Replenishing Hydrocarbon Reserves

Invited Presentation
for
Representatives to the Annual Meeting of the GBRN
and their Spouses

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Replenishing Hydrocarbon Reserves

[lights down and stars up and fly through the star system}

It is nice to be here with you this afternoon to look at the stars. The people I have the privilege to introduce today, chose, in their youth, to "build castles in the sky" and to "reach for the stars." The topic, even for most oil finders, is out of the mainstream. Reminds me of how the industry used seismic for direct hydrocarbon detection in the early 1970's and for interpreting sequence stratigraphy in the early 1980's. Looking at concepts for exploration in the 1990's, logic and location dictate we start this introductory presentation with a star tour.

Today, even more than most days, you have the opportunity to "take a walk in your mind."[1] I hope you rediscover, to quote the great oil-finder Wallace E. Pratt, that "oil is first found, in the final analysis, in the minds of men"[2] and women. As an up front acknowledgment, this presentation blends together many people's thoughts and work, often as direct quotes. I will not specify all of the quotes, because they are documented in a souvenir preprint. Please sit back, relax, and help me contemplate the implications of the work being done by the Global Basins Research Network (the GBRN), their corporate partners and their corporate sponsors.

[slide 1C: Replenishing Hydrocarbon Reserves]

"Replenishing Hydrocarbon Reserves" summarizes the research work I have the privilege of introducing. As a pre-recorded, general introduction to the more technical presentations to follow, this show aims to articulate the importance of hydrocarbons to society from the oil industry's point of view, to introduce the GBRN and the scientific principles they are studying, and to specify how this research work affects each one of us. The GBRN plans to use the information presented today to build a planetarium show that will tour the country, transferring the technology developed through the $10 million Department of Energy grant back to taxpayers.

But before we talk about the 1990's, let's go back way before the 1890's to review why hydrocarbons are so important to our society.

[slide 1L: Why are hydrocarbons important to society ?]

Anciently hydrocarbons were used as building mortar, perhaps to caulk Noah's ark and Moses' basket, for road making, as a medicine, for war, and, in a limited and generally unsatisfactory way, for lighting.[3] However, in the ancient Americas there is little evidence of hydrocarbon usage. To stress the relevance of hydrocarbons to today's society, our mindwalk starts in Oaxaca, in south-central Mexico, at the famous ruins of Monte Alban. One of the main reasons we are starting at Monte Alban is that the Burke Baker Planetarium has a three-dimensional model of the ruins, which introduces the visualization tools that will be used to show GBRN results later today.

[from the north star bring in the Monte Alban ruins and rotate them around]

This display was derived from data we collected in June of 1991 when the planetarium sponsored an eclipse trip to Oaxaca. I helped survey the ruins. On this trip, Dr. Carolyn Sumners, Director of the Planetarium, discovered how this monument at Monte Alban can be used to monitor the sun's movement through the year. This ability was critical to developing the accurate calendar they had. The oldest Meso-American calendar, found here at Monte Alban, dates to A.D. 432.[4] The cultures that built these monuments were tremendous stone masons, their first cities emerged between 500 B.C. and 200 B.C. Monte Alban was the first urban center.[5]

[bring up Monte Alban panorama slides]

By approximately A.D. 300 nearly all regions of Oaxaca contained urban centers.[6] These ancient centers of political, economic and religious power[7] were comparable to most America cities in 1859 when driller Edwin L. Drake made the Titusville discovery. Look at what has happened over the last 133 years since that discovery, with petroleum greasing the wheels of progress. This history is described in the 8 hour television mini-series of Daniel Yergin's Pulitzer Prize winning history of the oil business, "The Prize," (starting tonight at 8:00 on PBS (Channel 8)).

[slide 2C: Illumination]

Along with hydrocarbon exploration there literally came a new type of light into the world. In 1854, a Canadian, Dr. Abraham Gesner applied for a United States patent for the manufacture of "a new hydrocarbon, . . . Kerosene, . . . which may be used for illuminating or other purposes."[8]

[slide 1R and 2R: kerosene lamp(s)]

Shortly after this, a kerosene sales agent in New York learned of a lamp with a glass chimney produced in Vienna that burned kerosene.[9] Adding the right kind of lamp to existing technology and known reserves, man suddenly gained the power to push back the night.[10] This new light provided the initial economic basis for the oil industry. However, following Thomas Alva Edison's discovery of the light bulb, the power source for the "new light" switched from kerosene to electricity. The natural gas industry had to shift its markets to heating, cooking,[11] and providing light for rural areas.

[slide 3C: Heat]

Heat is really the basis of most uses of petroleum in modern society. That we use hydrocarbons as a means of generating heat testifies of their biotic origins. Life, after all, is very closely tied to heat. Think about how much visible life exists without sufficient heat.

