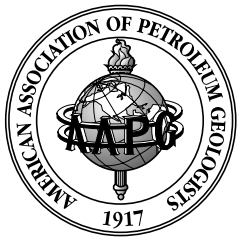
AAPG Memoir 42
SEG Investigations in Geophysics, No. 9

Interpretation of Three-Dimensional Seismic Data

Sixth Edition

By
Alistair R. Brown
Consulting Reservoir Geophysicist



Published jointly by
The American Association of Petroleum Geologists
and the Society of Exploration Geophysicists
Tulsa, Oklahoma, U.S.A.

Sixth Edition

Printed in the U.S.A.

Library of Congress Cataloging-in-Publication Data

Brown, Alistair
Interpretation of three-dimensional seismic data.
Sixth edition.

(AAPG memoir; 42) (SEG investigations in geophysics; 9)
Includes bibliographies and index.
1.Seismology-Methodology. 2. Seismic reflection
method. 3. Petroleum-Geology-Methodology. I. Title.
II. Series.
QE539.B78 1986 551.2'2 86-22341
ISBN 0-89181-364-0

AAPG Editor: John C. Lorenz
Geoscience Director: J. B. "Jack" Thomas

SEG Editor: Gerard T. Schuster
Investigations in Geophysics Editor: Michael R. Cooper
Director, Publications: Ted Bakamjian

This publication is available from:

The AAPG Bookstore
P.O. Box 979
Tulsa, OK, USA 74101-0979
Tel.: +1-800-364-AAPG (USA, Canada)
or +1-918-584-2555
Fax: +1-800-898-2274 (USA)
or +1-918-560-2652
http://bookstore.aapg.org
e-mail: bookstore@aapg.org

Society of Exploration Geophysicists
P.O. Box 702740
Tulsa, OK , USA 74170-2740
Tel +1-918-497-5500
Fax +1-918-497-5558
www.eseg.org/bookmart/
e-mail: books@seg.org

Geological Society Publishing House
Unit 7, Brassmill Enterprise Centre
Brassmill Lane, Bath, BA1 3JN, U.K.
Tel: +44-1225-445046
Fax: +44-1225-442836
www.geolsoc.org.uk
http://bookshop.geolsoc.org.uk
e-mail: dawn.angel@geolsoc.org.uk

Canadian Society of Petroleum
Geologists
#160, 540 5th Avenue S.W.
Calgary, Alberta T2P 0M2, Canada
Tel: +1-403-264-5610
Fax: +1-403-264-5898
www.cspg.org
e-mail: jamie.croft@cspg.org

Affiliated East-West Press Private Ltd.
G-1/16 Ansari Road, Darya Ganj
New Delhi 110 002
India
Telephone: +91-11-23264180
Fax: +91-11-23260536
E-mail: affiliat@vsnl.com

Preface to the Sixth Edition

Where oil is first found is in the minds of men.

-— WALLACE PRATT

This quotation is familiar to all geoscientists, but it is just as pertinent today as it has ever been. Today's advanced geophysical workstations are truly magnificent tools, but we should remember that they are only tools. The skill remains the geological interpretation of geophysical data. I sometimes apologize to myself and others that this still needs to be said — but it surely does! I am indeed disappointed by the general standard of seismic interpretation in the world today.

Too many interpreters rely on the workstation to find the solution. All too often, I am in contact with seismic interpreters who have misidentified a horizon, failed to understand the phase and polarity of their data, distorted the result with a poor use of color, used an inappropriate attribute, failed to recognize a significant data defect, or are still frightened by machine autotracking. We cannot benefit from some of the more advanced techniques available today until these issues have been properly overcome. More education at a fairly fundamental level is still required.

For these reasons, I have resisted the temptation to expand the book into various recent and more advanced topics. The present book is large enough, anyway! So, I freely acknowledge the omission or incomplete treatment of inversion, amplitude variations with offset, geostatistics, visualization, and converted and shear wave interpretation.

The modifications for the Sixth Edition, then, are not extensive. There are several updates and corrections, and some new data examples. Those still grappling with the phase and polarity of their data may find assistance in Appendix C. Appendix D is a Summary of Recommendations to help today's interpreter get more out of 3-D seismic data within a reasonable period of time. These recommendations and much of the book are aimed at redressing the problems discussed above. Please consider basic interpretation issues in conjunction with modern workstation techniques. Let's get the balance between geology, geophysics, and computer science *right!*

Alistair R. Brown
Dallas, Texas
April 2003

Preface to the Fifth Edition

It is less than three years since I was writing the Preface to the Fourth Edition. This rapid turnaround demonstrates the popularity of 3-D technology and the buoyancy of book sales. I hope this book remains an important reference for 3-D interpreters for many more years. For this edition we have included SEG as co-publisher in order to reach even more readers.

