KEYNOTE ADDRESS:

Second Wallace E. Pratt Memorial Conference

"Petroleum Provinces of the 21st Century"

January 12-15, 2000

San Diego, California

Exploration into the New Millenium [1]

by Michel T. Halbouty [2]

I am entering my 71st year as a member of our profession and as an explorer for petroleum. During those 71 years I have devoted much of my time and resources to activities pertinent to our profession and our association.

As I venture forth in the last few golden years of my life, I find that our geoscience professions have undergone many changes, particularly in the last 20 years — some good, some very bad — but the professions have always looked to the future, and that is the reason this conference was convened at the beginning of this millenium.

I am indeed honored ñ yes, very pleased – to have been asked to present the keynote address to this second Pratt Conference. The first was held in Phoenix, Arizona, December 2-5, 1984, and was called the Wallace E. Pratt Memorial Conference on "Future Petroleum Provinces of the World." I had the pleasure of presenting the opening address at that meeting on December 2, 1984.

That was the best conference of its kind ever held by our auspicious Association. I am honored to have had the privilege of chairing it and participating as a speaker. Fred Dix, who was Executive Director of AAPG, and Bill St. John who was program chairman, contributed much to the success of the Conference. Their contributions enhanced the Conference in every way.

The papers were put together in a volume as Memoir 40 and published less than a year after the conference and the books were sold out quicker than any other publication by AAPG. I tell you all of this with some braggadocio because at 90-1/2 years old I am very proud of that Conference, that publication, and what it achieved. Since this is the second of the Wallace E. Pratt Memorial Conferences on Future Petroleum provinces of the World, I think that it is proper to say something about the man whose name was attached to the first and now to this second conference. There are

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not many of us left who knew Wallace Pratt. I look over the young faces in this room and I feel compelled to say something about Wallace that really sets the theme and the full essence of this conference named in his memory.

Pratt was born in Phillipsburg, Kansas, on March 15, 1885, and died on Christmas Day, December 25, 1981, at the age of 96. He held multiple degrees from the University of Kansas.

Wallace Pratt was noted as one of the world's most eminent geologists and he recognized early in his prolific career that the most valuable natural resource in the world is the human mind. He concluded one of his most memorable papers with the words, "Oil is found in the minds of men." Pratt firmly believed that without the proper use of the ultimate primary exploration tool — the mind — all other "tools" from whatever source were inconsequential.

He was a founding member of AAPG and was its 4th President. In 1945, AAPG honored him with the first Sidney Powers Memorial Medal and 27 years later in 1972, he was awarded the first AAPG Human needs Award. Pratt and I were very close friends for over 40 years and it was indeed a privilege and an honor for me when he asked me to be his citationist for the Award.

His acceptance speech of the Human Needs Award was filled with the most beautiful of philosophic phraseology and one of the best is as follows: "Earthly life is the only life in the universe known to man — so far! And mother Earth is the only possible abode for life known to man — so far! There are within us the same chemical elements that make up the mountains, the pine trees, the seashore. We are indeed of the earth — brothers of the boulders, cousins of the clouds, and distant kin, by way of chemical tie-up, of the fossil plants and animals."

So it was that Pratt was a living symbol of the essence of geology. His creed was the science, and he lived as a student and teacher of it. His contributions to the science of geology will endure as long as the science of geology is practiced. We honor ourselves by naming this conference for Wallace E. Pratt — one of the all-time great geoscientists.

The world's energy requirements are so interconnected today that the development and production of future petroleum supplies in all countries must be considered jointly.
In the industrialized, developed countries of the world, science and technology are rapidly advancing toward the best exploitation of their remaining hydrocarbon reserves and potential. In the developing countries, exploration for commercial oil and gas deposits is intensifying.

Even though most of the world has begun a transition period from conventional oil and gas energy toward alternative energy sources, it is evident that the major means of world energy survival will depend on oil and natural gas supplies for at least the next four to five decades, and possibly beyond. Oil exploration has followed a very logical and economic pattern, which is to say that it has been carried on in those areas offering the greatest reward. This means the areas where there is the most favorable geology; where the chances are best of finding the most oil, most cheaply, where it can be produced and marketed at the lowest cost; where the markets are the strongest, the prices the highest; and where stable political and economic conditions can be expected.