[slide 3R: Walden Pond in the winter]

Henry David Thoreau must have thought about this when he spent two Boston winters here on Walden Pond.

[slide 4R: Replica of Thoreau's house at Walden Pond]

He caught the essence of heat's importance to life when he wrote "...the expression, *animal life*, is nearly synonymous with the expression, *animal heat*."[12] Today, many of us use natural gas heaters in our homes to provide the heat needed to "keep the fire within us."

[slide 4C: Power]

Other sources of power, of course, heat our homes and our food in addition to hydrocarbons. Gravity drives the generation of hydroelectricity, wind turns some modern turbines, uranium decomposes to nuclear waste in reactors, and the sun powers solar cells and life itself. Consider the source of coal, oil, and gas. It goes back to the sun, which originally provided the light for life. Is it any wonder that the Zapotec Indians at Monte Alban worshipped the sun? As shown in the earlier dynamic display, this monument at Monte Alban monitored the sun's movement through the year, and provably guided the planting of their crops. After all, agriculture anchored their civilization.

Firewood and coal initially powered the industrial revolution, a major turning point in the development of our modern society. Industrialization changed civilization from a rural and agriculturally based society to a basically urban and industrial one. And oil fueled this change in our society. With this new society came air and water pollution and war.

[slide 5R and 6R: Klaveness' World War II diesel powered battleship]

The wars at Monte Alban do not compare to the wars supported by the industrialized civilization. Under Winston Churchill's tutelage, oil fueled the Royal Navy in World War I. Justification came from oil's ease of storage, lower cost than coal, and the fact that it could move British battleships at twenty-five knots instead of the twenty-one knot maximum speed possible with coal power.[13] The value of oil as a source of power was well established by V-J Day, September 2nd, 1945, when Alf Klaveness, who is with us today, commanded this ship, the USS Brenham. His ship lead the battleship Missouri into Tokyo Bay, on which was signed the official statement of surrender by the Japanese. We only have to step next door to the IMAX theater to see the results of power gone corrupt, in the IMAX movie "The Fires of Kuwait."

[slide 5C: Transportation]

When we think about the next major use of petroleum, we can easily question who really surrendered in Tokyo Bay. It is hard to keep the facts in focus over even a fairly short historical time.

[slide 8R: Intersection at I-10 and West Belt]

Henry Ford's assembly line grew to dominate modern society. Petroleum provides the fuel, the roads and the runways. Automobiles and airplanes allow us to move from place to place faster, and with less obvious waste than that which horses leave to be shoveled up off the street. However, microscopic noxious gas pollutants from millions of sources creates serious pollution. Petroleum byproducts not only generate air and water pollution but also a large component of the non-biodegradable material filling landfills.

[slide 6C: Plastics and Fertilizers] **[slide 9R: Farm in the desert]**

Petroleum products permeate our society. Our clothes, our chairs, our tables, our computers, our brief cases, our money, our wallpaper, our roofs, and even our food and medicine derive from oil and gas. Not only does petroleum furnish the illumination, heat, power, transportation, and containers that make urban living possible, it also provides the fertilizer that grows our food. This is shown by the green around this farm in the desert. Unquestionably hydrocarbons have been critical to making our society different from those of ancient Meso-America.

[dissolve out the panorama slides of Monte Alban and slide in the center and on the right]
Everyone in this audience knows the importance of hydrocarbons. So why have I stressed the use and importance of hydrocarbons at the start of our mindwalk? Because we need to get this message of the fundamental necessity of oil and gas to the rest of the world, so everyone better understands the importance of finding new reserves and of optimizing the use of the reserves that have been discovered to date.

[bring up DigiStar display of 1st step of the Activity Model: Manage Data]

We have a lot of data about how important hydrocarbons are, where they might be, how to find them, how to get them out of the ground, how to transport them to where we can use them, and how to make the best use of available and known oil and gas reserves. However, we do not manage this data very well. Data is too often unavailable to those who need it to make decisions. Hydrocarbons, like any other natural resource, are only important to society if they are available and if they are used with prudence. In order to manage the resource, we must manage the data that describes the resource. The GBRN research demonstrates new ways to manage data, particularly data related to fluid-flow problems of dynamic oil and gas migration into reservoirs.

[slide 2L: Who are the GBRN?]

The GBRN is a new type of industry-sponsored academic research consortium. The applied research ties directly to industry needs. To date, this project has created several new concepts that are greatly improving industry knowledge of the hydrodynamics associated with hydrocarbon migration. The volume visualization you will see today, and the work relating multiple 3-D seismic surveys over the same area, is state-of-the-art research.