The Fifth Edition contains three new chapters: **Depth Conversion and Depth Imaging** is the longest. Depth conversion is a time-honored subject that has been long neglected by this book; I appreciate the help of Agarwal and Denham in filling the gap. Depth imaging is a new and important subject, so the results-oriented contribution by Abriel and his Chevron colleagues is a significant addition. **Regional and Reconnaissance Use of 3-D Data** is a demonstration of how extensive the use of 3-D data has become. Huge surveys and several normal-sized surveys joined together are providing new views of large areas. **Four-D Reservoir Monitoring** addresses the subject of multiple 3-D surveys over the same field being used to monitor changing reservoir conditions. This chapter shows some interesting results for several fields.

I have added examples of hydrocarbon reservoir reflections to Chapter 5. There are still good opportunities for recognizing hydrocarbons directly in our normal seismic data if we use the best modern data, we display it in an optimal fashion, and we think about it correctly. Important as AVO (Amplitude Variations with Offset) is, stacked and migrated amplitudes are still pregnant with hydrocarbon and reservoir information. My understanding of frequency-derived attributes has developed recently and this subject provides a significant addition to Chapter 8.

The importance of zero phase has always been a keen subject of this book and today there is a widespread appreciation of this important subject. When we get our data close to zero phase, difficult as this is, we are left with the option, or ambiguity, of two polarities. There is no true standard of zero-phase processed polarity and therefore the simple word "normal" has no universal meaning. However, there are distinct regional preferences which constitute local norms. Thus I recommend the adoption of the terms **American Normal Polarity** and **European Normal Polarity**, which are the most popular in these regions but are, of course, opposite to each other. American Normal, undoubtedly the most widespread in North America, is where a positive amplitude (peak, or in common color usage, blue reflection) represents an increase in acoustic impedance, and a negative amplitude (trough, or in normal color usage, red reflection) represents a decrease in acoustic impedance. European Normal, undoubtedly the most widespread in Europe, is where a positive amplitude (blue) represents a decrease in impedance and a negative amplitude (red) represents an increase in impedance. Neither America nor Europe is completely homogeneous in its polarity usage. The international movement of companies and their staff works against homogeneity, as do ignorance and errors in acquisition and processing, and a different interpretation of recording standards. Australia follows European Normal Polarity and appears to be the most homogeneous region of the world.

Let the data speak to you. Listen to what they have to say and try to believe it. Too many interpreters today impose on their data a geologic model that becomes a barrier to understanding. The seismic response (wavelet, phase, polarity, bandwidth, etc.) is the critical link between the seismic data and the geology. Understanding this response is vital if we are to grasp the detailed geology behind the data. Let us all remember this as we advance our competencies of information extraction.

A new subject not fully covered by this edition is Volume Visualization. We have had the first stages of this subject for several years and various volumetric displays are already in this book. However, recently Virtual Reality has arrived and Immersive Visualization Systems permit us to "experience the data directly." We are beginning to see vision domes, visionariums, virtual workbenches, and virtual caves using such tools as active or passive stereo, 3-D wands, haptic gloves, and sonification. Here is a new world of opportunity for collaboration of teams of people inside the data. It will be some time, however, before these systems are broadly available, so they will be reported fully in a later edition. These and other new computer developments are very exciting, but it is important to remember that they are just tools; they are not *the* solution. There remains no substitute for cogent geophysical and geological thought!

Alistair R. Brown
Dallas, Texas
March 1999

Preface to the Fourth Edition

Consider everything to be geology until proved otherwise.

—— MILO BACKUS

This is being written shortly after the 20th anniversary of the first commercial 3-D survey. Few could then have imagined how important and widespread the technology would become. Mature petroleum areas are now totally covered with 3-D, surveys being contiguous, overlapping or on top of each other. Speculative 3-D surveys are commonplace and have made more 3-D data available to more interpreters. Many speculative surveys are very large; one in the Gulf of Mexico covers 700 blocks or more than 16,000 km^2. Surveys over producing fields are being repeated for seismic monitoring of production, generally known as 4-D.

