Chapter 1

Developing a Philosophy of Exploration

by

Edward A. Beaumont,

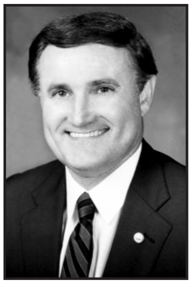
Norman H. Foster,

Richard R. Vincelette,

Marlan W. Downey,

and

James D. Robertson



Norman H. Foster

Norman H. Foster received a bachelor's degree (1957) and a master's degree (1960) in geology at the University of Iowa. In 1963 he completed his Ph.D. in geology at the University of Kansas. His geological career began in 1962, with Sinclair Oil in Casper, Wyoming. When Sinclair merged with Arco in 1969, Foster was offered expanding opportunities to participate in a number of important discoveries, including the giant Irian Jaya field in Indonesia. In 1979, he became an independent geologist and continued to prospect both in the United States and abroad. In addition to winning AAPG's Sidney Powers Memorial Medal for 1999, the former AAPG president received the Levorsen Award (1980), two Certificate of Merit awards (1987 and 1992), and the Distinguished Service Award (1985). He was a member of the AAPG Foundation and an AAPG Trustee Associate since 1979. His professional activities included GSA, SEG, SPE, SIPES, SEPM, and the National Academy of Sciences.

Edward A. Beaumont

Edward A. (Ted) Beaumont is an independent petroleum geologist from Tulsa, Oklahoma. He holds a BS in geology from the University of New Mexico and an MS in geology from the University of Kansas. Currently, he is generating drilling prospects in Texas, Oklahoma, and the Rocky Mountains. His previous professional experience was as a sedimentologist in basin analysis with Cities Service Oil Company and as Science Director for AAPG. Ted is coeditor of the Treatise of Petroleum Geology. He has lectured on creative exploration techniques in the U.S., China, and Australia and has received the Distinguished Service Award and Award of Special Recognition from AAPG.

Richard R. Vincelette

Richard Vincelette graduated with a B.S. degree in geological engineering from Montana Tech. in 1960 and received a Ph.D. in geology from Stanford in 1964. He has spent the last 35 years searching for, and occasionally finding, the elusive hydrocarbon trap. At present he is a geologist and chief curmudgeon with JOG Corporation in Healdsburg, California.

Marlan W. Downey

Marlan W. Downey is the J. Denny Bartell Professor and chief scientist of the Sarkeys Energy Center at the University of Oklahoma. He holds a B.A. degree in chemistry from Peru State College and both B.S. and M.S. degrees in geology from the University of Nebraska. Mr. Downey joined Shell Oil Company in 1957 and became its youngest chief geologist and the first Alaska Division exploration manager. In 1977 he became vice president of Shell's International Exploration and Production Division and later president of subsidiary Pecten International. Downey retired from Shell in 1987 but subsequently joined ARCO International in 1990 as senior vice president of exploration, then president. He retired from ARCO in 1996. He has been recognized as a Distinguished Alumni by both Peru State College and the University of Nebraska, knighted by President Biya of Cameroon for his service to that country, elected a Fellow of the American Association for the Advancement of Science, served as an AAPG Distinguished Lecturer (1986 and 1987), and named the AAPG Huffington Lecturer for the Far East (1996).

James D. Robertson

James D. Robertson, Vice President of Exploration for ARCO International Oil and Gas Company, received a B.S.E. degree in civil and geological engineering from Princeton University in 1970 and a Ph.D. degree in geophysics from the University of Wisconsin in 1975. He joined ARCO in 1975 and has held various technical and management positions, including director of geophysical research, geophysical manager of the offshore Gulf of Mexico exploration group, vice president of geoscience operations, and chief geophysicist of ARCO's international exploration and production division. Robertson has been active in the professional activities of various geological and geophysical societies and was the 1994–95 president of the Society of Exploration Geophysicists. He is a past president and honorary member of the Dallas Geophysical Society and serves on the advisory boards of the geology and geophysics departments of Princeton University, the University of Wisconsin, and the Colorado School of Mines.

Overview

Introduction

Developing a philosophy of exploration is an important step toward becoming a more effective explorationist, both individually and on a team. This chapter discusses various aspects of exploration philosophy with the intent of helping individuals develop their own philosophies.

In this chapter

This chapter contains the following sections.

Section A

The Art and Science of Exploring for Oil and Gas

by
Norman H. Foster and Edward A. Beaumont

Introduction

Great oil, gas, and mineral finders have common characteristics that allow them to succeed. By surveying a select group of successful explorationists, we discovered they love the thrill of discovery and the deep satisfaction of being able to use science and art to find a valuable resource for the benefit of all mankind. Specifically, we identified the following common characteristics:

1. Think positively (negative-thinking people do not find oil and gas)
2. Are self-motivated and self-starting
3. Are persistent
4. Have vivid imaginations controlled by facts
5. Develop creativity through visual thinking

In this chapter we concentrate on the role of creativity in petroleum exploration and how that creativity can be enhanced.

In this section

This section contains the following topics.

Who Finds Oil?

Introduction

Only a small percentage of people exploring for oil, gas, and other natural resources actually find those resources in commercial quantities. We fervently believe, however, that one learns to be an oil and gas finder. Two of the best ways to learn to become oil finders are (1) to familiarize ourselves with the successful approaches and techniques of other oil and gas finders and (2) to develop our visual thinking skills.

Academic training

Theoretically, every geologist with a master's degree or higher from an accredited institution has the necessary scientific background to be a successful explorationist. Thorough training in structural geology, stratigraphy, sedimentology, geomorphology, paleontology, remote sensing, mineralogy, petrology, volcanism, economic geology, geophysics, and geochemistry are fundamental. A course in petroleum engineering is very helpful. Also, a rigorous field geology course is absolutely essential because one must learn to observe and record information accurately in the field, thinking in the third and fourth dimensions and developing a sense of the size of geological features.

Impact of technology

A few years of experience in the industry should prepare an individual to use the latest technology. Computers process data rapidly, which was impossible just a short time ago. This has allowed us, for example, to develop 3-D and 4-D seismic data gathering and processing. In addition, computers allow us to compare thousands of data sets rapidly, as in surface geochemical ratios. But even with all the new technology, thorough scientific training, and new scientific and engineering understanding, only a small percentage of people searching for oil, gas, and minerals ever find them in commercial quantities.

Teams

To overcome the huge amount of technological know-how needed for successful exploration, most companies form multidisciplinary teams. The synergies achieved by several individuals with different specialized skills working to solve a problem can be a successful approach. However, the creative spark of one or more members of the team to correctly interpret the geology (with the aid of scientific understanding and technology) is the essential element for success.

Creativity

Given that most geologists and geophysicists are scientifically and technically competent, what is it that separates the oil and gas finders from the crowd? Creativity is the most important ingredient in exploration, and creativity is enhanced through visual thinking. We define creativity as the ability to look at the same data that everyone else has but to see something different. It involves looking at data from many different perspectives—thinking outside "the box," yet always honoring known facts to make an interpretation that varies from the beaten path. One must constantly attempt to see what might be there, instead of discounting what may not be known to us.

Who Finds Oil? continued

Visual training

Geology is a visual science. To make insightful observations and dream more imaginative concepts, the visual skills of the geologist must be developed fully.