[slide 10R: GBRN Goals]

I summarize the GBRN goals as: (1) identify locations of present-day hydrocarbon migration, (2) determine what geologic conditions produce hydrocarbon migration by transient expulsion of hydrocarbon-charged fluids from geopressured strata, and (3) determine how to produce these new hydrocarbon streams.

[slide 7C: A Research Network]

GBRN research covers larger study areas than a typical oil company prospect. It includes integration of more disciplines than are typically represented in an exploration team. The initial study area is the Gulf of Mexico, and specifically the field centered at Eugene Island 330, the largest Plio-Pliestocene oil field in the world. Although focused on the work in the Gulf of Mexico, we want to think of ways to apply these new hydrodynamic concepts in other basins around the world. And the GBRN researchers are spread all across the country, with ties to research organizations around the globe.

[slide 11R: Map of GBRN network]

This map shows the diversity of locations, institutions and disciplines involved in the GBRN. Most of this network was in place and operating prior to the DOE grant.

[slide 12R: University affiliates]

The grant has accelerated getting the computer equipment needed to build the network infrastructure. Equipment is just being delivered to several of the universities that allows them to connect to the Internet.

[slide 13R: Corporate Partners]

In addition to the universities, technology suppliers are helping support and develop the tools needed to do the research and implement the network.

[slide 8C: Professional Researchers]

[slide 14R: Roger Anderson, Lamont]
[slide 15R: Larry Cathles, Cornell]]
[slide 16R: Peter Flemings, Penn State]
[slide 17R: Jeff Nunn, LSU]
[slide 18R: Jean Whelan, WHOI]
[slide 19R: Jim Wood, MTU]

The GBRN can potentially achieve a type of augmented intelligence, by constructing a brain with the exact components needed for any given situation. With a team of dedicated professional researchers, the GBRN management team can fashion a nearly perfect brain to handle any kind of technical problem that comes up in their work. John Masters, former President of Canadian Hunter, described how this type of a composite brain can beat almost any single individual put up against it. Astonishingly the components are simply normal, smart, competent people who have become state-of-the-art experts in one particular specialty.[14]

[slide 9C: Large Scale Discipline Integration]

The GBRN composite brain has many lobes. There are lobes covering each of the following sciences:

- geophysics;
- geology;
- sedimentology;
- finite difference modeling;
- finite element modeling;
- physical chemistry;
- organic chemistry;
- hydrology;
- and various branches of engineering.

As with the two lobes in each of our heads, proper functioning of the brain requires proper connections between the GBRN lobes.

[slide 20R: GBRN activity model and subsets]

Activity models describe the connections between the lobes. We can look at each lobe as requiring input and producing some output. The input will come from another lobe, the output goes to some other lobe.

The GBRN researchers work within a larger environment of identifying locations of present-day hydrocarbon migration. They have divided their work into interrelated tasks. The activity model describes the relationship between these tasks which, in turn, are each described by their own activity model. We build activity models at finer and finer levels until the grains of activity can be performed by an individual lobe of the GBRN composite brain.

The activity model maps the relationship between the sciences being studied. Results from one activity that are fed to another activity are shown with the white arrows. The blue arrows indicate the group of people driving each activity. The brown arrows show the technology being used to perform each of the activities.

[slide 21R: Reservoir Characterization]

Each of the seven activities contain sub-activities. As a specific example, we see that the reservoir characterization activity actually consists of several sub-activities. Each of these subactivities has its own set of inputs and outputs. To make the diagram more meaningful, we annotate the arrows with descriptions of what is being transferred. If desired, we could look at each of these activities and see a further breakdown.

[slide 10C: Sedimentary Basins as Dynamic Systems]

Activity models break apart a work process into it's genetic components, much like sequence stratigraphy breaks apart a basin into packages of genetically related sediment. The integration of the activities and sub-activities, the scientific disciplines, the data, and the individual researchers allows us to comprehend the dynamics of how sedimentary basins change over time. This understanding relates directly to specific "products" that, in turn, are being transferred back to the GBRN industry sponsors.

[slide 22R: GBRN Products]

We can not predict the results of research. However, industry sponsors can directly apply the processes tested and developed by GBRN research. The field techniques to image ongoing fluid flow processes include:

- 4-D seismic surveys;
- structure and stratigraphic mapping;
- temperature and pressure mapping;
- organic and inorganic geochemistry;
- and production history.

In addition, researchers at Cornell are constructing a three-dimensional finite element fluid flow model to simulate and assist in the visualization of the origin and migration of hydrocarbons in an active sedimentary basin

The DOE co-funded wells within a large growth fault in Eugene Island block 330 will provide new data, specifically including a comprehensive suite of logs, as well as geologic and hydrologic samples researchers can use to test predictions of enhanced subsurface fluid flow. These wells will determine if enhanced oil recovery can be maximized by drilling directly into a conduit between a geopressured fluid source and a presently producing reservoir layer of rock.