There are now many published stories of exploration and exploitation successes attributed to 3-D seismic data. Three-D reduces finding costs, reduces risk, and improves success rates. Royal Dutch/Shell reports that its exploration success outside North America increased from 33% in 1990 to 45% in 1993 based largely on 3-D. Their seismic expenditures are now 90% on 3-D surveys. Exxon considers "3-D seismic to be the single most important technology to ensure the effective and cost-efficient exploration and development of our oil and gas fields." Exxon reports that their success in the Gulf of Mexico in the period 1987-92 was 43% based on 2-D data and 70% based on 3-D data; in the same period in The Netherlands the numbers were 47% (2-D) and 70% (3-D). Mobil reports that in the South Texas Lower Wilcox trend their success based on 2-D was 70% but this rose to 84% based on 3-D. Amoco have concluded that "the average exploitation 3-D survey detects six previously unknown, high quality drill locations," and "adds $9.8 million of value" to a producing property. Petrobras reports that in the Campos Basin offshore Brazil their success rate has increased from 30% based on 2-D data to over 60% based on 3-D.

With this tremendous level of activity and euphoria, and with exploration and development problems becoming more difficult, the issue of the moment is to apply the technology appropriately. There is still a great amount of data underutilization. In an attempt to correct this, let us not impose too rigorous a geologic model on our interpretations; let us seek a full understanding of the seismic character, and allow the data to speak to us. "Consider everything to be geology until proved otherwise."

On the other hand our data has its shortcomings and interpreters benefit greatly from an understanding of geophysical principles and of the processes that the data has been through before it reaches the interpretation workstation. Reductions in acquisition costs have sometimes been over-zealous resulting in significant data irregularities which can only be partly fixed in data processing. There is no substitute for good signal-to-noise ratio. We cannot expect "to make a silk purse out of a sow's ear" and 3-D is certainly not a universal panacea. Reservoir evaluation or characterization using 3-D data is popular today and so it should be, but data quality imposes limitations. I know several projects where the results have been disappointing because the data just wasn't good enough. We must have realistic expectations.

The largest single development in 3-D interpretation techniques since the publication of the last edition has been the generation, display and use of seismic attributes. This Fourth Edition has a whole new chapter on the subject. In addition there are many new data examples and procedural diagrams distributed throughout the book in an attempt to bring the treatment of every aspect of 3-D interpretation up-to-date.

Alistair R. Brown
Dallas, Texas
April 1996

Preface to the Third Edition

The 3-D seismic method is now mature. Few people would doubt this, and the huge number of geophysicists, geologists and engineers using it are testimony to the accepted power of 3-D seismic technology. Three-D seismic is used for exploration, for development and for production, and hardly a corner of the world is as yet untouched by the technology. Substantially more than 50% of all seismic activity in the Gulf of Mexico and the North Sea is now 3-D! The total land area of The Netherlands is now 30% covered by 3-D seismic data! Execution of 3-D surveys is a condition for the granting of some licenses. Some companies, or divisions of companies, have given up 2-D data collection altogether!

The new Foreword to this edition provides a striking accolade for 3-D seismic and its association with the interactive workstation. Workstations are today almost as numerous as 3-D surveys, and so they should be. But both of them are underutilized. The amount of information in modern 3-D seismic data is very great and the capability to extract it lies in the proper use of the computer-driven workstation. All too many of today's practitioners are applying traditional 2-D methods carried over from their experience of 2-D data. This is natural but inefficient, time-consuming and misdirected. The 3-D interpreter needs to understand and use the tools available to him in order to do justice to his investment in 3-D data. Oil company management needs to offer appropriate encouragement to geoscientists. The next phase of our technological evolution must be to make proper use of what we already have.

Another impediment to proper utilization of 3-D data is confused terminology. We find a plethora of terms referring to the same product. For example, a horizontal section or time slice is also referred to, unfortunately, as a Seiscrop, Seiscrop section, isotime (slice or section), horizontal time slice, time-slice map or seiscut. At one time companies saw a competitive advantage in special or trademarked names, but that time has passed. Everybody in the 3-D processing or display business can make a time slice. Interpreters of three-dimensional data need to make regular use of time slices as they are essential to a complete interpretation. Fancy names just encourage inexperienced 3-D interpreters to distance themselves from the product and develop the opinion that they are a phenomenon to be marvelled at rather than a section pregnant with geologic information. I believe that much of the confusing terminology has arisen because of a lack of distinction between the process and the product. We use the process of *amplitude extraction* to make the product of a **horizon slice**; we construct a section in the *trace* direction to make a **crossline**; we *reconstruct a cut* through the volume to make an **arbitrary line**. The interactive system vendors generate most of these capabilities for us and are concerned more about the procedure. Interpreters are concerned more about the utilization of the product. This book attempts to clarify these issues by using only the more accepted terms.