From the beginning of modern oil exploration until the 1930s, the evidence sought for locating likely

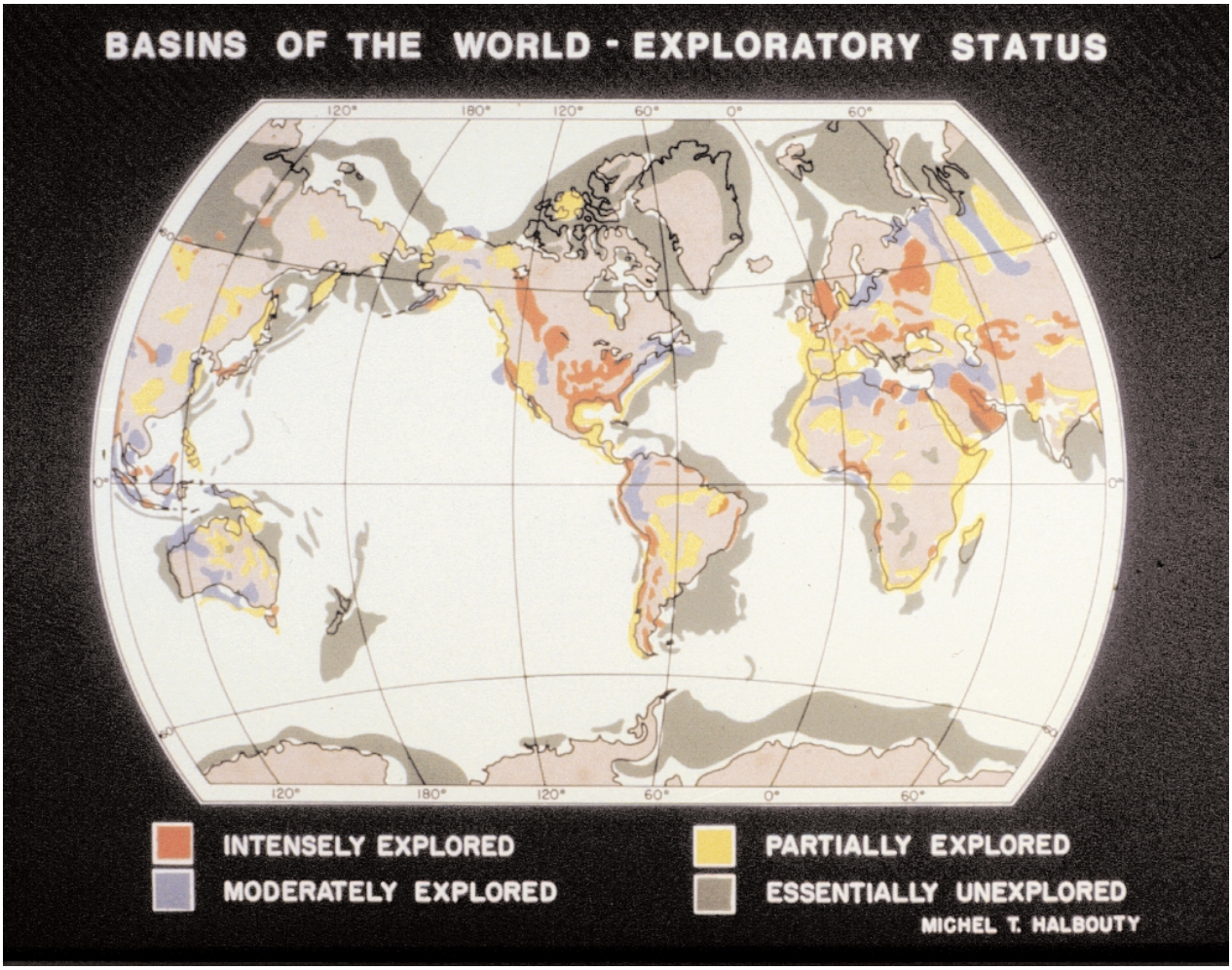

Figure 1 – Petroleum exploratory status of the basins of the world.

spots to drill was found principally on the surface — oil and gas seeps, areas where the sediments could be seen dipping away in all directions, forming a structural dome, suspicious mounds for hills in otherwise flat lands, and curvature of rivers and creeks around areas of higher elevation. In other words, surface indications of any and every kind.