[dissolve out slide on right]

To summarize, the GBRN is a network of professional researchers who are doing large scale discipline integration to study sedimentary basins as dynamic systems.

[bring up DigiStar display of 2nd step of the Activity Model: Interpretation]

The key results of GBRN research is proof of a theory: the theory of transient fluid flow.

The data interpretation makes this proof possible. Researchers bring all of the geological, geophysical, geochemical, petrophysical, and hydrodynamic data together and interpret it in ways made possible by new developments in computer technology.

[slide 3L: What are the scientific principles being studied ?]

The GBRN pushes back scientific frontiers in several areas. One of the most practical frontiers is: How do you get a group of researchers located at different research facilities all over the country to communicate effectively? Of course, semi-annual reviews for the sponsors, like this meeting, are key. Executive committee meetings, technology committee meetings, visits by industry sponsors, professor and student exchanges contribute as well. However, one of the real breakthroughs occurs when Internet, the federally funded digital computer network, links scientific workstations at different sites together.

[slide 11C: A HyperLinked Network of Minds]

Internet presently connects, at least by e-mail, each university and each Corporate Partner. In addition, any of the sponsors can get a commercial connection to Internet. This provides a framework for communication. To date Internet has been used for electronic-mail, image transfer, and data and model volume exchange. But the experiment is really only beginning.

[slide 23R, 24R, 25R: Three slides showing the amount of data available today]

The problems begin immediately with the growing size of the data files and the speed with which they must move over the network. A typical data set is 2 gigabytes (10**9 bytes) in size. To put this in perspective, at 9600 baud, the speed of a FAX machine, it takes over 55 hours to transfer 2 gigabytes of data over a phone line. In addition, the information comes from multiple or heterogeneous sources. The oil industry also needs tools which can find and combine information from multiple sources.

The GBRN faces the same problems: increasing amounts of data are available on-line; and different disciplines need to share available data. The fact industry and academia only use a small percentage of available data to make exploration and production decisions means those choices are not as good as they should be.

In a logical scientific approach to this problem, the GBRN researchers are currently installing a technology that lets individual researchers capture the data important to their personal work. One researcher has referred to this process as "training the computer" about what is relevant and which associations or links between different pieces of data are obvious to them as a researcher.

[slide 26R: The promise of hypermedia]

The technology that allows this training of the computer to occur is called hypermedia. The concept has been around longer than computers. With hypermedia, while doing or reviewing one thing, you can build a connection to any other related piece of data or process available on the network. Referred to as set theory, this concept derived from George Booles discovery of symbolic (or Boolean) logic in the 1840's and George Cantor's theory of sets developed in the late 1800's. Marvin Minsky at MIT noted that "one dissects a body but finds no life inside." and "one dissects a brain but finds no mind therein." He goes on to say that, "words like living and thinking are useful for describing phenomena that result from certain combinations of relationships," i.e., how larger assemblies interact.[15]

This concept is quite different from the sequential processes John Von Neumann introduced and that were implemented in the EDVAC computer in 1949. Von Neumann logic strongly influences the super computers, workstations and personal computers used today. The success of "sequential processing" caused "associative processing" to atrophy. Hypermedia technology supports a rebirth of associative processing by combining the concepts of hyperlinks and multimedia. This technology promises a user-friendly front-end to multiple databases on multiple computer systems at multiple sites.

[slide 27R: multimedia description]

Multimedia means that a single computer screen can have text (word processing), numbers (spread sheets), images (drawings or photographs), sound (speech or music), video, and simulations all running at the same time. Hyperlinks connect any one piece of data, say a screen capture of a Landmark interpretation, with any other piece of data (i.e., sound byte, image, text string, simulation process, etc.).

[slide 28R: Turning data into information]

The connection between different pieces and types of data provides meaning to the data, turning the data into information. Of course, the information is only useful if it is used to inform someone. This results in the creation of more data. As users generate, capture and classify data, the process expands.

As a specific example, imagine Jeff Hanor at LSU, an expert in the impact of salinity on fluid movement, takes the key results of his work and builds a hyperjournal. This hyperjournal includes copies of all the key articles on the topic, along with a classification of each piece of data and the links between pieces of data that Jeff knows are related, but might not be obvious to other researchers on the network. Once this hyperjournal has enough information to be of benefit to others, it is put on the network. As Jeff works he continues to adds data to the hyperjournal. Whenever a colleague has a question, he and Jeff discuss it over the telephone; Jeff tells him where to search in the hyperjournal for answers to the questions. In effect, the computer can now train others about Jeff's associations and make this information available to any other researcher on the network. In addition, other researchers can monitor key new work as soon as Jeff makes it available on the network and thus continually learn from the hyperjournal.