The Third Edition sees a further significant expansion in material with many new companies—oil companies, service companies, and interactive workstation vendors—contributing data examples. Examples from Europe play a more significant role than in previous editions and there are five new case histories.

Alistair R. Brown
Dallas, Texas
September 1991

Preface to the Second Edition

Since publication of the first edition, 3-D seismic technology has continued its trend toward universal acceptance and maturity. Much of this has resulted from the emphasis on development and production prompted by the recent depression in exploration.

I have found a great demand for short courses on interpretation of three-dimensional seismic data, for which this book has served as the text, and this has fueled the need to update the content for a Second Edition. The expansion in text and figures is about 30%, including more case history examples. During the expansion my objective has been to extend the application and appeal of the book by broadening the field of contributing companies, of types of display, interactive system and color usage, and of the range of subsurface problems addressed with 3-D seismic data. Emphasis continues on the synergistic benefits of amplitude, phase, interactive approaches and color.

Alistair R. Brown
Dallas, Texas
June 1988

Preface to the First Edition

The whole is more than the sum of the parts.

— ARISTOTLE

Three-dimensional seismic data have spawned unique interpretation methodologies. This book is concerned with these methodologies but is not restricted to them. The theme is two-fold:

—How to use 3-D data in an optimum fashion, and

—How to extract the maximum amount of subsurface information from seismic data today.

I have assumed a basic understanding of seismic interpretation which in turn leans on the principles of geology and geophysics. Most readers will be seismic interpreters who want to extend their knowledge, who are freshly confronted with 3-D data, or who want to focus their attention on finer subsurface detail or reservoir properties.

Color is becoming a vital part of seismic interpretation and this is stressed by the proportion of color illustrations herein.

Alistair R. Brown
Dallas, Texas
January 1986

Acknowledgments for Subsequent Editions

I really appreciate the help that so many people have provided. Most particularly I must thank the principal authors of the contributed material. Also, many individuals provided me with one, two or three figures and secured for me their release; in some cases this involved considerable effort because several companies were involved in group surveys. My classes of short course students have provided critical comment and discussion and these have prompted me to sharpen up the subject matter and to generate several new explanatory diagrams. To all of these helpful people—a big Thank-you.

Acknowledgments for the First Edition

I have found the writing and organization of this book daunting, challenging and rewarding. But it certainly has not been accomplished without the help of many friends and colleagues. First, I would like to thank Geophysical Service Inc. (GSI) and especially Bob Graebner for encouraging the project. Bob Sheriff, University of Houston, has been my mentor in helping me to discover what writing a book entails. Bob McBeath has been a constant help and source of technical advice; he also read all the manuscript. I am indebted to many companies who released data for publication, and also to the many individuals within those companies who provided their data and discussed its interpretation with me. In particular, Roger Wright and Bill Abriel, Chevron U.S.A., New Orleans, were outstandingly helpful. Colleagues within GSI who provided significant help were Mike Curtis, Keith Burkart, Tony Gerhardstein, Chuck Brede, Bob Howard, and Jennifer Young. Last but not least, my wife, Mary, remained sane while typing and editing the manuscript on a cantankerous word processor.

About the Author

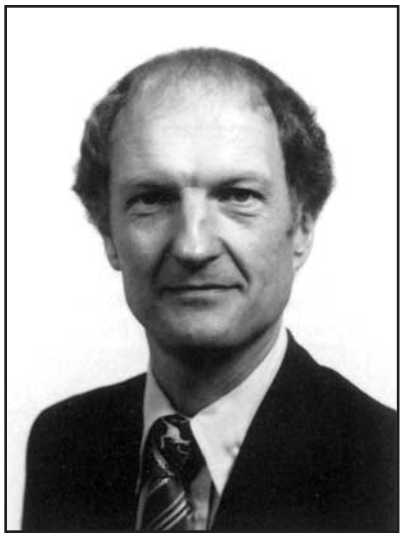
Alistair Ross Brown was born and raised in Carlisle in the northernmost part of England. The first and middle names demonstrate Scots ancestry. He graduated in Physics from Oxford University in 1963, having attended The Queen's College. Later the necessary geology component was obtained at the Australian National University in Canberra, Australia. He married Mary, another Oxford graduate, in 1963 and they have three children. Now there are also two grandchildren.

Alistair's professional career in geophysics began in Australia where for seven years he was employed by the Bureau of Mineral Resources, and there gained experience in seismic data collection, processing, and interpretation. The Brown family returned to England in 1972 where Alistair worked for Geophysical Service International (GSI). He soon specialized in experimental seismic interpretation and was asked to interpret the first commercial 3-D seismic survey in 1975. Early experimental 3-D interpretation and display soon brought him to Dallas, the worldwide headquarters of GSI, and the family relocated there in 1978.