In the past, some geology or earth science departments required a basic course in drawing for a baccalaureate degree. The ability to draw freehand and illustrate various geological phenomena was deemed indispensable. Many geologists became quite proficient in sketching thin sections, fossils, outcrops, and other geological features. But beginning in the 1930s, the drawing requirement was dropped. With the development of the camera and the ease and economy of its use came the belief that drawing proficiency was no longer necessary. All one needed was to snap the camera with the proper exposure and focus, and an even more accurate record (more accurate than drawing the feature oneself) could be obtained.

Today, of course, there is the choice of black-and-white or living color. Earth scientists have retained some of the knowledge of how to diagram and draw by making maps, cross sections, and block diagrams. Unfortunately, by not learning to draw at an adult level, we have largely given up one of our most powerful tools of learning: to think visually and to observe critically. These are the keys to creative thinking, problem-solving, and developing new concepts.

The Thinking Process

Introduction

In the 1960s, Roger Sperry published his Nobel prize-winning brain hemisphere research based on split-brain studies. He and his students found that the two lobes of the cerebrum think in fundamentally different modes.

Thinking styles

The two lobes of the cerebrum are referred to as the left and right hemispheres. Betty Edwards, in *Drawing on the Artist Within,* refers to the thinking style as L-mode and R-mode.

The table below summarizes the styles.

L-Mode Thinking	R-Mode Thinking
Linear	Lateral
Conscious	Subconscious
Logical	Spatial/Visual

In addition to identifying thinking styles, Sperry's research showed that the left and right hemispheres have different functions. L-mode thinking functions include language, mathematics, logic, and sense of time. R-mode thinking functions include intuition, emotion, visualization, spatial movement, and interpretation of the whole from fragments of data. Some endeavors tend to be dominated by left-brain thinking and others by right-brain thinking. Earth scientists should attempt to achieve a balance between L- and R-mode thinking, which is called whole-brain thinking.

Thinking Creatively

Introduction

The creative thinking process consists of six stages and involves switching back and forth between L- and R-mode thinking. The table below shows the six stages. The first five stages are well established in the literature, and we have added a sixth stage—application. Unless we *do* something about our creative idea, no progress will be made.

Stage	Thinking Mode	Description
First Insight	R-mode	Noticing something seems wrong or is missing
Saturation	L-mode	Saturating the brain with information
Incubation	R-mode	Putting a problem away for awhile
Illumination	L-mode	Becoming aware of a solution to a problem
Verification	L-mode	Testing the solution
Application	L-mode	Applying the solution

First insight

In petroleum exploration, with first insight (primarily a right-brain activity) one might become aware of an area's potential because of good hydrocarbon shows and reservoirs, or because of the presence of an accumulation that may have analogs nearby, or because a new technique might change the economics of a play.

Saturation

Saturation follows first insight and involves the complete study of all available information pertaining to the problem. This is mainly a left-brain activity. When the mind becomes fully saturated with all the available data, such as well control, surface geology, and seismic data, then it is time to incubate, which involves switching back to the subconscious right side and analyzing the data.

Incubation

One of the main blocks to creativity comes at the end of the saturation stage. Our educational system trains mainly the left side with subjects such as reading, writing, and arithmetic. We become conditioned to believe that once the data have been gathered and studied, we should be able to plug these into a formula and come up with a quick answer. That is not the way creative thought occurs. The information must be processed on the right side to find patterns and solutions to the problem. After saturation, it is best to relax and allow the subconscious mind to work on an answer. We need to let the problem "simmer." This is known as the incubation stage.

Illumination

Usually at a quiet moment in the middle of the night or on a walk or when you have your feet on the desk and are gazing out the window, the answer will come as a flash of insight. Suddenly, the left side becomes aware of the solution to the problem that the right side developed. This relatively short period is the illumination stage. The answer usually is in almost complete form.

Thinking Creatively, continued

Verification

The new insight to the problem may or may not be correct. Therefore, one must switch back to the left side and rigorously test the idea against the data. In petroleum exploration this includes all well and surface control. If, after thorough verification, it is still possible that the idea is correct (and it may not be), then we move to the final stage—application.

Application

The application stage is another major block to creativity in exploration because so many outstanding prospects go untested. If an idea can be right, then we must find a way to drill a well or, at an earlier stage, to conduct field work or perhaps shoot seismic data. Managers and individuals must find the funds to get the good ideas drilled because, of course, no petroleum will be found without drilling the creative plays. The newly created idea must be applied to have value.

Enhancing the Creative Thinking Process

Introduction

Three conditions promote creative thinking: motivation, information, and flexibility (McKim, 1980). We must be motivated because creative thinking is hard work. We must have the right information; valid new exploration concepts are created from information that is correct and readily available. Finally, we must be flexible. When our concepts are wrong, we must be flexible enough to change them. Once we have met these three conditions, what else can we do to enhance our creativity? There are many methods for enhancing creativity in petroleum exploration, such as building a knowledge of oil and gas field case histories or overcoming mental blocks. However, one of the most important methods for enhancing creativity in petroleum exploration is improving our ability to visualize.

Visualization

Both Betty Edwards and Robert H. McKim, in his book *Experiences in Visual Thinking,* stress the importance of learning to draw and diagram to aid visual-perceptual thinking. Through drawing and other visual exercises, one can learn to bring the right side to a conscious level and thus greatly improve our creative abilities.

Visualization & petroleum exploration

The great oil finders have long stressed developing creativity through visualization. Wallace Pratt said, "Where no one any longer believes that more oil is left to be found, no more oil fields will be discovered, but so long as a single oilfinder remains with a mental vision of a new oil field to cherish, along with freedom and incentive to explore, just so long new oil fields may continue to be discovered." In the same paper, Pratt said, "One indispensable attribute of the oilfinder is vision. If it is in the mind of the geologist or oilfinder that new fields first take form, then discovery must wait on our mental visualization—our imagination."

Drawing

Learning to sketch and draw is perhaps the best way to enhance creative visual thought. As Betty Edwards discovered, turning the object upside down turns off the dominant logical L-mode of thought because it does not like to deal with upside down. This allows the subdominant R-mode to take over. We see an object's shape, shading, highlights, negative space, and other visual features, and we can draw the object much more easily. For an observationally based science such as geology, a person who knows how to draw will be much more observant and imaginative than someone who does not know how to draw. Drawing forces one to abstract only the important elements of a subject. For numerous techniques and exercises to enhance visual thinking, refer to McKim and Edwards.

Enhancing the Creative Thinking Process, continued

Geologists who draw

Many great earth scientists have or have had an artistic flair. The outcrop sketches and abstractions of geology from the drawings of people such as William Henry Holmes and P.B. King are legendary, as were the drawings and paintings of many early geologists. Shown below is a P.B. King outcrop field sketch (A) and extrapolated cross section (B) of the Victorian flexure from the Permian basin in the United States. By drawing the outcrop and abstracting stratigraphic relationships, King was able to understand and demonstrate the progradational nature of the carbonate platform.

