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GEOLOGICAL SURVEY

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Natural gas - a perspective on resource availability

by

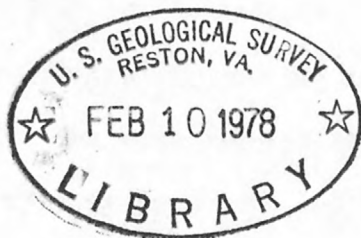
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# Natural gas - a perspective on resource availability

by

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U.S. Geological Survey



This is an exciting time for those of us in the energy business. What we do and say really has the capacity to affect the quality of the day. Obviously, then, we have a responsibility to lay out the best possible picture of the reality of energy conditions that we can. To present that reality as clearly as possible will require the joint thinking and hard work of both geologists and engineers. I welcome, therefore, the opportunity to give you the view of at least one geologist in the Survey and to tread a little into your territory in an effort to analyze the problem that the Nation faces.

My view is, and I will attempt in the course of the talk to give you at least a modicum of data to back it up, that it will be very difficult if not impossible to maintain the gas production rates of the past several years, not because the resource base is limiting, at least for the next several decades, but rather because of limitations on our rate of discovery and production. I will first try to give you some overview of the national scene and will then address myself to some of the local conditions that might serve to provide some modest though temporary relief.

Figure 1 near here.

As you can see, the real heartland of gas production is the Gulf Coast/Midcontinent. There is a pretty good-sized gas producing area in the Appalachians comprising mostly Lower Silurian Clinton reservoirs, but its contribution to total U.S. production is small. As some of



Figure 1. --  **GAS FIELDS OF THE UNITED STATES**  
 **PROSPECTIVE GAS AREAS**

you may have heard, though, the rumor is very strong that Amoco may have opened up an extraordinary Tuscarora play in Centre County, Pennsylvania, with a well reported to have tested 20-40 million CF/day. So this area may not be through yet. The discovery of Prudhoe Bay in Alaska rather significantly changed the center of gravity of gas production in the U.S. in that over 10 percent of our reserves are presently in that one field. Associated or gas-up gas, however, marches to the tune of the oil production, and as Todd Descher noted in Congressional testimony the other day, we had best be careful about assuming we can take that gas now lest we damage the capability of the reservoir to produce oil. The point is, gas discovery does not necessarily mean availability, and we mustn't be too quick to hitch our future to ALCAN or any other quick-fix panacea.

Figure 2 near here.

You all are familiar with the USGS classification of reserves and resources. The diagram in red on the right shows our judgment of the distribution of identified and undiscovered gas resources. This figure differs from the Circular 725 presentation in that I have shown in a lower box the remainder of the gas in place. We don't think that that last 10 percent will ever be recovered, but I have included the numbers for clarity of presentation and for arithmetic completeness. The middle row of data shows what we called subeconomic in 1975, but certainly gas prices have moved in the direction that will encourage the withdrawal of this part of the resource base. We must consider, however,

CRUDE OIL RESOURCES OF THE UNITED STATES (BILLIONS OF BARRELS)  
TOTAL U.S. CUMULATIVE OIL PRODUCTION 112 BB 12-31-76

	IDENTIFIED			UNDISCOVERED	
	MEASURED	INDICATED	INFERRED		
ECONOMIC (RECOVERABLE)	31	4	14	50-127	0
SUB-ECONOMIC (POTENTIALLY RECOVERABLE)	107-141			44-111	32
NONRECOVERABLE	178-201			62-159	60
					100

PERCENT RECOVERY

NATURAL GAS RESOURCES OF THE UNITED STATES (TRILLION CUBIC FEET)  
TOTAL U.S. CUMULATIVE GAS PRODUCTION 514 TCF 12-31-76

	IDENTIFIED		UNDISCOVERED	
	MEASURED	INFERRED		
ECONOMIC (RECOVERABLE)	216	135	332-655	0
SUB-ECONOMIC (POTENTIALLY RECOVERABLE)	50-108		42-82	80
NONRECOVERABLE	102-108		42-82	90
				100

PERCENT RECOVERY

Figure 2.

that this is the last gasp of a reservoir and it will most certainly be produced at a significantly lesser rate than will be the gas produced under higher pressures.