As 3-D surveys became more and more numerous during the 1980s, Alistair continued to investigate the best ways to interpret them. Interactive workstations emerged in the early part of the decade and he started using an early version in late 1980. After presenting several papers on aspects of 3-D interpretation in the late 1970s and early 1980s, Alistair started teaching the subject to oil company personnel. This led to his independence in 1987.

He is now a Consulting Reservoir Geophysicist specializing in the interpretation of 3-D seismic data, the effective use of interactive workstations, and the understanding of seismic amplitude. His courses and consultation are acclaimed worldwide and his time is dedicated to helping interpreters get more out of their 3-D seismic data.

Alistair is an active member of SEG, AAPG and EAGE. He received SEG's Best Presentation Award in 1975; he was recognized by Texas Instruments as a Senior Member of Technical Staff in 1981; he has been a continuing education instructor for SEG and AAPG; he was an AAPG Distinguished Lecturer in 1988, an SEG Distinguished Lecturer in 1991, the Petroleum Exploration Society of Australia Distinguished Lecturer in 1994, and the first joint AAPG/SEG Distinguished Lecturer in 1999/2000. Also he was Chairman of *The Leading Edge* Editorial Board during 1986-88, and, in 1998, he received SEG's Special Commendation Award. Alistair is an Honorary Member of the Geophysical Society of Houston.



Contents

Foreword

The Business Impact of 3-D Seismic

William K. Aylor, Jr.
Coordinator, 3-D Seismic Network of Excellence, Amoco (Retired)

The oil and gas business has witnessed over the past decade a quantum leap in effectiveness of geophysics in E&P operations. Indeed the industry may never before have witnessed a technological advance as profound as or with the overwhelming business impact of 3-D seismic. Under refinement and development for almost three decades, the 1990s saw the coalescing of technical cross currents that have shaken the economic foundations of the oil and gas industry, and have fueled a world economic growth spurt. Today oil prices have been reported as being at the lowest level in 50 years, due in a major part to inordinately high supplies; that is, higher volumes found by 3-D seismic.

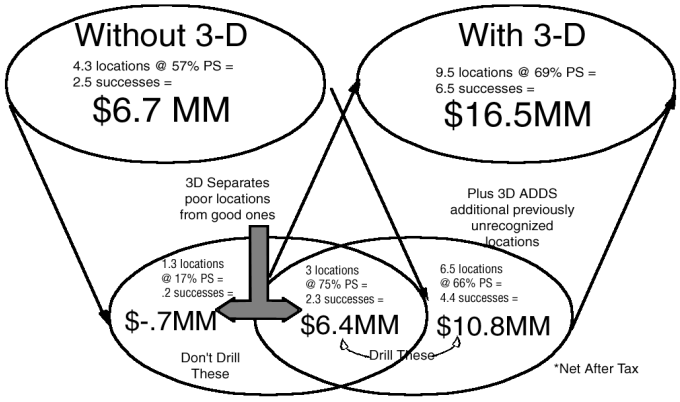


Fig. F-1. The average Amoco exploitation 3-D survey added $9.8 million of present value when applied to a typical international development opportunity.

From our current perspective at the end of the millenium, we can only marvel at what has occurred. The contributors to this achievement have been numerous, but certainly to be included in a tally of major contributors would be improvements in our understanding of scattered noise in acquisition design, recording electronics with routine availability of thousands of recorded channels, development of high bandwidth, high-density storage devices, availability of massively parallel as well as high-speed, low-cost computers, development of high-speed networks, development of depth imaging algorithms, advances in rock properties and direct hydrocarbon detection methods, and refinement and integration of seismic interpretation work stations with geological and engineering methods.

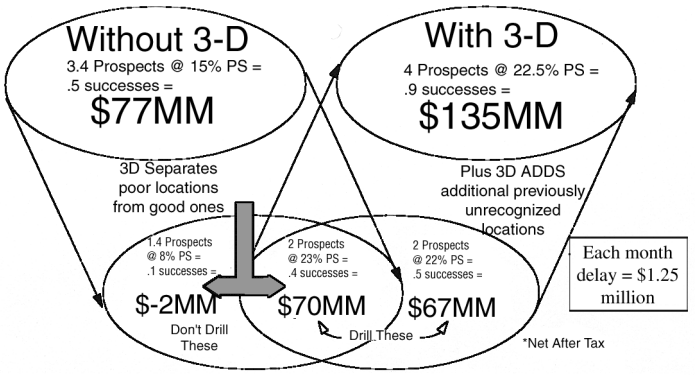


Fig. F-2. The average Amoco exploration 3-D survey added $58 million of present value when applied to a typical international exploration opportunity.

