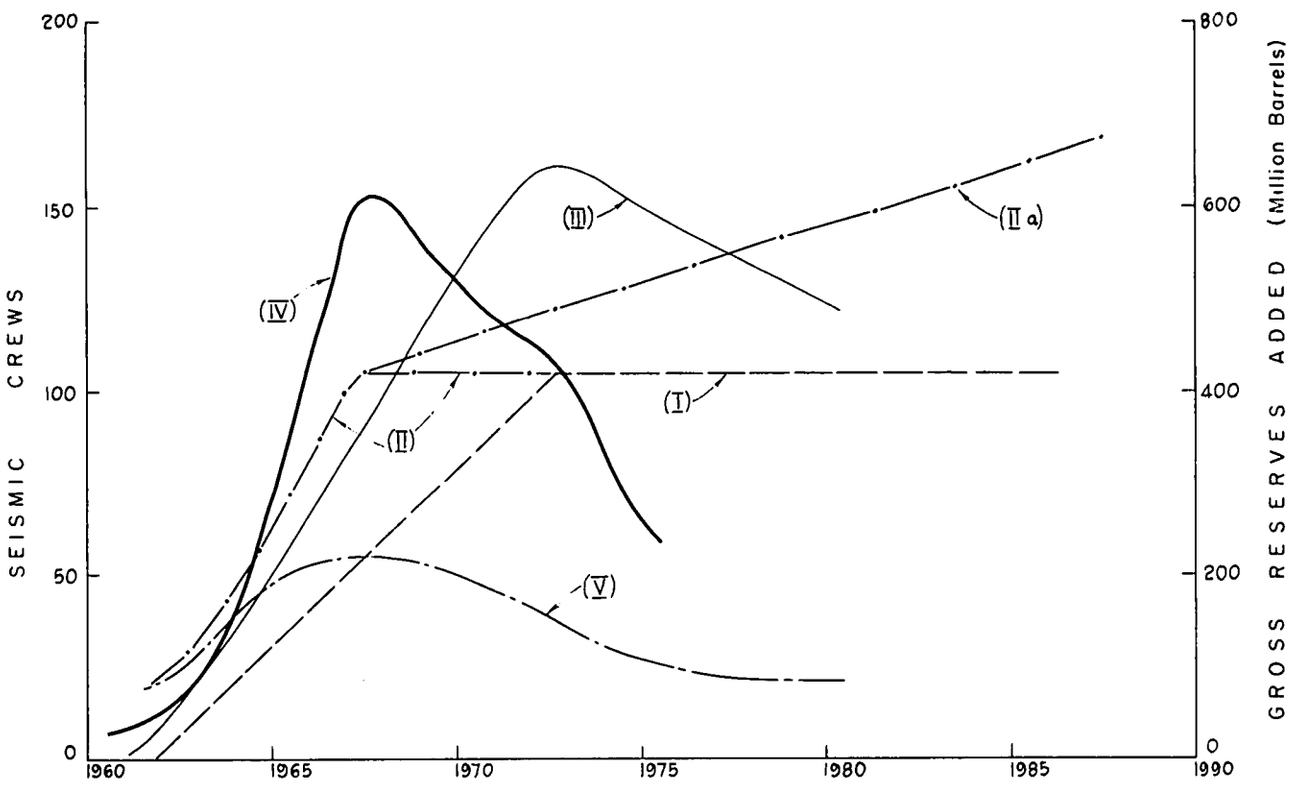

Fig. 8

_____ (I) Assumed Gross Reserves Added (Discovery Rate)

_._._._ (II) Estimated Seismic Crews needed to sustain (I)

_._._._(IIa) Estimated Seismic Crews needed to provide for increase in Discovery Rate

_____(III) Actual Discovery Rate, Canada (1945-1960)

_____(IV) Actual Seismic Crew activity, Canada (1945-1960)

_ _ _ _ _ (V) Estimated Seismic Crew activity if prospecting is unfavourable