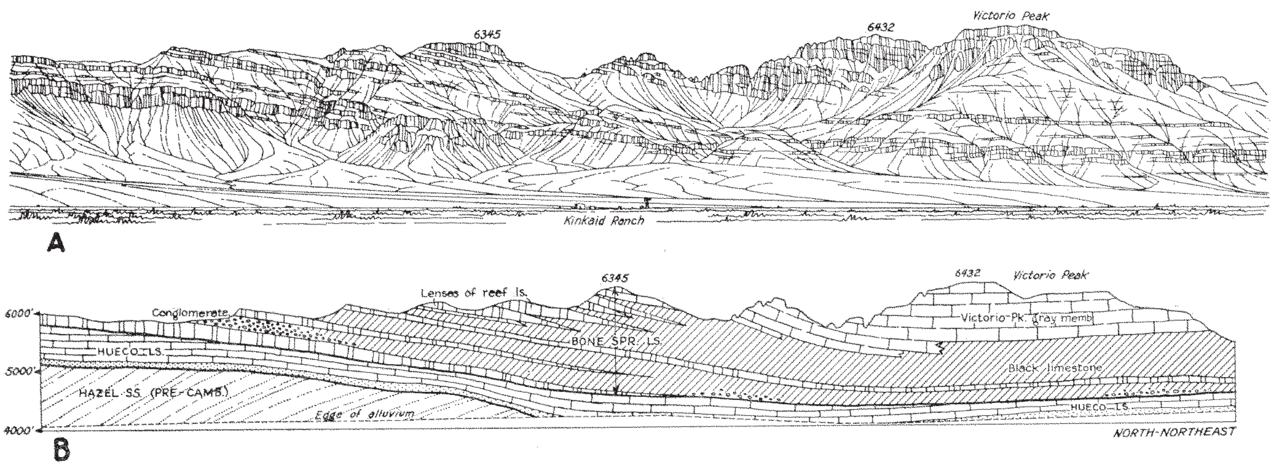


Figure 1–1. From King (1942); courtesy AAPG.

Section B

Characteristics of Oil Finders

by

Edward A. Beaumont, Norman H. Foster, and Richard R. Vincelette

Introduction

What is an oil finder? Oil finders are people who have not only found oil or gas but who seem to have a nose for it. This section presents the results of a survey of oil finders that gives insight into the personality characteristics of oil finders and their philosophic approach to exploration.

In this section

This section contains the following topics.

Characteristics of Oil Finders

Introduction

What are the characteristics of people who are effective at finding oil and gas? What do they do when exploring for oil or gas that sets them apart? What are their hobbies? How do they approach exploration? How do they overcome creative blocks? To gain insight into the traits and work habits of oil finders, we surveyed a select group of 44 explorationists who had found oil or gas to see if similarities emerged. Respondents answered the questions enthusiastically. Their answers are fascinating and fun to read. We can all learn from their philosophies and approaches to exploration.

Survey respondents

The survey was sent to a wide variety of explorationists: women and men, major company employees and consultants, old and young, domestic and international. Although broadly different in background, this select group of explorationists had one thing in common: not only have they found oil or gas, but they have found it often enough that one would have to conclude they are not just lucky. They all fit the definition of oil finder.

Survey Responses

Survey questions

The survey questions were grouped into eight categories:

- General
- Personal attributes
- Education/training
- Visual skills
- Methodology
- Business and personal contacts
- Blocks to creativity
- Working environment

Responses to the survey showed the individualism and diversity of participants. Answers to questions were varied. The differences and similarities were significant and informative. Typical responses to a few of the questions are noted below. Anyone wishing to become an oil finder should find them fascinating and useful.

Advice for aspiring oil finders

Question: What advice would you give to someone who wishes to become an oil finder?

Summary: Get a good education, work with an oil finder mentor, study oil and gas field case histories, and use every scrap of information.

Typical responses:

"1. Love the excitement of the oil industry. 2. Love the smell of sulfur and crude oil. 3. Study what oil finders have written. 4. Know that finding oil requires endless effort. 5. Associate with an oil-finder, if possible. 6. Pay very close attention to oil tracks—shows." (Gerald Loucks)

"Find space to dream. Believe in yourself and your capabilities, and believe that if you keep trying, tomorrow you'll win. Keep an open mind and be willing to change it. Learn to be a realistic business person. Maintain a good sense of humor. Marry someone who also believes in you." (Donald Todd)

"1. Educate yourself widely in geology, geophysics, and engineering. 2. Work in several different basins of varied stratigraphy, structure, etc. 3. Learn the petroleum history of your area. Know what people were thinking when wells were drilled in the '40s, '50s, '70s, etc. 4. Input every scrap of information you can find, continually." (John Masters)

Survey Responses, continued

Learning to find oil

Question: Can explorationists be taught to find oil?

Summary: Most said “yes.” Many said desire is critical.

Typical responses:

“Yes, it is much more a learned skill than a natural talent. However, a good oil finder must be an optimist. He has to believe that he can find prospects that others overlook in order to be effective.” (Jack Elam)

“Yes, but only if that’s what they want to do. Most do not want to be oil finders, or at most it is a secondary objective. Also, most explorationists think they already know how to do it—they don’t!” (James Lantz)

“1. Yes, to a point! 2. The exceptional hydrocarbon finders, I believe, have ‘powers’ (understanding and visualization) that may be intuitive.” (Robert Sneider)

Skill versus luck

Question: Which is more important, skill or luck?

Summary: Skill. Many said luck plays a role, but skill makes the difference over the long term.

Typical responses:

“A skilled practitioner employs controlled, creative imagination. The control consists of utilizing all geological and geophysical data available. Creative imagination involves the application of a broad academic and experience background. I will be grateful for luck but to depend on it is no better than your chances of hitting a moving target with a dart in a high wind.” (Dan Busch)

“Although many discoveries are attributed to luck, if investigated, it would be found that many hours of consideration, thinking, construction, and data presentation were involved in creating the ‘luck.’ I think circumstances that involve good or bad results because of a myriad of reasons have been the basis for many a philosophical discussion through the history. ‘Lucky’ is in my vocabulary, but whether it be true or not, I do not know, and I don’t think I want to know.” (Graham Curtis)

“As important as the basic skills are in becoming an oil finder, these aren’t of much consequence without a bit of luck. Luck doesn’t happen if you don’t expose yourself and take changes. For those you have included in your survey, many times more were equally capable and took big risks but luck was not with them.” (Donald Todd)

“Skill! Luck is what others call an oil finder’s skill. I have some regrets of permitting salesmen of ‘luck’ to persuade me to forego good judgment and take a chance on ‘luck.’” (Gerald Loucks)

Survey Responses, continued

Productive age

Question: What was the most productive period in your life?

Summary: Most respondents said they were not successful until they had five or more years' experience. Many said they are most productive now, indicating they feel experience is critical.

Typical Responses:

"From 1948 to 1975, which is when I was between 30 and 58 years of age. I was involved in 15 discoveries between 1948 and 1965." (Ted Bear)

"Different tasks are more easily accomplished at different ages. I fortunately feel I have been very productive at all mature stages of my life. When I lose that a feeling, I will retire." (Roy Huffington)

"Ages 18 through 50, when I was actually allowed to explore. I directly found 7 large fields and participated in about 20 other discoveries (2 giants). I also found one hard rock ore body which became a commercial mine." (David Powley:)

"Between 40 and 70 years of age." (Dan Busch)

"I am still productive at 89 years of age. I have been productive in every decade of my professional life, which spans 70 years, indicating that I have not slackened my pace." (Michel Halbouty)

Motivation

Question: We all recognize that successful exploration is related to a number of important factors: motivation, opportunity, and environment. What has motivated you in your career, and what do you think are the most important motivating factors in general?

Summary: The excitement of the hunt; money is nice, but it isn't the real motivator.