The impact of any new technology on an industry is dependent on two major factors, the effectiveness of the pre-existing technology (that used immediately prior to introduction of the new technology) and the effectiveness of the new technology itself. The greater the gap in capability between the two, the greater the impact of the new technology.

Having personally used the 2-D methods of the 1970s and '80s during my career, I can attest to the fact that, when these methods were employed, they seemed to be highly viable and capable. Indeed, adoption of digital recording over analog recording brought multiple fold, and much better images of apparent 2-D cross sections of the earth. This improvement helped us

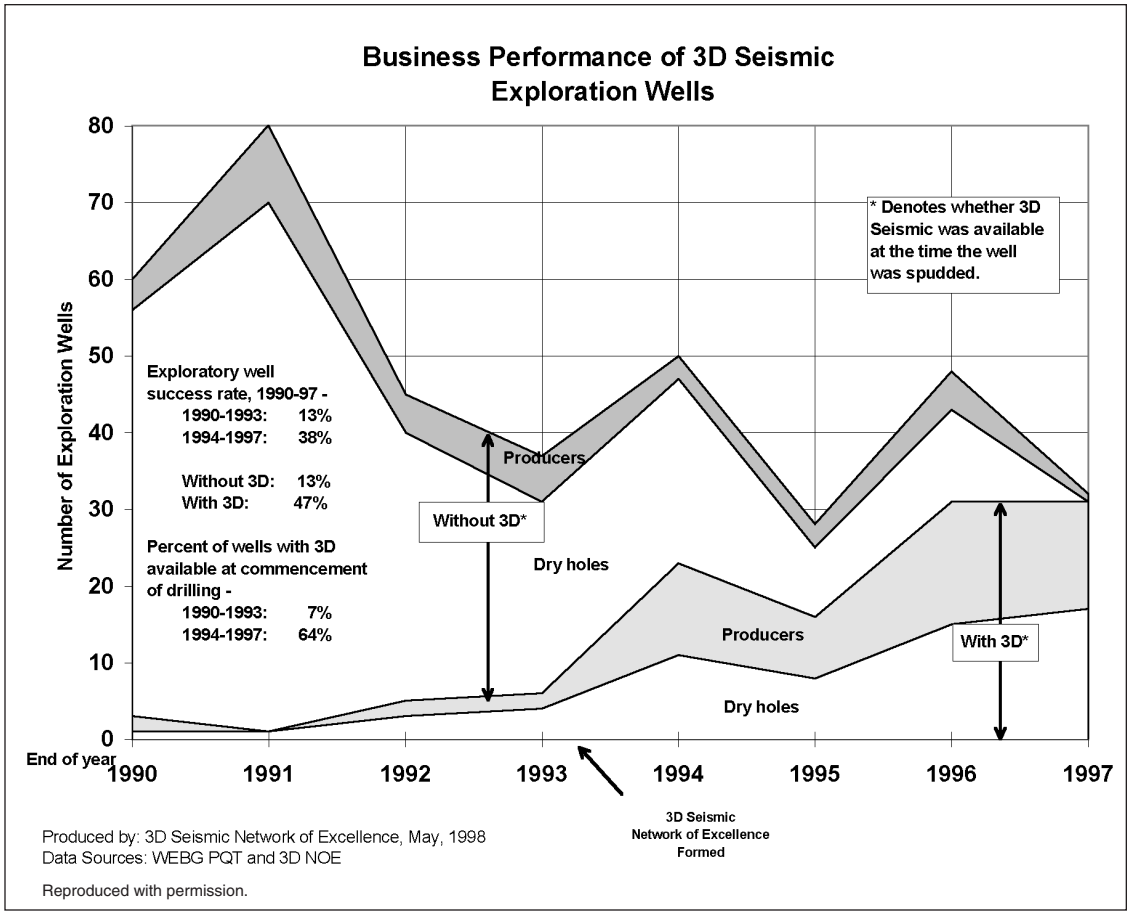


Fig. F-3. Since 1993, there has been a marked increase in the proportion of Amoco exploration wells drilled with 3-D coverage and a steady improvement in drilled success rate.