With the advent of geophysics and technology exploration took a different course and subsurface imaging controlled where wells would be drilled.

Consequently, most of the easy-to-find accumulations of petroleum worldwide have been found. This is not an original statement. You have heard it or read it on many occasions in recent years. As a reflection of this situation, statistics during the past decades show that worldwide discovery successes have been declining not only in numbers, but also in quality or economic worth.

A Petroconsultants' report covering the past decade of the 90s, cited that less than half the world's production has been replaced by new discoveries. It also reports that over the past five years the replacement ratio dropped to just over 40%. Meanwhile, gas discoveries are nearly keeping up with production.

Figure 2 – Sedimentary petroleum basins – currently productive and potentially productive.

Petroconsultants' comments that a recent poll of more than 100 internationally active companies rates the UK followed by Australia as the most attractive places on earth for future exploration and production investments. This is in contrast to the last five years in which Africa led the world in terms of both new oil discoveries and reserves replacement.

It is obvious that the exploration thrust will not be in the US as very little exploration has taken place in the last decade. Production in the US has fallen at an average rate of 240,000 b / d / year since 1985. This accentuates the reasons we are importing more oil each year. Our consumption increases and our production declines — necessitating greater imports. Since the very beginning of the petroleum industry the independents were its backbone and drilled more and found more oil and gas than all the majors combined — but this is no more. The independents have shown an uninspiring performance in exploration and development. Last year, the accelerated drop in oil prices took a heavy toll among them which drastically slowed down exploration. The changes in the industry in just the last 5 years has had desultory effects on the independent. The "mega-majors" rule the roost in every factor of the industry. Overall, the drilling activity in the US is near record low rates — whereas in foreign lands exploration activities are increasing.

Worldwide, the explorationists are still confining most of their exploratory efforts to searching for