Typical responses:

"I think that motivation changes throughout one's life. The early years of survival and family maintenance require more of a technical adherence. Eventually there is the emergence of that inner challenge of you vs. Mother Nature and the need for the thrill and satisfaction of discovery—and then just one more! I believe motivation and the best scientific oil finders come from a basic love, understanding, and appreciation of their science, as well as the exploration business, i.e., playing the game for the game's sake!" (Graham Curtis)

"First was appreciation by my superiors for a job well done. Then it was acceptance of my ideas by my peers. Then it was financial success. But overall it was the fun and challenge of the 'race' and the pride of accomplishment." (Donald Stone)

"My greatest motivation has always been the thrill of the hunt, of looking for the pot of gold at the end of the rainbow. I just happen to really enjoy using my skills and talents in exploring for oil and gas. And once you have had success and felt the thrill of victory, it motivates you even more." (Richard Vincelette)

Survey Responses, continued

Training

Question: How did you learn to find oil? Did someone teach you, or were you largely self-taught?

Summary: Although earlier the respondents said mentors were very important, most said they were self-taught.

Visual thinking

Question: Do you consider yourself to be a visual thinker?

Summary: Yes.

Sketching

Question: Do you like to draw or sketch?

Summary: Yes (86%).

Typical responses:

"Yes, I draw and sketch landscapes, seascapes, people, things—outcrops in the field. It helps me to visualize, to see things I otherwise would never notice. I keep sketch (visual) notebooks. Drawing and sketching are the most important ways to learn to think visually." (Norman Foster)

"Yes. Even though I am very adept at 3-D visualization, I still have to put it down on paper to get it properly in mind. I continually redraw cross and seismic sections in 3-D, taking the earth's curvature into consideration." (Jack Elam)

"Absolutely. I believe I understand concepts, etc., only after I can draw it for myself and explain it to others." (Robert Sneider)

"Yes, all the time—have even tried etching and monoprints. Took up watercolor as a well-site geologist. Used blank DST charts to scratch pictures on. I have done some carving. Mostly I paint in oils and acrylics." (Donald Todd)

"My imagination and the pages of my books are my best, most used visual aids. From these I sketch, I interpret, I classify, I discard, and I refine each concept based on the information available. When everything meshes and I feel good and secure, I become fairly sure I have found oil or gas—reached my goal." (Gerald Loucks)

Survey Responses, continued

Idea development

Question: Where do you get your best ideas for new plays?

Summary: Developing and applying analogs from a strong knowledge of case histories is valuable.

Typical responses:

"From surface geology, either directly from the field or from aerial photos compared to surface expression of analogs. From the patterns of productive trends in similar basin settings. From studying nearby analogs and looking for similar anomalies. From analogs in faraway basins and applying them to the prospect area." (Norman Foster)

"Most of the best ideas I have had were based on plays that developed in other parts of the U.S. that were look-alikes to things that I was already doing." (A.V. Jones)

"Sometimes while driving, sometimes while sleeping, sometimes in church, sometimes through field studies, once by looking at a map of the northern polar region of Mars." (Douglas Strickland)

"Reading and hearing professional talks are first. Sometimes in teaching or preparing to teach. Also on airplanes when listening to music." (Robert Sneider)

"In the shower. While doing rig operations, short-term input for drilling wells. While messing around in my databases, doing things that 'I ought to let someone else do.'" (James Lantz)

Frontier vs. mature basins

Question: Do you prefer frontier or mature basins?

Summary: Frontier, 60%; mature, 20%; both, 20%.

Peers

Question: Discuss other oil finders you know or have known. What characteristics made them oil finders?

Typical responses:

"The scientific oil finders' characteristics, I believe, are as follows: observant, curious, logical, intelligent, creative, dedicated, outdoorsy, risk oriented, independent, derives pleasure when making order out of chaos. I hope the above does not sound too much like a horoscope reading, but all or parts of each are needed." (Graham Curtis)

"They are optimistic, positive thinkers (negative-thinking people do not find oil). They develop creativity through visual thinking, they have vivid imaginations controlled by facts, they are also very curious, they have a great desire to find oil, they are self-motivating and self-starting, they are persistent, and they love the trill of discovery and the deep satisfaction of finding something of value for the betterment of mankind." (Norman Foster)

"They were there first. Even before geophysicists, there was no substitute for being there first. As for characteristics, 1. Persistence is #1. 2. Enthusiasm for oil exploration. 3. Self-confidence. 4. Risk-takers. 5. Intuitive sense of where exploration opportunities exist. 6. Ability to diagnose critical elements of a play." (David Powley)

Survey Responses, continued

Blocks to creativity

Question: What do you think are the biggest blocks to creativity in petroleum exploration?

Summary: Management that doesn't understand oil and gas exploration or the creative process. On the other hand, a boost to creativity was working in a place that has the resources to test ideas.

Typical responses:

"Most explorationists are under too much pressure to produce. Exploration is an art form, and you don't stand over an artist and criticize his work. Large companies have to show a profit every year. Even if they are doing their jobs, they are going to have a bad year. Bosses and stockholders should look at the longer term and overall results." (A.V. Jones)

"Extraneous activities which constantly interrupt the concentration of the explorationist." (Frank Harrison)

"The single, most destructive block is the desire to quantify results and relate those to economic rates of return. Usually this takes the form of a single answer which is subjective and doomed to be wrong! Another block is attitudinal—it is always easier to destroy a hypothesis than it is to nurture one. Nurturing ideas is hard work!" (Harry Jamison)

"A management lacking geologic knowledge and exploration know-how. In the case of an independent, lack of sufficient resources to acquire necessary geologic data, well data, maps, and pertinent information." (Howard Lester)

Overcoming prospector's block

Question: How do you overcome prospector's block?

Summary: Typically, respondents said they put the problem away for awhile—they let it incubate.

Typical responses:

"I usually work on two or three projects during the same time period. When I get bogged down on one, I go concentrate on one or two of the others. This usually works for me every time." (Robert Sneider)

"If I understand what you mean, I clean up the office, put things away, and start by studying regional maps and doing some general reading. Or perhaps going through old files for leads never followed up." (Donald Stone)

"Yes. I go for drives in the country, go camping, go fossil collecting, etc." (Douglas Strickland)

"Cleaning my desk and my office helps clear my mind. (Sometimes this takes a few days.) Quit your job. Twice in my career I quit good jobs because I was left no room to dream." (Donald Todd)

Survey Responses, continued

Working environment

Question: Describe what you consider to be the best working environment.

Summary: Most individuals described a comfortable environment where other optimistic colleagues worked and with whom they could interact.

Typical responses:

"In an office with all the data, around a number of optimistic geologists, and with a supervisor tht doesn't have preconceived ideas, does have an open mind, and is a smart geologist." (Ted Bear)

"Large room; lots of (magnetic) wall space; long layout table; easy access to database and exploration files and well-stocked library. Experienced, enthusiastic teammates. Ample freedom within framework of time and company's strategic targets." (H.M. Helmig)

"Comfortable, well-lighted working areas with access to all the better exploration aids and no worry about financing your projects. Optimistic exploration friends are also quite valuable in helping to overcome some occasional exploration slumps." (Roy Huffington)

Working alone versus working on a team

Question: Do you function best alone or on a team?

Summary: They like an office where they can be alone but, when they need to test an idea, have someone there to help.