Simulations are another example of how we can turn data into information. The following video clip is an early simulation of fluid movement up a fault plane.

[video clip 1: fluid movement up the red fault] 35 seconds

Slides 29R and 30R: landsat photographs

Note how the fluid collects at the geopressure boundary, and as it breaks through, it spreads out and moves up different migration pathways. It is like an upside down river drainage system, where the driving force is not gravity but geopressure within aquifers and fault systems. Drainage systems are bounded by outcrops and fault scarps and driven by gravity. The video shows, most importantly, how fluids can move up a fault plane, and the spatial relationships of the fluid movement and the fault plane.

[slide 12C: Simulation of Hydrodynamic Processes]

The geologic processes to be simulated are not only physically large, but they are very computationally intense. GBRN researchers plan to have parallel processing machines at the Cornell Theory Center computing the different components and different parts of the same component of a single integrated model simultaneously. The integrate model will simulate: (1) sedimentation; (2) tectonics, specifically movement of growth faults; (3) salt movement; (4) pressure; (5) temperature; (6) fluid movement; and (7) multi-phase chemical interactions. These programs need results from each other to proceed, and so they have to update each other at each step, as the simulation proceeds.

To digress a little, I remember the night Roger and I were working with a regional 2-D seismic survey over the study area on a workstation at Landmark Graphics. We had digitized the interpretations from a few regional maps of key geologic markers provided by one of the GBRN sponsors. When we put the maps together and rotated the image, we saw the need to interpret the major faults. So we brought up cross-sections along key lines and interpreted faults from the input map data. Later the interpretations from these cross-sections were digitized. But as we rotated that information around in a perspective display it all clicked in Roger's mind, and he understood the relationship of the salt, the fault, the geopressure, and temperature anomalies. It took me several months to understand what Roger saw that night, but I will always remember going out to his car at about 11:30 that night, sitting on the hood and looking up at the stars, talking about what we had displayed and Roger saying "Life doesn't get any better than this!" Except for maybe the planetarium eclipse trip to Monte Alban referred to earlier.

[slide 31R: Survey Tool, 32R: Monte Alban, 33R: Fireworks, 34R: Aerial View]

Sometimes we have to stand back and look at the whole scene we are studying in order to put it in perspective. The simulation video introduces another key scientific principle the GBRN is studying; namely "How do you visualize three-dimensional information and the complex interactions between data and dynamic processes?"

[slide 13C: Visualization of Dynamic Geologic Processes]

Many of the areas of GBRN research require new methods to visualize the results. Later this afternoon, Roger Anderson will show you how the Planetarium's DigiStar computer system is used to assist in a new type of visualization. Ernest Cockrell encouraged the renovations of the Burke Baker Planetarium, which included purchase of the Evans & Sutherland DigiStar.

It is hard to describe how much insight 3-D computer visualization brings to this type of study. Dr. Phil Romig, Chairman of the Department of Geophysics at Colorado School of Mines, recently referred to the new visualization technologies as GeoNintendo.[16] Technology has moved from the flatland of contour maps, past the rotation of surfaces, to the spatial visualization of dynamic processes over time. Roger took his three year old son Forest's misnaming of Nintendo as Pretendo, and has referred to this new means of hypothesis testing by using visualization tools as GeoPretendo.

[video clip 2: slicing the 3-D seismic cube] 21 seconds

Here we have slices through a low-frequency seismic attribute of the 3-D survey over Eugene Island 330, to study the geometry of the column's bright seismic amplitude. This kind of dynamic interaction with the data opens new insights into the geology, and specifically to migration pathways. Interpreting the shapes of amplitude columns allows the creation of three-dimensional meshes, which will be shown in the video following this talk. The visualization process leads to understanding. Eventually the simulations will show how geologic processes evolve.

Growth faults and salt domes characterize the geologic tectonics of the study area. As sediments are deposited and get thicker over geologic time, several geologic processes happen simultaneously. First, water gets squeezed out of the deeper layers. Second, the weight of the newly deposited sediments turns thick salt layers into a liquid, and the salt swells into salt domes. Third, large slide-plane faults develop (also called listric or growth faults), allowing sediments to slip into the deeper basin. Fourth, these faults not only displace rock layers, they also displace the layer of overpressured water that has been squeezed out of the deeper layers. This displaced overpressure tends to move towards equalization across the fault boundary. Fifth, the temperature of the rocks are different in the salt structures and on different sides of some of the key faults.