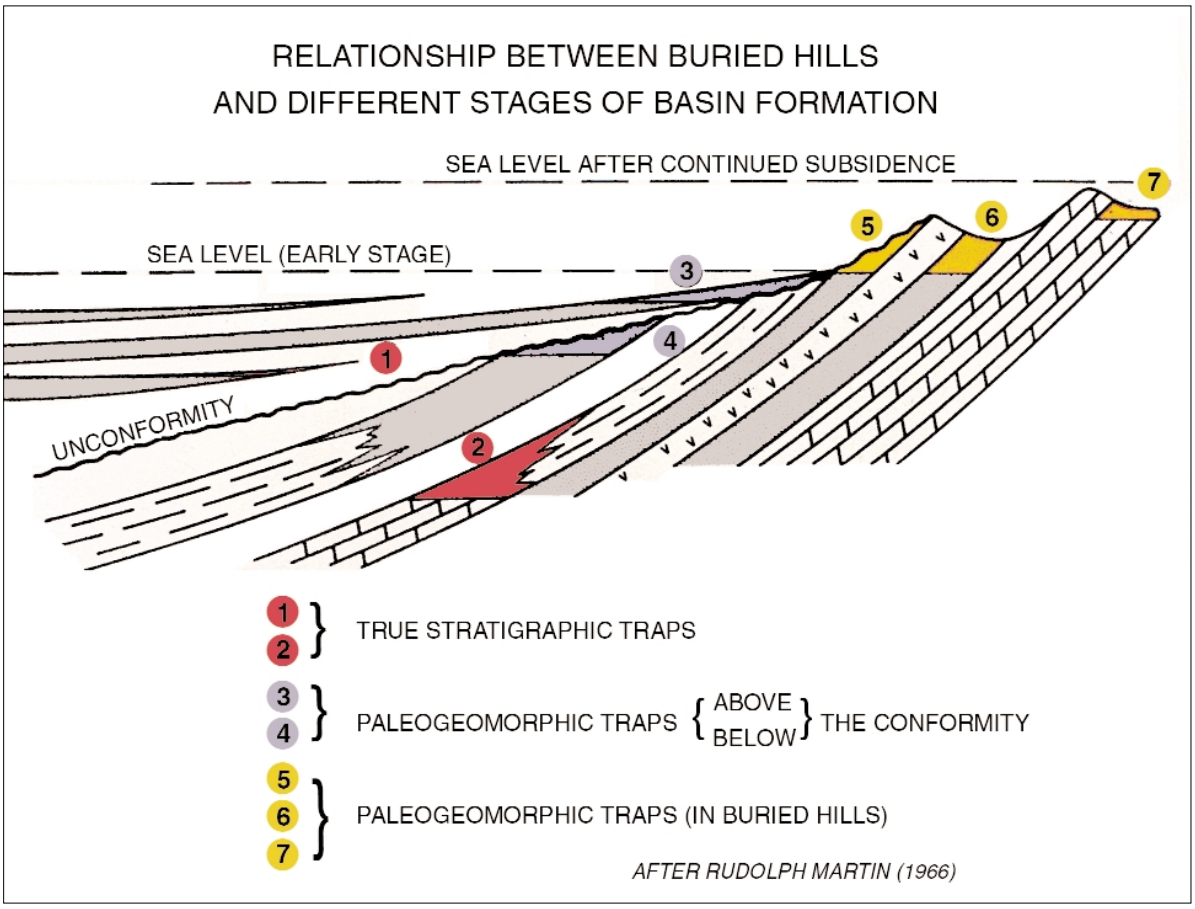

Figure 3 – Subtle traps.

the obvious types of reservoirs which are becoming scarce, and to a large degree, can be attributed to a generally lazy attitude in exploratory thinking which motivates us to continue looking for structures which can be seismically imaged with very little cranium effort.

Psychologically, explorationists are pressured to look for anticlines, domes and fault structures because this type prospect is most likely to be acceptable and salable to management. In other words, we geologists and geophysicists have made little effort to purposefully search for the traps which are obscure, and we just continue to look for the salable anomaly which can easily be detected by seismology.

I certainly am not advocating that we should turn our backs on the obvious play, but I am strongly suggesting that we must diversify and concentrate a substantial part of the exploratory effort on looking for traps that are subtle and, consequently, are most difficult to find. I have more to say about this subject later.

Nevertheless, a vast petroleum reserve potential exists in the world. As part of a unified successful exploration effort, each specialized geoscientific discipline, whether geology, geophysics, or petroleum engineering must provide the bold and innovative thinking which will lead to future discoveries of oil and gas.