Typical response:

"Alone, I think pure individualism is essential because, in my case, committee efforts tend to defuse my aim. With total concentration, I am able to massage my data and imaginatively draw or conceptualize my targets without diversion. After my study is complete, I consider it important to subject it to constructive expert review (provided they agree with me)." (Robert Gunn)

"Initially, I function best alone; but as an exploration idea develops, more and more teamwork is required in order to bring to bear all of the talents and disciplines of the team. This is particularly true now and in the future as geology becomes more and more a multi-disciplined science." (Howard Lester)

"I like to work alone, essentially, but with access to a team of specialists because I am not very strong technically." (John Masters)

"Creatively I have always functioned best alone. After the conceptional stage, however, team effort is most necessary. Rarely does a creative oil finder fit into a bureaucratic corporate mold for very long. I function best out of my hip pocket." (Donald Todd)

"I have had my greatest success in a team environment, but where independent thought and action are also encouraged. Most creative ideas are probably developed by the individual pondering alone on a problem or goal. But those ideas are immeasurably enhanced through brainstorming and interaction with others concerned with the same problem or goal." (Richard Vincelette)

Section C

Leading and Managing Explorationists

by
Norman H. Foster

Introduction

People who understand the creative process and how it applies to petroleum exploration are best qualified to lead and manage explorationists in an exploration program. Explorationists are more creative when their ideas are nurtured and they are surrounded by a supportive team.

In this section

This section contains the following topics.

Developing and Leading Multidisciplinary Teams

An analogy

Metaphors help develop an understanding of any subject. To help understand the highly effective dynamics of teams, let's consider the four-person scramble in golf. Many professional golf tournaments are usually straight medal play for the championship, where the person with the best score wins. In these tournaments, scores are determined by individual handicaps so anyone has a chance to win.

In a scramble, teams are assembled. Everyone on a team tees off and plays every shot. After a shot, members of a team decide where the best ball is located. Each team member participates in the next shot, and so on. Compared with medal play, the transformation in attitude and teamwork is amazing. Each team member wants his teammates to succeed. The members are no longer competing against each other but are working toward a common goal. The enthusiasm feeds on itself, resulting in a greater enjoyment of the game. The team shoots a much better score than any one individual could post, and team members share equally in any prizes that may be won.

Past and present

Multidisciplinary teams of geologists, geophysicists, engineers, geochemists, petrophysicists, landmen, and businessmen are far superior to any one individual working under the old district concept if arranged in the proper scramble format. The district concept of petroleum exploration used by the industry tended to pit fellow workers against each other, as well as groups of specialists such as geologists and engineers. Fiefdoms tended to form to protect turf.

Maximum brain power

Early in my career at Sinclair Oil Corp., I was inspired by Michel Halbouty's paper entitled "Maximum Brain Power." Halbouty advocated the formation of multidisciplinary teams to maximize the exploration effectiveness of an organization. I proposed this type of organization to Sinclair's exploration manager, S. K. Van Steenburg, and he formed the Williston Basin Exploration Team.

The original group consisted of geologists (a carbonate stratigrapher, a structural geologist, and a photogeologist), a petrophysicist, a geophysicist, and a landman. The team was so highly effective that within six months the entire Western Region was reorganized into exploration teams. The Williston basin team developed more prospects in about a year than the entire corporation did worldwide. It leased acreage quickly after generating the prospects, and its work led to several important discoveries, including the Weldon oil field in Montana (the best field on a per-well basis in Montana).

Take dead aim

Just as in golf, if you take dead aim, you will be more effective. What are you trying to do? Make a profit for the company. How do you do this? Find and produce commercial accumulations of hydrocarbons. When you focus on the goal—to find and produce commercial accumulations of hydrocarbons—all sorts of things start to fall into place, especially when individuals are organized into teams.

Unfortunately, we frequently tend to get sidetracked into many extraneous areas that have little or no bearing on where commercial hydrocarbons are located. When this happens, we need to focus again on the goal, asking the same fundamental questions for every prospect:

1. Are mature source rocks present?
2. Have the source rocks generated and expelled enough oil to provide commercial accumulations?
3. What are the migration pathways?
4. Are sufficient reservoirs present?
5. What types of traps are probable, and where are the traps located in which the hydrocarbons may have accumulated?

Leadership

Leaders and managers have a unique opportunity to help the effectiveness of exploration teams. Their experience in widely diverse areas and traps enables them to provide many helpful and sometimes critical ideas for generating and evaluating prospects. Their experience of evaluating many widely different types of plays can be applied in innumerable ways to help a team take dead aim. Leaders and managers should always put people first. Stephen Covey, author of *The 7 Habits of Highly Effective People,* says, “The first imperative for today’s leaders is the top line, not the bottom line.” By this, he means that if we concentrate on people (the top line), the bottom line will take care of itself. Try to provide an environment that nurtures creative thinking—one that encourages taking a different path.

Test ideas

If a creative idea has held up under the closest scrutiny, then the idea is ready for the drill and it is the duty of the manager to do everything possible to get the idea evaluated. Find the money to drill inside the company or, if not available internally, farm out the prospect. One of the great killers of creativity is that new ideas frequently are not evaluated.

Getting ideas

Managers must make sure they and their employees keep abreast of developments in their field. Managers should encourage explorationists to attend conventions, present talks for professional societies, publish papers, take/lead seminars, enroll in continuing education courses, participate in study groups, serve on committees and as officers of professional societies, and read the published literature. One of the lamest excuses is “My company won’t let me publish.” Companies will succeed if their people are able to reach their maximum potential by interacting with professionals outside their companies.

Developing and Leading Multidisciplinary Teams, continued

Team life cycles

Effective exploration teams are extremely flexible and are formed for a specific purpose and goal. When those goals are achieved, the team should be disbanded.

Recognizing oil finders

How do managers and leaders recognize oil and gas finders? Finders are positive thinkers (negative-thinking people do not find oil), they develop creativity through visual thinking, they have vivid imaginations controlled by facts, they have a great desire to find hydrocarbons, they are self-motivating and self-starting, they are optimistic, they are persistent, and above all they love the thrill of discovery and the deep satisfaction of being able to use science and art to find a valuable deposit for the benefit of all mankind.

Establishing a Creative Environment

Idea killers

The great enemy of ideas and a creative environment is the killer phrase. New ideas are very fragile and must be nurtured until they can be tested. Most new ideas fail because they are not correct; however, a small percentage of new ideas will prove to be right. If an organization is to survive and prosper, an environment must be established where new ideas are allowed to come forward, be tested, and, if workable, be integrated into the business.

What is a killer phrase?

A killer phrase is a negative word or statement that is inevitably hurled at any new idea. Frequently the result is to shoot down the idea without a fair evaluation. Examples of killer phrases are . . .

- "We tried that before."
- "That's irrelevant."
- "Don't waste time thinking."
- "It's not in the budget."
- "Your ideas only have limited use in their present format."
- "It will be more trouble than it's worth."
- "We've done all right so far."
- "No."
- silence

Killer phrase generators

Everyone issues killer phrases: you, me, our spouses, our bosses—everyone. It's part of human nature, our culture, and our upbringing. One study showed that negative no-can-do statements outweigh positive can-do statements by big margins. At home, parents say, on the average, 18 negative statements for every one positive statement they utter. We even issue killer phrases to ourselves by creating self-doubt: "I'll look stupid" or "Somebody has already done it" or "I don't have time." How often have you had a great idea but failed to follow through? Idea generators must be aware of killer phrases, know how to recognize them (no matter how subtle), and be prepared to defuse them.

Defusing killer phrases

Killer phrases become institutionalized. Every organization has its own favorite negative statements. To defuse the inevitable killer phrases that appear at any stage of a new idea, be prepared. Anticipate them, and have a response ready such as the following:

Killer phrase—"We did that 10 years ago."