[slide 14C: Episodic Fluid Ejection]
[surrounded by laser vortex]

In theory, the equalization of geopressure across the faults is caused by periodic and episodic pulses of fluid up the fault plane or through the acquifers. We believe these fluid pulses contain hydrocarbons, and the seismic amplitude anomalies represent residual, and possibly in-place hydrocarbons that have migrated up from deeper sources. Because the temperature and pressure anomalies at Eugene Island are still prominent across the red fault, GBRN researchers believe a fluid pulse occurred within the historical past. The comparison of two 3-D seismic surveys shot over the same area at different times (4-D seismic) supports the present-day dynamics of fluid movement. If we can tap these pulses with the drill bit, it is technically feasible to draw fluids up a geologic straw from depths greater than drilling technology can presently reach. This is analogous to turning on the garden hose to tap the city water supply.

[video clip 3: Fault Rupture + Rotation of Data Cube] 21 seconds

This video clip shows a model or numerical simulation of a fault opening up and a pressure pulse moving through the surrounding rocks. Similar simulations of temperature dispersion have been done by the GBRN researchers in order to understand temperature pulses.

If it is possible to drill into the fault plane and bleed off the geopressure difference across the fault, it will potentially bring up tremendous residual hydrocarbons from depths that can not be reached with current drilling technology. The implications of this are staggering.

[slide 15C: Testing the theory with the drill bit]

The U.S. Department of Energy has committed $10 million to the GBRN project. With industry data collection and drilling to test these ideas the total research expenditures could exceed $30 million. In exchange, the ideas and results of these tests are to be made available to the oil and gas community and to the U.S. public, thus the planetarium show.

Over this next year, the matching funds make it economically possible for several financially stretched oil companies to test dynamic reservoir refilling in the study area.

[bring up DigiStar display of 3rd step of the Activity Model: Interpretation]

John Masters could have been talking about researchers at the GBRN when he described Canadian Hunter as ". . . Just smart guys applying major company-developed technology in a purposeful, directed way to geologic problems not generally visible to conventional organizations." He continued: "I predict that we still have left to find some of North America's largest fields."[17]

[slide 4L: How does this work affect modern society ?]

[slide 16C: Minerals and Hydrocarbons]

The transient fluid flows we describe here have direct implications as to mineral concentrations as well as hydrocarbons. Understanding these processes should better help us know where to look for both. If we do find these natural resources and can extract them, then we need to improve optimizing their use and making sure that waste disposal minimizes impact on the environment.

Several years ago, Buckminster Fuller quoted a Denver oil geologist where he said "...with all that cosmic-energy processing (as rain, wind, and gravitational pressure) and processing time (paid for at the rates you and I pay for household electrical energy), it costs nature well over a million dollars to produce each gallon of petroleum."[18]

[slide 17C: Is this a perpetual energy source ?]

Does concern about available hydrocarbon resources change if there are greatly increased hydrocarbon reservoirs that are naturally replenished by Mother Nature at commercial rates? The answer is no! I believe the earth is full and there is enough to spare,[19] but I also believe that we are agents unto ourselves[20] and that there are natural consequences to the misuse of available natural resources. Population is the driving force concerning the use and misuse of natural resources.[21] It is time our society make some hard, belt-tightening choices.

Thoreau noted in his day that "while yet it is cold January, and snow and ice are thick and solid, the prudent landlord comes from the village to get ice to cool his summer drink; impressively, even pathetically, wise, to foresee the heat and thirst of July now in January,--wearing a thick coat and mittens!"[22] Note that in regards to ice, Walden Pond is a replenishing, but not an unlimited reserve. To recognize that the resource is being preserved, think of the problems the developer James C. Rosenfeld's, had a couple of years ago, attempting and failing to build a 148,000-square-foot office building across from Walden Pond.[23]

[side 18C: New knowledge]

Universities have always been in the business of discovery. The GBRN is a small part of this great tradition. This group not only develops the new, but captures both the current work and old knowledge so that neither becomes lost. The creation of a digital memory of a project, as comprehensive as this one is, will have a profound effect on research in all areas it touches for many years. However, individuals must still learn about and take advantage of this new knowledge.

As Phil Romig pointed out, although "education is the employee responsibility, universities will provide professional training and outreach"[24] to support the employee.

Projects like the GBRN are a mechanism for this technology transfer. It is technically possible for Internet to reach from individual university researchers directly into the workstations of every explorationist in an oil company. The industry now needs to overcome the political and economic barriers that keep this from happening. The more brain cells that are connected together to solve this type of complex problem, the better the solution will be.

[slide 19C: What is the rate of fluid movement ?]