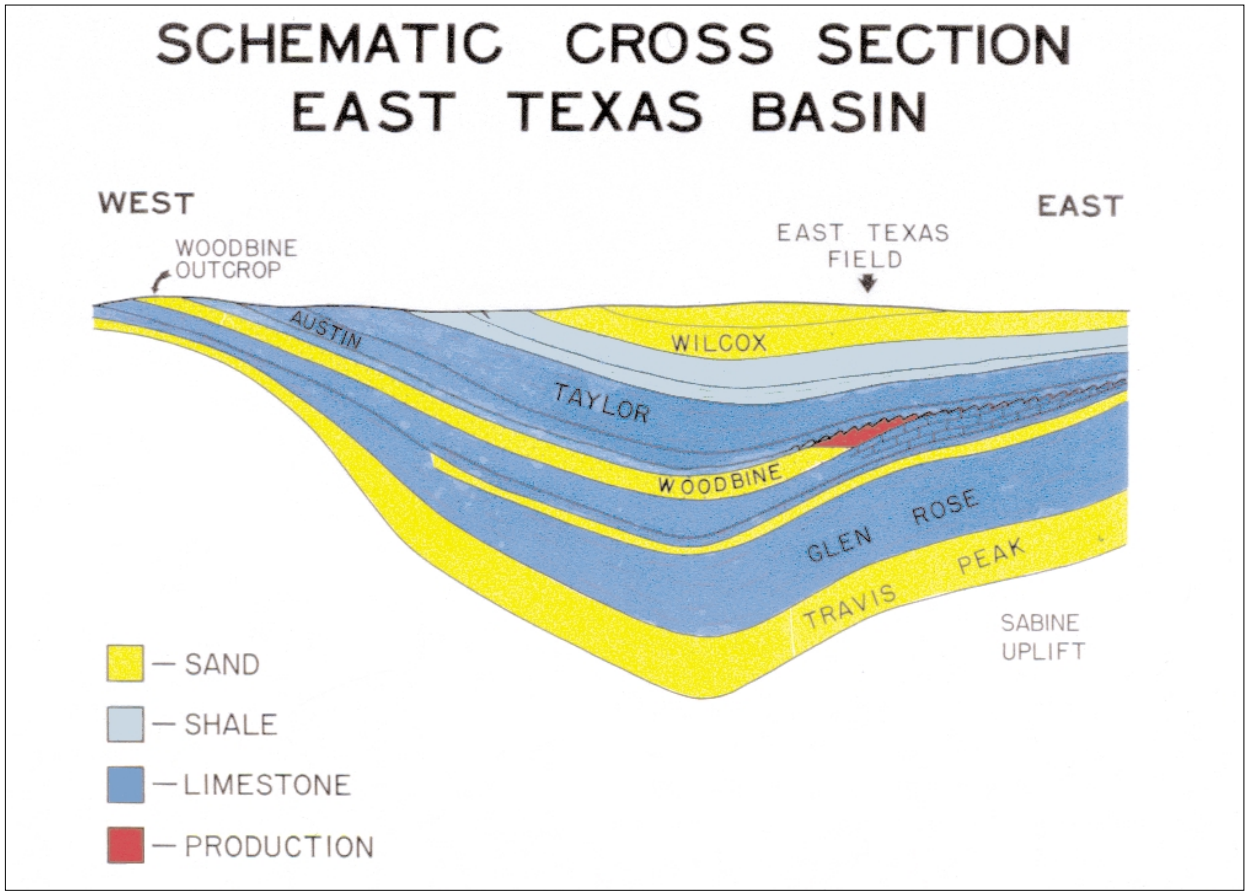

Figure 4 – Generalized cross section, East Texas basin, showing wedging of eroded Woodbine sandstone between Austin and Wachita limestones, forming trap for East Texas field on western flank of Sabine Uplift. Note outcrop of Woodbine beds west of East Texas basin (depth in feet).

There has been a continuing worldwide search for new reserves of petroleum for many decades. Yet there remains scores of geologically attractive areas, which need to be extensively explored to meet the soaring demand for petroleum supplies.

The figure shows the status of exploration in the sedimentary basins of the world. For brevity, many of the basins have been combined. Of the world's prospective sedimentary basins categorized as intensely explored, moderately explored, partially explored, and essentially unexplored, only 29% currently produce commercial hydrocarbons. Another 39% of the basins have been partially and moderately explored and tested, but have not yielded large quantities of commercial production. The remaining 32% of the world's basins have had little or essentially no exploration activity.

Onshore basins hold high potential in many parts of the world, especially in the more mature productive areas. Geologists and geophysicists have good opportunities to find additional petroleum reserves by using advanced technology. Three-dimensional seismic investigations, digital re-calculations of old seismic data, and the use of remote-sensing images from satellites and spacecraft are some of the methods they use to find clues for discovering "new" reserves in "old" areas.

The majority of the unexplored basins are considered the frontier areas of the world. These basins