Possible response—"Lots of improvements and new understanding have occurred since then. Let me gather the details for you so we can review them at our next meeting and avoid previous mistakes."

Institutionalize the term "killer phrase" so everyone learns to recognize one. This will greatly reduce their use. Point out old ways of thinking in a fun way, such as by throwing paper wads at each other whenever a killer phrase is hurled at a new idea. Before long, you won't let the "It hasn't worked in the past" way of thinking affect the way you operate today.

Section D

Applying the Scientific Method to Petroleum Exploration

by
Marlan W. Downey and James D. Robertson

Introduction

Successful exploration results when we apply technology and intelligence to the task of finding oil cheaply. We must know whether intelligence and technology are being properly harnessed to deliver exploration success. If technology is being properly utilized, it should lead to predictable outcomes and improvement in performance measures such as exploration costs. On the other hand, if the application lacks focus or direction, technology will have no benefit, even though it may be intellectually interesting. Proper application of technology in petroleum exploration is geologically directed and follows the scientific method. It is important for all explorationists to realize that scientifically directed petroleum exploration reduces risk and therefore impacts the economic success of any petroleum exploration program.

This chapter reviews the scientific method and discusses its application to exploration. Also discussed are ways to measure and evaluate the confidence level of a scientific interpretation.

In this section

This section covers the following topics.

What is the Scientific Method?

Introduction

In looking at past actions and past outcomes, it is easy to analyze whether exploration predictions were correct. If they were correct, the technology used for the predictions was probably proper and correct.

In real-time monitoring of whether technology is used properly, managers must rely on subjective measures. One helpful approach is to assess whether a company's technical efforts are truly part of a scientific approach to exploration. A scientific approach requires that technology be used in a logic sequence to solve problems, i.e., be deployed not for its own sake but as part of a scientific methodology.

The scientific method

The logic sequence, or *scientific method,* has been the basis of scientific work since the time of Copernicus and takes the form shown in the following table.

Step	Action
1	State a problem.
2	Collect observations relevant to the problem.
3	Formulate a hypothetical solution (interpretation) of the problem, consistent with the observations.
4	Predict other observable phenomena from the hypothesis.
5	Test predictions by observing occurrences or nonoccurrences of the predicted phenomena.
6	Accept, modify, or reject the hypothesis (interpretation) in accordance with the degree of fulfillment of the predictions.

Measuring the merit of predictions

Technical work in exploration is most valuable when it both conforms to and lasts through the entire logic sequence. We can appreciate a solid technical effort that produces a good initial interpretation. However, the true measure of merit is the accuracy of the predictions inherent in this first hypothesis and the robustness of the interpretation when these predictions are tested by new data.

Applying the Scientific Method to Exploration

Introduction

Technical effort in petroleum exploration that follows the six steps of the scientific method is the only effort that can consistently progress toward an acceptable solution. The table below shows how to apply the scientific method to petroleum exploration.

Examples

Step	Action	Example(s)
1	State the problem	Asking "Where are the economical hydrocarbon accumulations?"
2	Collect observations	Collecting outcrop, seismic, and well log data
3	Formulate hypothesis	Correlating seismic records with well logs Contouring structural and thickness data
4	Make predictions	Recommending lease purchases Recommending drilling a test well on the basis of map interpretation
5	Test predictions by observing phenomena	Seismically detailing a structural prospect Drilling a wildcat well
6	Accept, modify, or reject the hypothesis	Drilling another wildcat well Promoting a well to test a modified hypothesis Dropping acreage

Step 1: State objectives

In exploration, the general problem is locating substantial quantities of hydrocarbons that are economical to produce. A host of specific problems arise in given instances, but we should recognize that the major problem (objective) of an exploration effort is to find large amounts of oil or gas cheaply.

Step 2: Collect observations

Much of the technical work done in exploration can be categorized as collecting observations (data). Under this heading comes work such as logging samples, recording shows, compiling sediment interval thicknesses, acquiring field seismic data, and identifying paleontologic data.

Step 3: Formulate a hypothesis

In step 3, explorationists formulate hypothetical solutions (interpretations) to the problem stated in step 1 (Where are the hydrocarbons?) that are consistent with the observations of step 2. When explorationists interpret data, they formulate hypothetical solutions to the problem of finding commercial accumulations of hydrocarbons.

Unfortunately, exploration technical work often bogs down at step 3. Many people believe a modern interpretation derived from recently collected and carefully measured data is a high-level scientific piece of work that deserves a high level of confidence. In the rigorous context that we are attempting to describe, such an interpretation is only an untested hypothesis (step 3).

Applying the Scientific Method to Exploration, continued

Step 3: Formulate a hypothesis (continued)

We should continuously evaluate whether the products of an exploration effort have passed step 3. For example, compare these two pieces of stratigraphic work:

- A simple gross sand isopach map that is essentially unaltered by results of considerable additional drilling. Such correct predictions represent work that has earned a high scientific confidence level and therefore is well past step 3.
- A newly prepared environmental, lithofacies, and seismic–stratigraphic interpretation of a similar sand unit. Although prepared with an impressive degree of advanced technical competence, this is only an untested hypothesis and therefore has only reached step 3.

The scientific method recognizes the degree of proof of the hypothesis, not the sophistication of the data used to prepare it.

Step 4: Predict results

Step 4 in the scientific method sequence is predicting that hydrocarbons can be found and economically produced at a specific location, using the maps, cross sections, etc., made in step 3. Predictions are of most value when their specific components are properly recorded in advance of verification along with some estimate of the degree of confidence in the components.

Step 5: Test predictions

Next, we must check or observe the predictions of step 4 against the outcome of some test, such as drilling a well or seismically detailing (reshooting) a prospect.

Step 6: Accept, modify, or reject the hypothesis

Drilling a wildcat well on a prospect rarely completely proves or disproves the original interpretation. Generally the test performed at step 5 modifies the interpretation to a greater or lesser extent and always alters the confidence level attributable to the interpretation. Depending on the confidence retained in the interpretation, we may drill another wildcat well, promote a test, or drop the acreage, in descending orders of confidence. Step 6 of the scientific method as applied to petroleum exploration is accepting, modifying, or rejecting the hypotheses or interpretation developed at step 4.

Measuring and Evaluating Scientific Predictions

Introduction

There is a common tendency to regard a single well on a prospect as conclusive proof or disproof of an interpretation. However, we need to analyze the wildcat well far more intensively than "Is it a dry hole or not?" We need to provide a series of specific predictions about what the well will find to compare with what the well did find.

Evaluating predrilling hypothesis

How do we know when a predrilling hypothesis is correct? If drilling proves we were correct on most or all of our predictions, then we can be confident in our interpretation. If the well comes in low with very thin, tight reservoirs and no oil shows, then we need to give our interpretation and ourselves a failing grade.

Measuring confidence level

Is it possible to measure the confidence level (degree of scientific proof) of a mapping interpretation without drilling numerous additional wildcats or shooting more seismic? Certainly! Where possible, maps should be constructed in two stages:

Stage 1. A preliminary interpretation that deliberately excludes a random portion of the available information.

Stage 2. A revised map incorporating all the information to compare and test the interpretation.

Such a two-stage mapping procedure lets us test our interpretation with available data rather than drilling expensive new wildcats and shooting seismic surveys.

Follow these steps to measure the confidence level of a mapping interpretation before drilling.

Step	Action
1	Construct a first-stage map, leaving out a random and significant portion of the available data.
2	Insert all withheld well data into a second-stage map and compare predicted vs. actual.
3	If predicted vs. actual does not match, review the original contouring hypothesis and adjust it to fit the data.