Of course, there are still key questions yet to be answered. This is one of them. We are sure there is fluid movement, and also that there is reservoir replenishment. We do not know how fast the refilling occurs and under exactly what conditions. Computer simulations will help develop models of what replenishment rates are physically possible. Monitoring existing wells and reviewing multiple 3-D seismic surveys will assist in confining the models. However, the key is to test the rates with the drill bit, and then to tie this data back into the simulations and iteratively derive the rate of fluid movement.

[bring up DigiStar display of 4th step of the Activity Model: Simulation]

Simulating processes, in order to confirm or improve results, is the natural next step to the visualization that accompanies interactive 3D interpretation.[25]

[slide 5L: How does this work affect my family?]

This research directly affects everyone in this audience, whether as an active participant through monitoring the project, as a spouse, or as a user of hydrocarbons. Thoreau put it well when he said: "I have been anxious to improve the nick of time, and notch it on my stick too; to stand on the meeting of two eternities, the past and future, which is precisely the present moment; to toe that line."[26]

As we look to the future, no complete replacement for oil and gas has been identified. Even if the replenishment rates prove to be fast enough for commercial exploitation, a tremendous need for new hydrocarbon sources exists because of the pervasive use of oil and gas in modern society. Society must optimize the use of available hydrocarbons. In closing, I will review some specific suggestions for this optimization.

[slide 20C: Plastics and Fertilizer]

Plastics and specifically fertilizer are where the industry and society should center future hydrocarbon usage. Maybe an oil company should set a precedence, sell off all their service stations, and only sell their hydrocarbons for making fertilizer and plastics. When I heard this was a possibility, it seems like a fantastic public relations coup and something that can really help focus society's proper use of available hydrocarbon reserves.

[slide 21C: Transportation]

Governments should tax hydrocarbons used for transportation to encourage alternative living. Humanity needs to develop plans for an entirely new way for humans to live together economically. The history of cities shows development occurred before electricity and automobiles.[27] Networked intelligent cityscapes can allow humanity to escape dependence on the automobile. The construction and urban planning technologies available today allow new and rebuilt cities to be designed at a people scale instead of around automobiles.[28] Implementation of these technologies will allow society to stop wasting hydrocarbons in internal combustion engines.

[slide 22C: Power]

[slide 32R: Fuller Projection]

The sun, gravity and wind should be the main sources used to generate electricity. As Buckminster Fuller taught at the World Game seminar in 1969[29], "we must integrate the world's electrical-energy networks." We must be able to continually integrate the progressive night-into-day and day-into-night hemispheres of our revolving planet.[30] With the dissolution of the USSR, it is feasible to connect the Asian, European, and African electrical power grids with those of North and South America. Electrical-energy integration of the night and day regions of the Earth will bring all the capacity into use at all times, thus doubling overnight the generating capacity of humanity, because it will integrate all the most extreme night and day peaks and valleys.[31]

[slide 23C: Heat]

Everyone cannot use firewood for heat, or there would be no trees and a lot more smog than we now have. Natural gas is plentiful and should be used to heat our homes and food. It is just possible that similar geologic forces to those the GBRN is studying can be tapped to extract abiotic methane trapped beneath the crust. The GBRN is striving to find new sources of heat to keep entropy from snuffing out the fire within mankind.

[Bring up panorama slides of Monte Alban]

To summarize, if we don't use available petroleum reserves better, our grandchildren will be lucky to live as well as the Indians did at Monte Alban.

[slide 24C: Illumination]

With modern means of illumination, we get caught up in the stuff that flies out of our television screens, and forget the fragility of life. "We are wont to forget that the sun looks on our cultivated fields and on the prairies and forests without distinction. They all reflect and absorb his rays alike, and the former make but a small part of the glorious picture which he beholds in his daily course. In this view the earth is all equally cultivated like a garden. Therefore we should receive the benefit of his light and heat with a corresponding trust and magnanimity."[32]

[Dissolve out the panorama slides of Monte Alban and Illumination]

[bring up DigiStar display of 5th step of the Activity Model: New Theory]

John Masters wrote: "I will tell you right out there are unexplored frontiers here in North America. They contain large fields. . . . I am talking about what I call "invisible frontiers". Now, I'll define that a little more clearly. I mean those parts of the rock section, sometimes thousands of feet thick, that have previously been invisible - but are now visible to state-of-the-art technology. I am talking about new advances in seismic methods and interpretation, new electric logs and other bore hole tools. I am talking about scanning electron microscopes which magnify thousands of times, new drill stem test (DST) methods and interpretations, and advanced hydrodynamic techniques."[33]

[dissolve into full activity model and then rotate DigiStar display and fly it off into the

stars]

"Such is the contrast between winter and spring. Walden was dead and is alive again."[34] So flows the oil industry. "Ideals are like stars; [we] will not succeed in touching them with [our] hands. But like the seafaring man on the desert of waters, [we] choose them as [our] guides, and following them [we] will reach [our] destiny."[35]

Thank you for your attention.