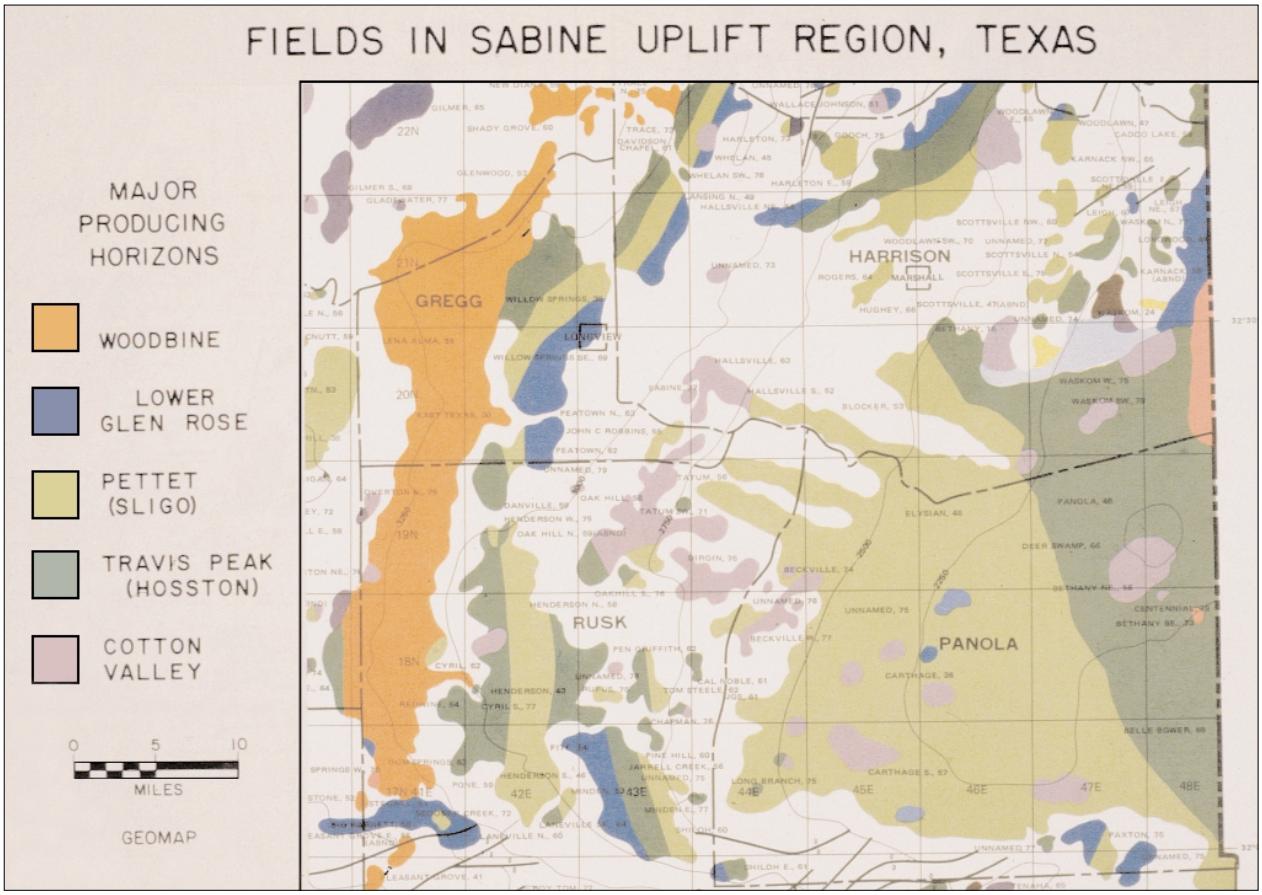

Figure 5 – Productive areas east of the East Texas field. The stratigraphic trap is considered to be one of the largest accumulations of oil in a single pinch-out.

are located in harsh physical environments such as the Arctic, in deep water, or remote interiors of continents. Many of these frontier regions are restricted because of disputes, political boundaries, or governmental regulations. Others have been bypassed because of a combination of remote location and low geologic potential.

A careful examination of the world's productive sedimentary basins and those areas remaining to be explored shows that many regions remain to be tested.

Figure 2 shows the basins of the world, those currently productive, and the potential areas for future exploration. The purple color covers both the onshore and offshore, but take a long look at the color covering the offshore areas. These areas are frontiers which are located in harsh physical environments such as in the Arctic regions, in deep water, or in remote interiors of continents. This is where the future high cost exploration will take place and where large reserves of oil and gas will be discovered. When you look at the offshore areas to be explored it can be surmised that it would take many decades for most of the areas to be evaluated. The purple color covers a large part of the earth and it is expected that the large "mega-corporations" will be the explorers.

More and more attention will be paid in coming decades to the world's challenging offshore

petroleum frontiers because, in today's offshore drilling, neither depth, nor harsh environmental condition can be considered impossible. As explorationists look further to the oceans for major new reserves, especially to deeper waters and hostile environments such as those in the Arctic regions, engineers are diligently working on designs of new drilling rigs and production platforms to meet the challenges thrust upon them.