Now, if you will focus your attention on the upper row of numbers. Let's make sure that everyone has a common understanding of the numbers in those boxes. In the upper left-hand corner, the 216 TCF represents the AGA proved reserves as of 12/31/76. Given a reserve to production ratio of 10, it indicates that at 20 TCF of annual production, we are presently producing at an absolute national reservoir maximum. If this level of production is not replaced annually by an equivalent level of reserve additions, production will have to decline. The inferred reserve represents that part of the gas resources that we have estimated will be found as growth components on the margins of existing fields. The significance of that number is that there are a few 10's of TCF of gas that can be discovered with a minimum of risk and lag time in getting on stream.

Figure 3 near here.

This figure shows gas well completions through time. Judging from the fact that overall well completions are going up sharply, and overall (Figure 4 near here) additions to reserves and discoveries per se are going down, we must assume that the exploration targets that we presently are drilling are close in and safe, but are located where the chances for a discovery that will affect the quality of the day are really rather slight.

## NUMBER OF GAS WELLS COMPLETED

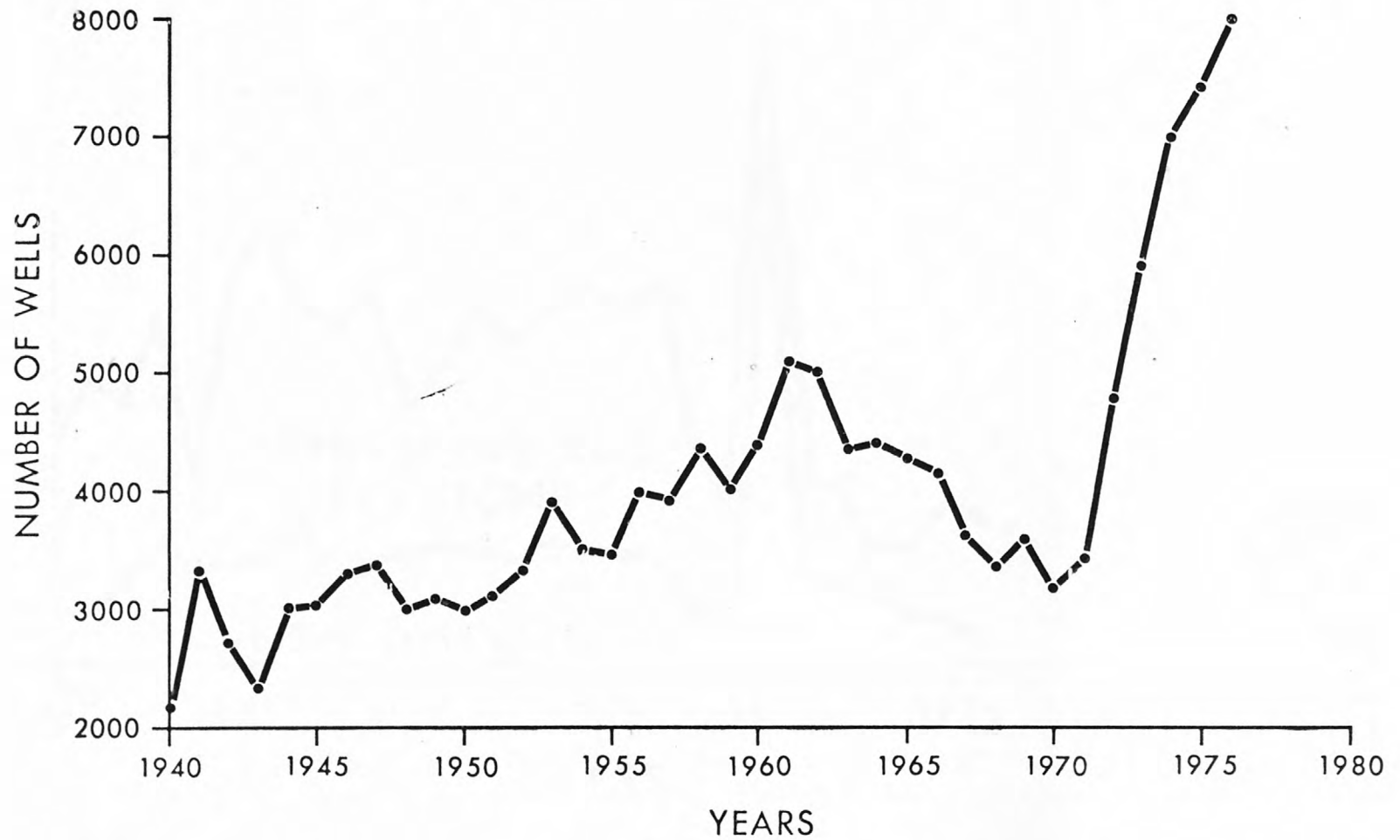


Figure 3.