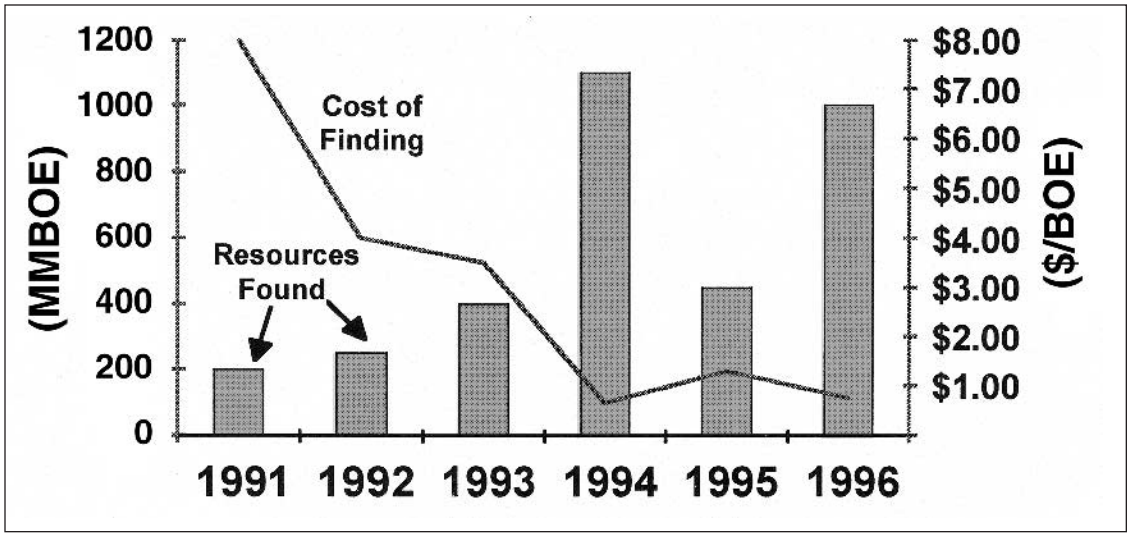


Fig. F-4. Exploration finding costs dropped and resources found increased during this period.

chip away at a better understanding of the subsurface, even though the industry correctly re-adopted the time-honored slogan generally applicable to each generation of oilmen, "all the easy oil has already been found." Likewise, development of synthetic seismograms, wave equation 2-D time migration, true amplitude processing, and 2-D seismic modeling all had incremental impacts on the volumes and rates of finding and producing oil and gas.

But in my view, none of the above comes close to the impact that 3-D seismic has had on the oil industry. I have been very fortunate in the last few years to be in a position within my company to view firsthand the dramatic impact that 3-D has had on our E&P operations. Some companies were undoubtedly ahead of the pace of Amoco's 3-D activity, and many lagged our pace, so I like to think of the Amoco 3-D experience as a microcosm of the experience of the

industry in general. Whether this is the case could be debated, but if it is close to being true, then this technology's impact on the industry and the world economy has been profound.

In 1994, Amoco's upstream business units collected data to characterize to what degree 3-D was impacting E&P operations. Using pre-drill estimates of success, we characterized the number and quality of prospects prior to and subsequent to acquiring a 3-D survey. Both exploitation and exploration surveys were analyzed, and the results are summarized in Figures F-1 and F-2. Here we see that 3-D segregated poor, low-probability of success (PS) prospects from better, higher-PS prospects. Even more importantly, 3-D also found new high-PS prospects that had not been previously detected at all. When we applied suitable investment and revenue streams (using $15/barrel of oil equivalent), we found the value of these 3-D surveys was tens of millions of dollars. All of this analysis had been done looking at changes in PS in prospects prior to drilling; but would the value hold up when drilled wells were analyzed?

To understand the impact of 3-D on exploration drilling results, we began to monitor success rates of wells drilled with the benefit of 3-D prior to spudding versus the success rates of wells without 3-D. These data have been reported in several forums throughout the mid- to late 1990s, and are recapped in Figure F-3. This remarkable chart shows the transition from a

Table F-1. Impact of 3-D on Amoco major field revisions in 1997.

Degree of 3-D coverage	Number of fields	Total revisions*	Average revision*
Full coverage	17	444,108	26,124
None & Partial	21	-7,609	-362
Total	38	436,499	11,487

*thousands of BOE

Table F-2. Coverage of major Amoco fields by 3-D in 1997.