As long as there are inspiration, courage, innovative skills and financial backing, there is no limit to what the global petroleum industry can accomplish – offshore and onshore.
Forty years ago, it was felt that the entire North Sea was out of the question for exploration and production of petroleum because of the extremely hostile environment. Yet, since 1969, when the first commercial discovery was made in the North Sea, the numerous oil and gas finds have made this part of the world practically self-sufficient in petroleum energy.

As recently as 25 years ago, drilling in 200 to 300 feet of water was considered too hazardous and difficult. Production in over a thousand feet of water from a conventional platform has proven to be very common – whereas less than a decade ago it was perceived to be quite dangerous. Today, production from a thousand feet is considered to be relatively shallow.

Drilling in water depths of 10,000 feet and beyond is rapidly becoming approachable. Some say in 5 years, some say even sooner. Drilling water-depth records keep falling as exploration technology advances. The present record, set in the Gulf of Mexico is 7, 718 feet and was drilled by Chevron with Global Marine's Glomar Explorer rig. The average water depth for most offshore Gulf of Mexico wells is 475 feet.

Engineering and technological breakthroughs are fast opening vast areas heretofore considered almost impossible for exploration – areas such as the deeper portions of the Gulf of Mexico, the Mediterranean Sea and the South China Sea, to name only a few.

It is my opinion that there have been more new conceptual ideas in geoscience in the last ten years, than have been promulgated in the preceding 50 years. The next few years will contribute more breakthroughs to solving today's so-called "impossible" problems. In this regard, it is also interesting to note that explorationists pay too little attention to the deliberate search for those reserves which lie in the less obvious, subtle traps.

As I stated earlier, we must turn more of our studies toward those not-so-obvious reservoirs of petroleum; those in stratigraphic traps, those lying below unconformities, those which are associated with buried geomorphological features and those which may or may not be associated with structure.

The huge oil accumulation in the East Texas Field is contained in a simple stratigraphic trap which occurs where the truncated edge of the Woodbine Sand crosses regional nosing on the west flank of the Sabine Uplift.

The simplicity of the geologic trap created a prime exploratory objective which, incomprehensibly, has been ignored in favor of the structural trap variety.

The size of East Texas is best shown by Figure 5. Notice that the Woodbine accumulation does not

Figure 6 – Size comparison of Antarctica and the State of Texas.

transcend beyond the field.

The pinch-out cut off the sand so completely that no Woodbine oil escaped to the East. This is the perfect stratigraphic trap which allowed the accumulation of 7 billion barrels of oil at shallow depths wherein, prior to its discovery, every major company and many independent companies, with their expertise and seismic black boxes ran their equipment repeatedly over the area and agreed that it did not have the parameters for the accumulation of oil.

Isn't it possible that along the flanks of some monoclinal, or uplift area, which shows no elliptical closure, there might be another East Texas type field waiting to be discovered by an ingenious geo-scientist who thinks differently, or by another Dad Joiner who happens to be a dreamer — and a real believer!!

The geophysicists' computers and new chart mechanisms are tremendous aids in developing some of the scientific facts needed for finding subtle traps. Great advances have been stimulated by the use of seismic modeling, better data acquisition and data processing, and the extensive use of color seismic display formats.

Mapping and discovering the elusive traps will require highly imaginative thinking combined with every applicable scientific discipline and tools – and the most important tool is the mind. That

supersedes all of the others.

Seismic control and interpretation can materially assist in locating the subtle trap – but geophysics is not the full answer. What is needed more than any other facet is the hard work, "pure geology," to ferret out the source and kind of sediments, the facies changes, paleogeologic history, tectonic effect of sedimentation and the various kinds of environmental conditions which were present during deposition. That requires detailed study of stratigraphy, paleogeomorphology, paleogeography, paleostructure, paleontology, and palynology. Now, that takes hard geological probing, but the resulting discoveries would warrant the effort.

I contend that the future large reserves will be found in subtle traps and the explorationists must put their effort toward them and not around them.
These traps represent the last domain of petroleum exploration.