## GAS RESERVES ADDED/YEAR

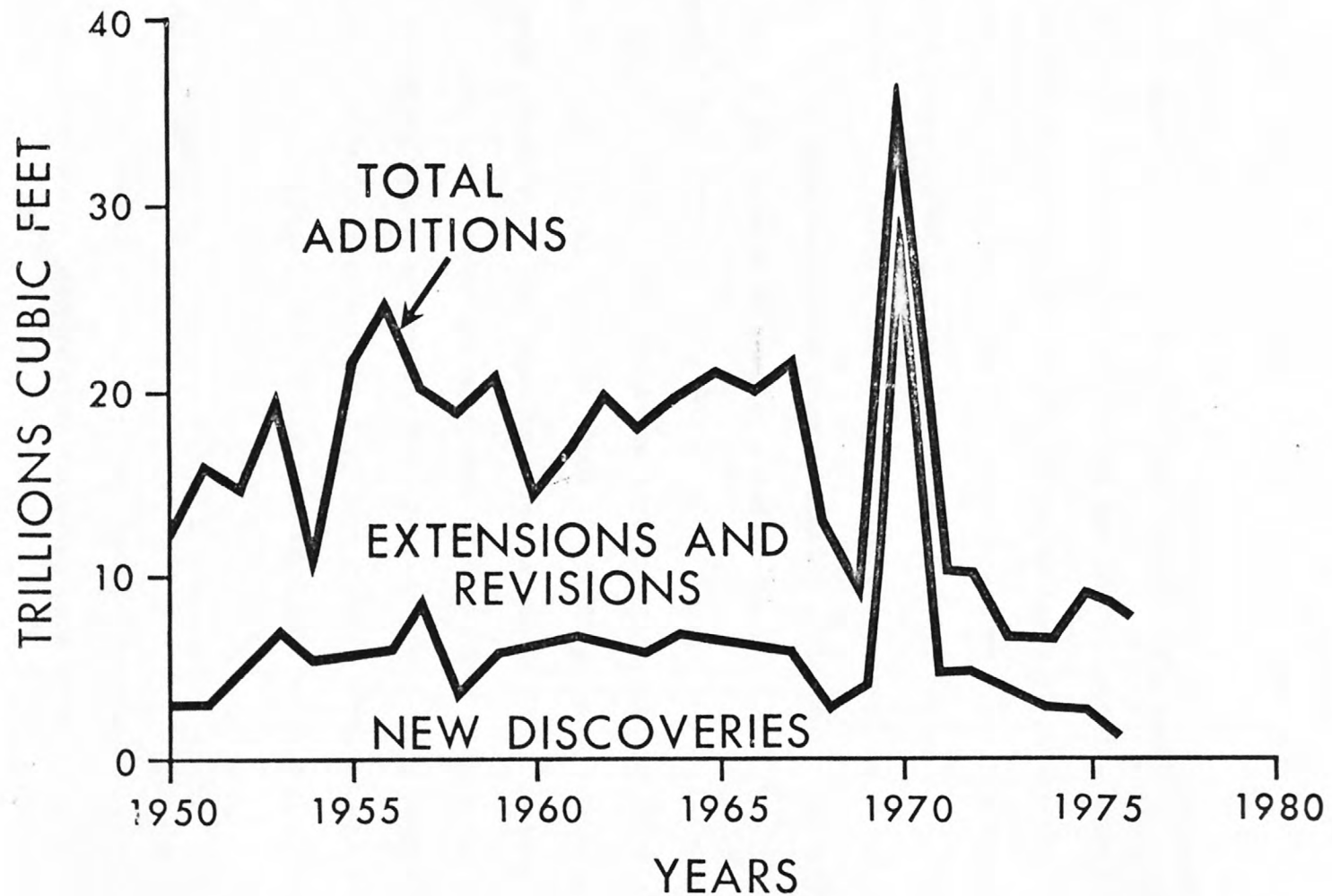


Figure 4.



The last box on the right shows our judgment, within a range of probabilities, of the gas available for new discoveries. This number does not include tight gas sands, nor geopressured reservoirs, nor shale gas, nor gas in the OCS beyond 200 m of water depth. I will comment on all of these exceptions later, but for now let's make sure we all understand the significance of the numbers. The range of numbers includes 90 percent of all of the gas we can conceive exists. The lesser number represents a 95 percent probability of occurrence, the greater number a 5 percent probability of occurrence. If one wants to consider lesser probabilities, the number goes up, but we concluded that this was a reasonable range of values for purposes of national planning. Given discovery rates in the vicinity of 10-20 TCF/yr, we clearly have a few decades of hunting ahead of us.

Figure 5 near here.

Now, in a nutshell, the problem we face today is that reserves are steadily declining at a rate of about 10-12 TCF/yr, and unless we can markedly increase our additions to reserves, which have remained steady for quite a few years now at a rate of about 8-10 TCF/yr, we will be forced to reduce our production. In fact, the latter possibility would seem to be a foregone probability; just to stay even, we would have to double our present rate of reserves addition, which we probably cannot do.

Figure 6 near here.

Some measure of the difficulty of the task of increasing our reserve additions can be seen in this discovery rate curve. The green