Slide 25C: **<u>Acknowledgments</u>**
Planetarium Visuals and Controls:
Steve Brown
A Production of Walden 3-D, Inc.

Slide 6L: **Research Results:**
GBRN Researchers
Enterprise Models
Charles Rego
GBRN HyperJournal:
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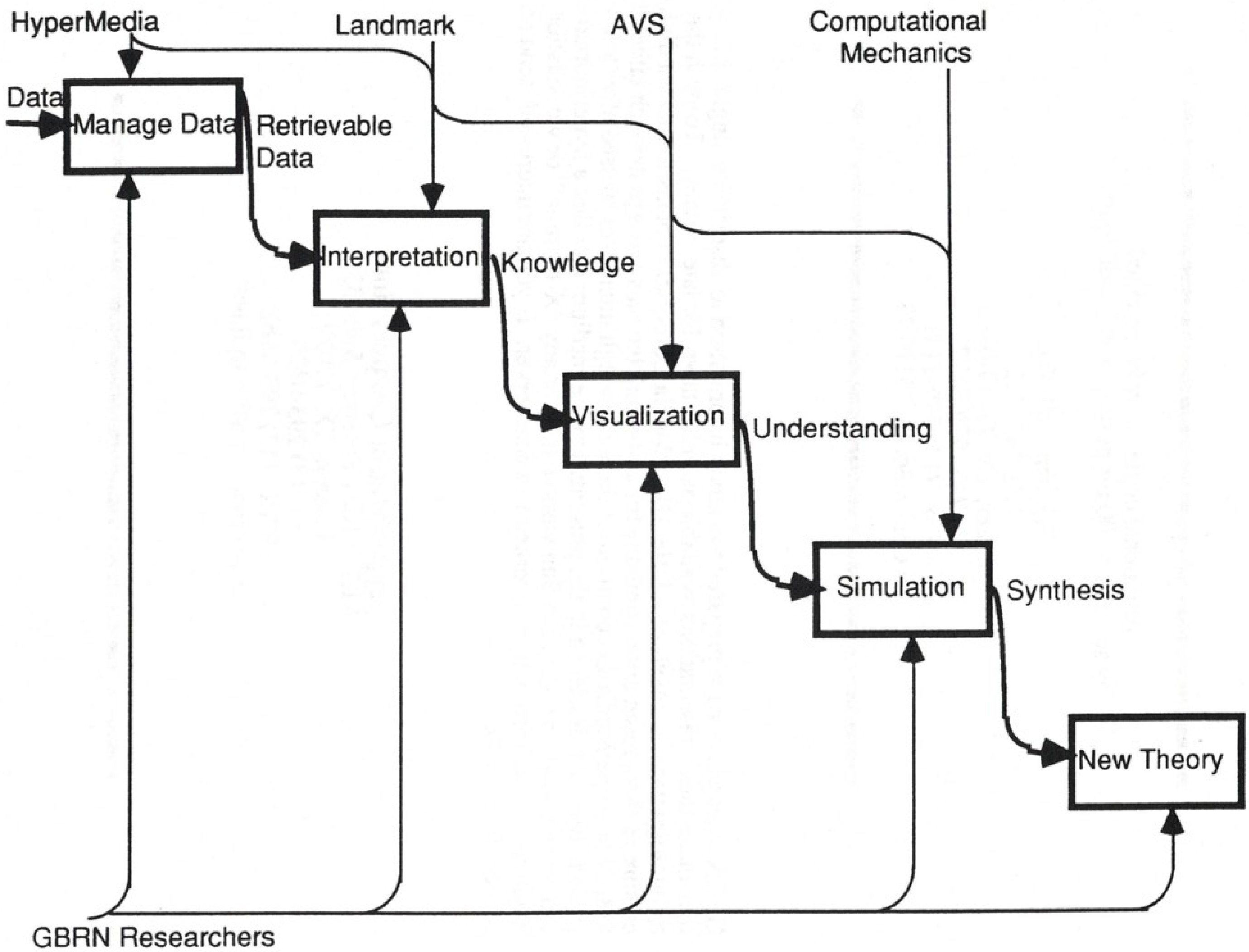
Slide 36R: **Monte Alban Panorama:**
Gary Young
Monte Alban 3-D Model:
Bill Bavinger
Shisha Van Horn
Original Music:
H. Roice Nelson, III

Slide 26C: **Astronaut picture of Earth**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