At this point, I would like to make a few comments about the world's future oil and gas supplies. It has been predicted over and over for decades that the world was running out of oil and gas. Those pessimistic doomsayers have consistently been proved wrong. New oil and gas fields are being discovered almost daily, all over the world, in both known producing areas and in the frontier regions both onshore and offshore.

Geoscientists are limited only by their imagination, innovation and determination. In the coming decades there will be tremendous strides made in petroleum geology, geophysics and petroleum engineering. The challenge for all of us – whether we are geologists, geophysicists, engineers, independent explorationists, or company or government explorationists – is to devise new concepts and skills to explore in areas considered to be out of the question or impossible.

Look what industry has accomplished in the heretofore "impossible" Arctic regions! Success in discovering, producing and transporting oil in such a harsh environment has been phenomenal. The Circum-Arctic region as a whole covers a vast territory. Many researchers feel that in the combined total Arctic basins, there is the potential for accumulations of oil and gas that may equal to those of the Middle East.

Exploration in Arctic basins represents the most costly search ever, but the chances of discovering giant accumulations are excellent. Along the United States and Canadian continental shelves, there are seismic indications of thick layers of sedimentary rock with trapping features that could hold oil and gas accumulations equal to those already found in onshore fields. The Prudhoe Bay and Kuparuk Fields in Alaska and the Urengoy Field in the Soviet Union are prime examples of the giant field potential of the region.

There is another "impossible" area where eventually large reservoirs of petroleum will be found if drilling is ever conducted on this remote continent — Antarctica — the last true frontier resource area on the earth. Its continental margins occupy an area roughly similar to the continental margins of North America and are comprised of sediment wedges many kilometers thick.

Figure 6 shows Antarctica with Texas imposed on it to illustrate the size of the continent. Geoscientific studies and surveys have indicated that a sizable potential exists in the immediate offshore areas.

Bill St. John in his paper, "Antarctica – Geology and Hydrocarbon Potential" wrote, "Based on limited data, geologists have identified 21 sedimentary basins for the Antarctic and immediately adjacent areas. These include 6 onshore, subglacial basins and 15 offshore basins. Excluding 11 basins considered to have little, or no potential, the other 10 basins contain an estimated 16.9 million cubic kilometers (4.05 million cubic miles) of sediment having a potential hydrocarbon yield of 203 billion barrels oil equivalent."

St. John ends his excellent paper by stating that "Antarctica does have potential for large hydrocarbon reserves, and the technical expertise, ultimately, is available. The sole hindrance is jurisdiction – from whom do we get a drilling permit?"

When it becomes necessary to drill in harsh environments, such as Antarctica, the cost to produce that oil would be very high, but if the world still demands the use of oil, those hostile places will be drilled and the high prices to use that oil will be paid accordingly. Antarctica is the epitome of the definition of a petroleum frontier.

What I am saying here is that the end of the oil era will be affected solely by economics. When the cost of finding oil and gas is absolutely prohibitive – exploration will stop and the beginning of the post-petroleum era will begin.

When we scan the petroleum potential areas of the world, it is obvious that as long as the desire exists to find new supplies of oil and gas, for years and years to come, there will be an area in the world worth the risk of exploration.

In my seven decades of petroleum exploration, I have observed that whenever substantial reserves of oil and gas have been discovered, they have always been brought to market from the hostile areas of the world. I am optimistic and believe that as long as it is economical, and as long as the geoscience professions, together with the petroleum engineers, increase their technology and methodology of searching and producing, discoveries will be made, even in the harshest of environments such as the deep oceans, in swamps, on the ice, in the mountains, in the deserts, in the forests, jungles, and who knows maybe — yes, just maybe — many, many years from now, exploration and production even in space.

As one familiar with the world's geologic potential, I firmly believe that in the future at least as much oil and substantially more gas will be found than we have produced to date.
Our giant fields of today were once the frontiers of yesteryear and, surely our continually advancing exploration concepts, methods and technology will convert the frontier areas of today into the giants of tomorrow. What we all will learn from this symposium and its excellent selection of literature will add immeasurably to the wealth of knowledge that men such as Wallace Pratt left as a legacy to us all.

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