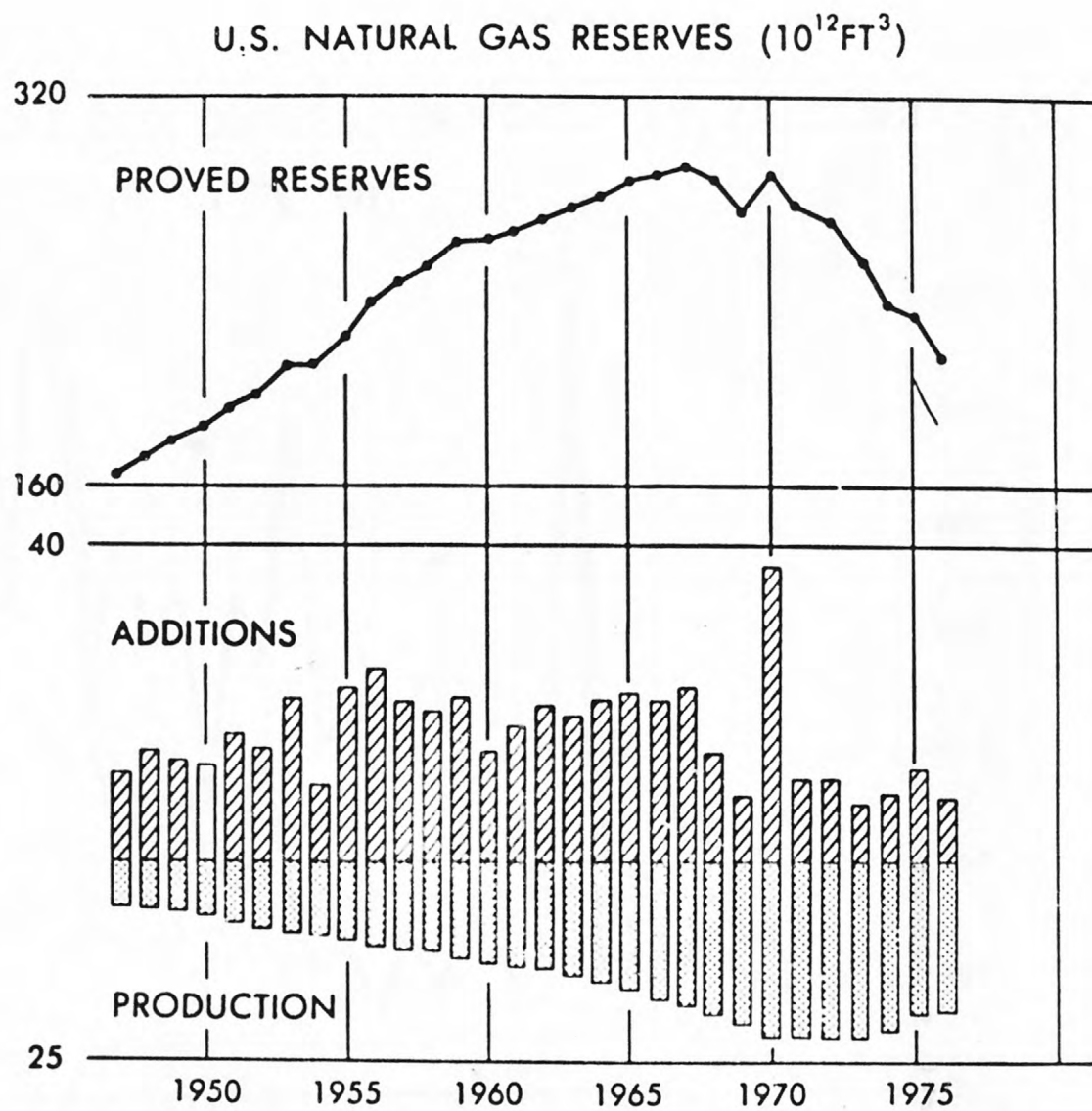


Figure 5.