Example

The following is a hypothetical example of a two-stage mapping to measure confidence before drilling:

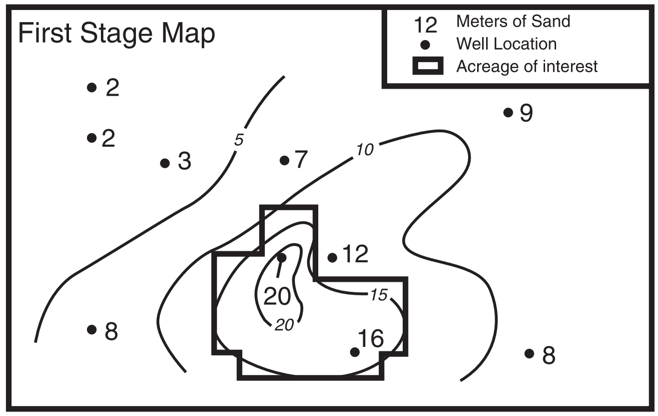
Assumption: Commercial oil production in the zone of interest in the map area shown below requires more than 15 m of sand.

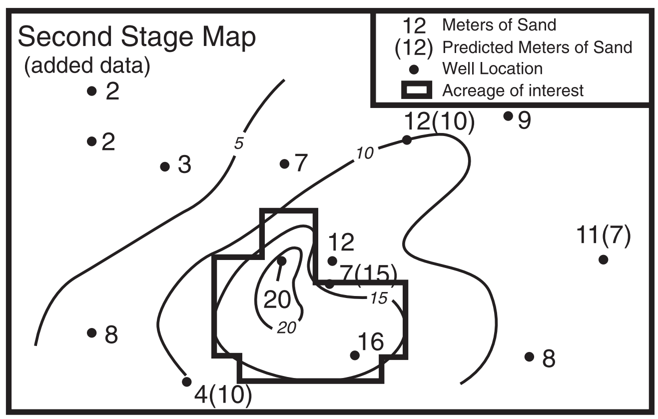
Measuring and Evaluating Scientific Predictions, continued

Example (continued)

Task: Map sand thickness in available wells and select the area most favorable for leasing and drilling.

Procedure: Follow the procedure detailed on the preceding page.





Conclusion: Four wells were left out of the first map. The second map shows that the two wells closest to the prospect outline had thinner sand than predicted. The two wells away from the outline had thicker sand. The interpretation should be adjusted by recontouring the data.

Judging confidence level

The most difficult single decision in exploration is judging the level of confidence to place on an interpretation. If we want exploration technical work to be scientific work, we must learn to recognize the real usefulness of our technical work: What step in the scientific method are we actually attaining? Our technical work needs to provide internal measures of its uncertainty.

A common approach of developing confidence in an interpretation might be to drench the area in data—drilling wells and acquiring 3-D seismic data. A more thoughtful and economic approach would be to test the robustness of the original interpretation. If we conduct our exploration technical studies with scientific logic, we will be more successful in our exploration business ventures.

Section E
Analog Exploration
by
Norman H. Foster

Introduction

Each trap is unique because of the complex combination of all the geologic variables that define it. Some argue that this fact makes the analog approach weak. But the analog approach does not assume there is an exact look-alike. Instead, the analog approach draws look-alike features that are critical elements of the play from appropriate fields both within and outside the basin of interest. This section discusses how to apply analogs to petroleum exploration.

In this section

This section contains the following topics.

Using Analogs to Identify Critical Elements

Introduction

Many people looking for oil and gas do not have a mental image of what they are searching for. How can one recognize something if they do not know what it looks like? A hunter would not have much luck finding rabbits if he had very little idea of the appearance of a rabbit. He also would not have much luck finding rabbits if he did not understand their habits—where they live or what and when they eat. In the same way, we learn about oil and gas fields by studying their habitat.

Visualizing the trap

Visualizing an accumulation is the key to exploring for any type of trap. The explorer must have a mental image constantly before him to maximize his chances of success. Keeping visually focused on what you are looking for (the critical elements derived from analogs) helps define exploration methods, wellbore location, and penetration direction. This is known as the analog method of exploration.

The analog method is the most effective method, in the author's opinion. It closely follows the scientific method: establishing the critical factors of the known and then looking for the same critical factor in an unknown area. In essence, if you can visualize it, you can find it.

Finding analogs

Oil and gas accumulations fall into broad categories, i.e., structural and stratigraphic traps, but there are hundreds of variations of these trap types. The explorer must carefully study the many ways in which oil and gas accumulate. Many local and international geological societies publish field studies that can serve as analogs. AAPG's 11-volume *Treatise of Petroleum Geology, Atlas of Oil and Gas Fields* is an excellent example of where to find analogs.

Critical elements

These excellent descriptions and analyses provide the explorer with mental images of various trap types, which are essential in recognizing certain critical elements of traps. Usually, at least three to five critical factors must be present for a particular type of trap to work. When we study local analog fields within a region or basin, or perhaps in a similar productive setting in another part of the world, we can develop the critical elements of a specific play, which in turn lead to discovery.

An Example of Applying Critical Elements

Critical elements of the Niobrara play

In the fractured Upper Cretaceous Niobrara play of the central Rocky Mountain region, specific critical elements must be present for a prospect to be successful. Since the Niobrara Formation is its own oil source rock, there is no bottom water; gas expansion along with gravity drainage provide the main reservoir energy, so the structural position of a well is not a critical factor. Synclines, anticlines, and any structural location in between will work. The main critical element is to find a sufficiently fractured sweet spot in which the fractures remain open during production. Careful study of numerous excellent Niobrara producing fields shows that the following critical elements must be present to achieve commercial success.

- Maximum bed curvature
- Normal fault cutting through area of maximum bed curvature
- Presence of a cross-lineation
- Open calcite crystals lining the fractures
- Well must penetrate above critical elements in a more fracturable (more calcareous) bench within the Niobrara
- Completion must be open hole (hang a slotted liner) with cement-block fractures
- Drilling must be conducted with underbalanced mud or air to prevent fracture damage. The Niobrara is an underpressured reservoir with petrostatic (0.33 lb/ft gradient) rather than hydrostatic (0.43 lb/ft gradient) pressure.

Applying the critical factors

Once the critical factors from the analog field(s) are fully understood, we can devise the best exploration methods to delineate the critical factors.

Niobrara structure

In the Niobrara play, a subsurface structure map on top of the Niobrara formation is a first step to locate areas of maximum bed curvature. Normal faults should then be mapped from subsurface well control, photogeology, and good old-fashioned field work. Cross-linears may be mapped from photogeology and satellite imagery. Below is an example Niobrara structure map.