No. of fields fully covered by 3-D	42	55%
No. of fields not covered by 3-D	10	13%
No. of fields partially covered by 3-D	25	32%
Total no. of important fields	77	

2-D seismic world to a 3-D one, and the impact amazes me even today. As can be seen, the company went from a 14% drilled success rate in 1990 to 47% in 1997, 5% of prospects covered by 3-D in 1990 to 97% in 1997, a drilled success for oil wells during 1990-1997 of 3% without 3-D vs. 37% with 3-D, and a drilled success for gas wells during 1990-1997 of 24% without 3-D vs. 54% with 3-D. Because of this success in this period, there have been major improvements in the cost of finding and in volumes found, as is shown in Figure F-4. Here we can see that the cost of finding has dropped from around $8 per barrel to under $1 per barrel, while volumes found in 1994 and 1996 were about 1 billion BOE per year. This in turn has very beneficially impacted Amoco's production replacement profile as is shown in Figure F-5.

Development effectiveness has also been dramatically improved by 3-D. Figure F-1 shows that looking at pre-drill numbers, we were seeing a dramatic segregation of low-PS development locations from high-PS ones, and we were defining new, high-PS locations not previously recognized. With 3-D and without 3-D drilling results were not available for development wells, so a different means of judging the effects of 3-D on development work had to be devised, which is shown in Table F-1. Here we have measured the impact of 3-D on field revisions for 1997. Field revisions are a useful way of summarizing changes in reserves for the major properties owned by the company, as well as the major changes in reserves for all the

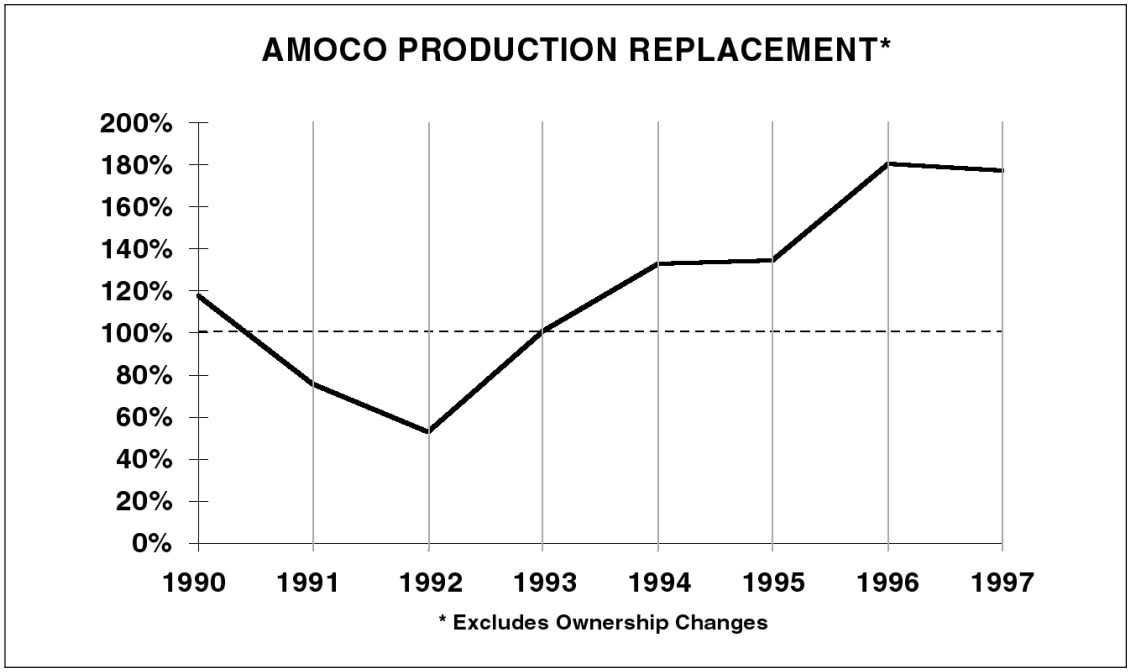


Fig. F-5. Since 1992 there has been a steady improvement in production replacement performance at Amoco.

company's properties. Here we see that fields which had full 3-D coverage experienced much higher positive reserve changes than fields that were partially or not at all covered. Table F-2 shows another interesting aspect of these data: in spite of the huge success of 3-D in both exploration and development work, at least within Amoco, 3-D was slow to be adopted for development work. Indeed, by 1997, only 55% of Amoco's fields were fully covered by 3-D, even at a time when 97% of its exploration wells were covered by 3-D.

Often in the practice of geophysics, our progress is so incremental that its business impact is difficult to notice and quantify. Once in a while we are privileged to witness a quantum leap in effectiveness and proficiency caused by our technology. Such has been our experience with 3-D seismic. Maybe in the future there will be technologies that rival 3-D's capabilities and proficiency at predicting economic accumulations of hydrocarbons. However, the huge impact on world hydrocarbon supplies and prices caused by the great leap forward from 2-D to 3-D seismic technology will be very difficult to match, because the bar has now been raised so high by this magnificent technology.