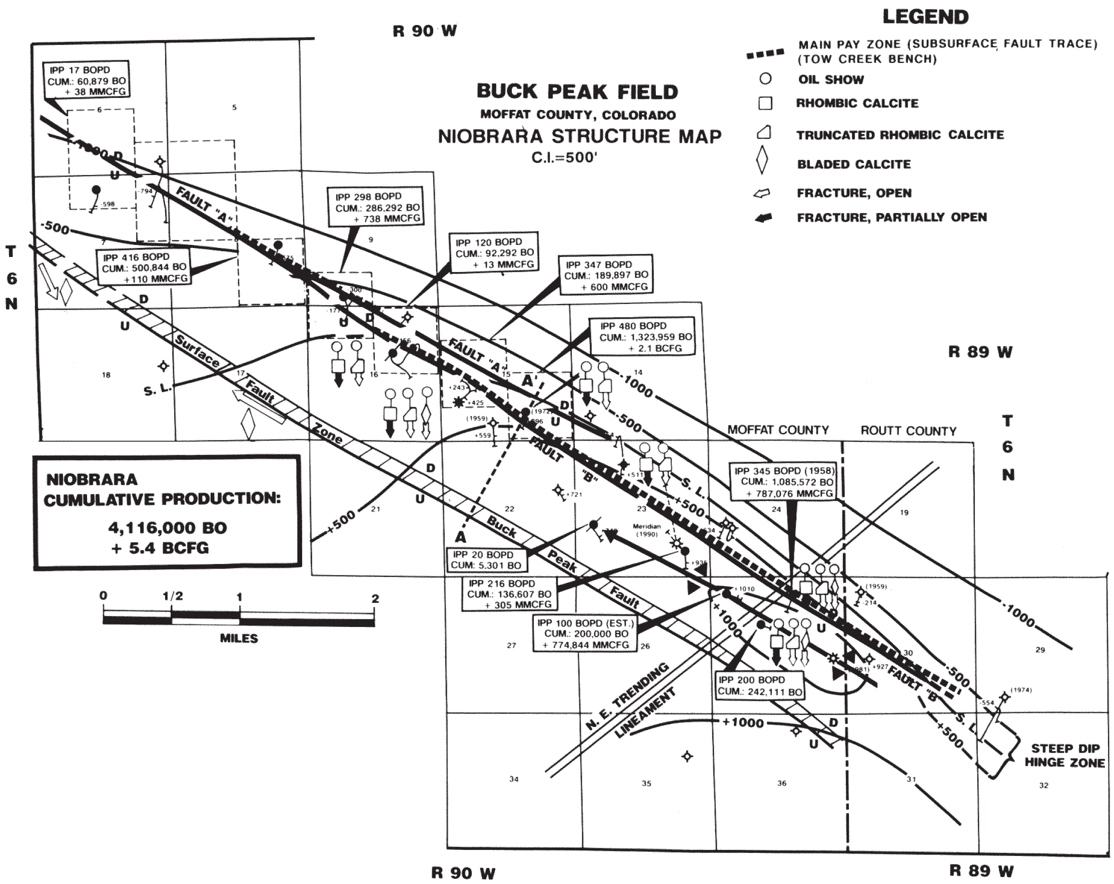


Figure 1–2.

Niobrara maximum bed curvature

Higher resistivity on electrical logs shows the brittle, more fracturable benches within the Niobrara. Constructing a detailed cross section, showing fracturable benches, maximum bed curvature, and any surface and subsurface normal faulting, allows the explorer to visualize and accurately plot the angle at which the well bore must be drilled to penetrate the critical elements.

Seismic surveys are not particularly helpful in mapping normal faults because they are listric with about 100–300 ft of throw at the surface and about 30–80 ft of throw in the Niobrara. The faults are usually not present below the Niobrara. Therefore, although the Mesa Verde provides good seismic marker beds, the underlying Mancos and Niobrara

An Example of Applying Critical Elements, continued

Niobrara maximum bed curvature (continued)

Formations usually do not have them. Occasionally, upward-lying normal faults will produce. Seismic data are useful in delineating these faults because good marker beds are usually present below the Niobrara. The fault can then be projected upward and is sometimes associated with a dim spot due to attenuation of seismic data in fracture zones.

Below is a Niobrara structure cross section.

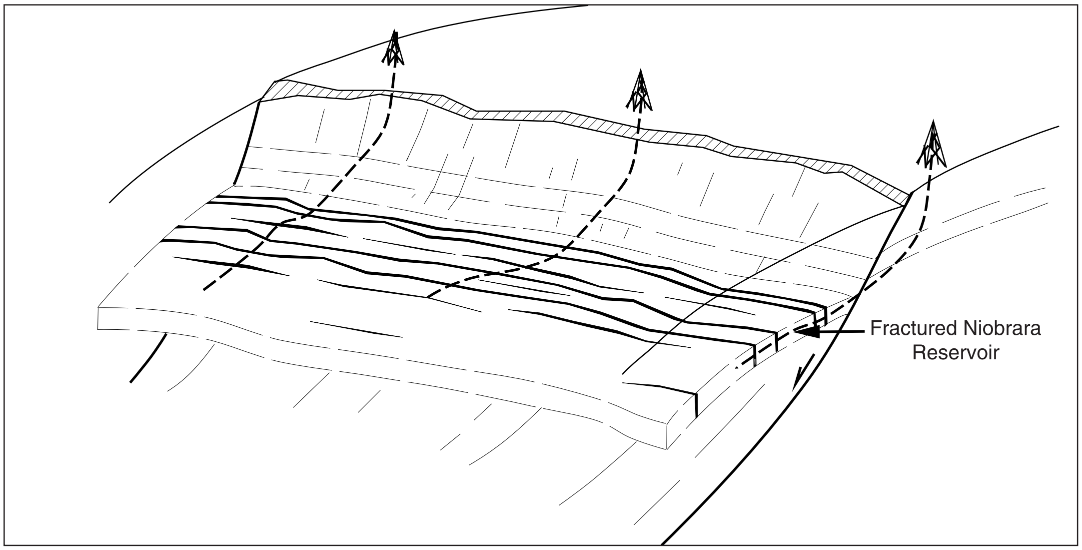


Figure 1–3.

Niobrara open fractures

Running samples on Niobrara wells will reveal whether open calcite crystals are present in the fractures. In addition, field work has shown that the same kind of calcite present in subsurface fractures within the Niobrara also occurs in fractures associated with brittle beds at the surface, such as the Mesa Verde group.

Surface geochemistry applied to Niobrara play

Surface geochemical methods—specifically, soil gas surveys—have proven useful in exploring for these types of traps. The computer compares hundreds of soil–gas ratios very quickly. Also, very sensitive chromatographs have improved the detection of vertical microseepages of hydrocarbons above these fractured reservoirs. The main method of exploration with this technique is to conduct surveys over a number of known commercial accumulations to establish productive signatures. Then a survey over the prospect may provide useful information that can be integrated with the other exploration techniques to help locate a drillsite.

Conclusion

Critical elements of the Niobrara play were identified by studying known accumulations. Knowing what elements were critical allowed a focused effort that saved time and improved effectiveness. Study known examples of trap types of interest to discover critical elements, and the result will be a more effective program.

Section F
References

Covey, Stephen R., 1989, The 7 Habits of Highly Effective People: New York, Simon and Schuster, 358 p.

Edwards, Betty, 1987, Drawing on the Artist Within: New York, Simon and Schuster.

Foster, Norman H., and Edward A. Beaumont, Eds., 1992, Oil is First Found in the Mind: The Philosophy of Exploration: AAPG Treatise of Petroleum Geology, Reprint Series No. 20, Tulsa, AAPG.

Halbouty, Michel T., 1966, Maximum brain power: AAPG Bulletin, vol. 49, no. 10, p. 1597–1600.

King, P.B., 1942, Permian of West Texas and New Mexico: AAPG Bulletin, vol. 26, no. 4, p. 535–763.

McKim, Robert H., 1980, Experiences in Visual Thinking: Boston, PWS Publishing, 183 p.

Pratt, Wallace, 1952, Toward a philosophy of oil-finding: AAPG Bulletin, vol. 36, p. 2231–2236.