# OIL AND GAS DISCOVERED PER FOOT NEW-FIELD WILDCAT

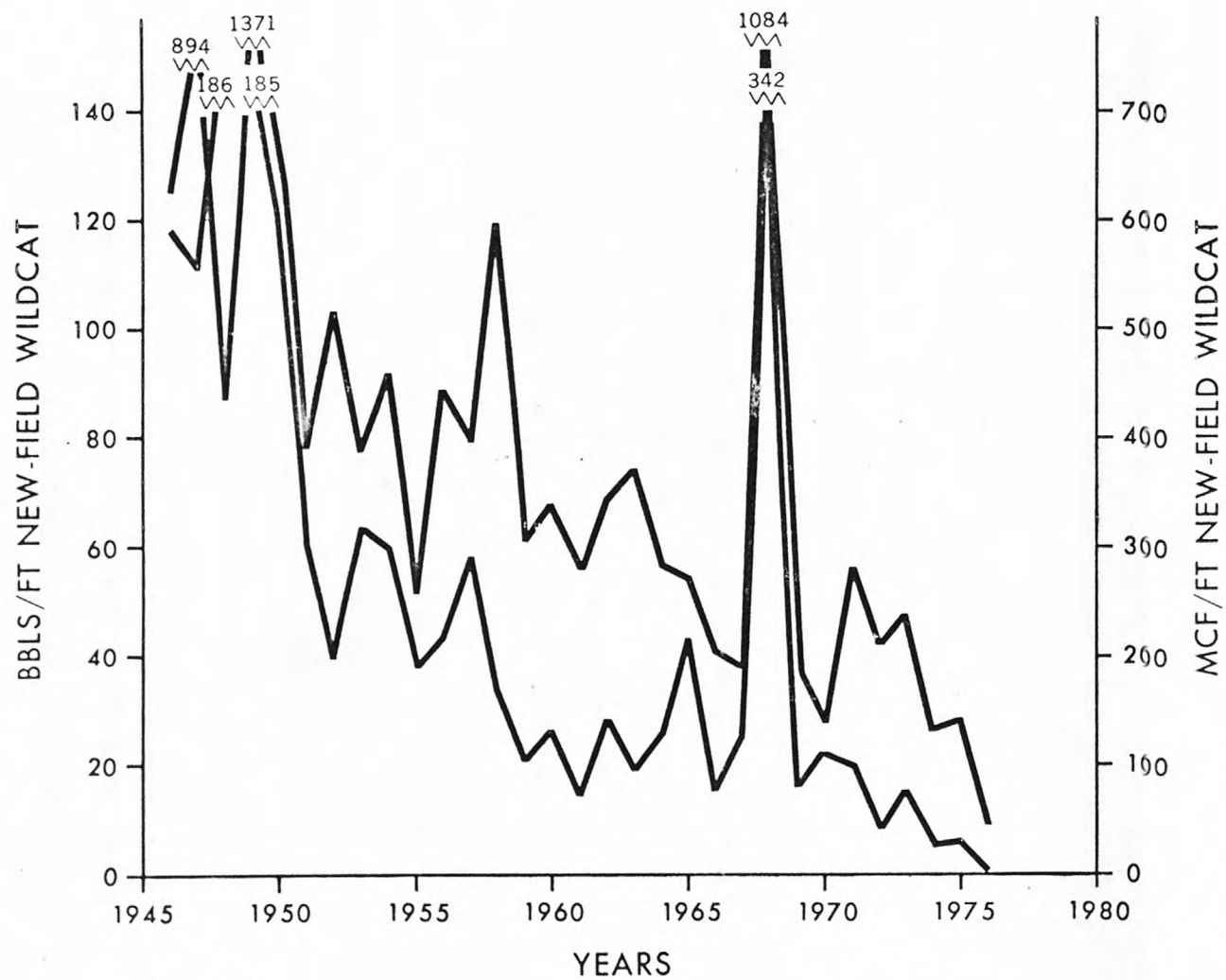


Figure 6.

is for oil, the red is for gas. The data clearly show that in spite of an improved technology and exploration methodology, gas and oil are just getting progressively harder to find. And, incidentally, the decline is the same, whether new gas is plotted against numbers of wells or against wildcat footage. In the face of this kind of drastic decline in success ratio, even Mike Halbouty's call for 25,000 exploratory wells annually, double our present number, may be insufficient to stem the tide.

Figure 7 near here.

Now if I may, let's turn to the nonconventional and local sources of gas. I call the nonconventionals the gold in the ocean problem-- shale gas in the east, tight gas sand in the west, and geopressured reservoirs on the Gulf Coast. The quantity of gas in these deposits is possibly stupendous. What's actually available and at what price, however, is the \$64 question, and the question you, ladies and gentlemen, are supposed to answer. Before you can do your job right, however, the geologists must do a much better job of characterizing the potential reservoirs. The problem to date is that we have, with a little bit of data on gas saturation, multiplied that number by large rock and water volumes to get astronomic potential gas resource estimates. The truth of the matter is that we have very little data on porosity and permeability distribution in tight gas sands; we do not really know solubilities in geopressured areas, nor do we have very good data on water transmissibility throughout most of the Gulf Coast

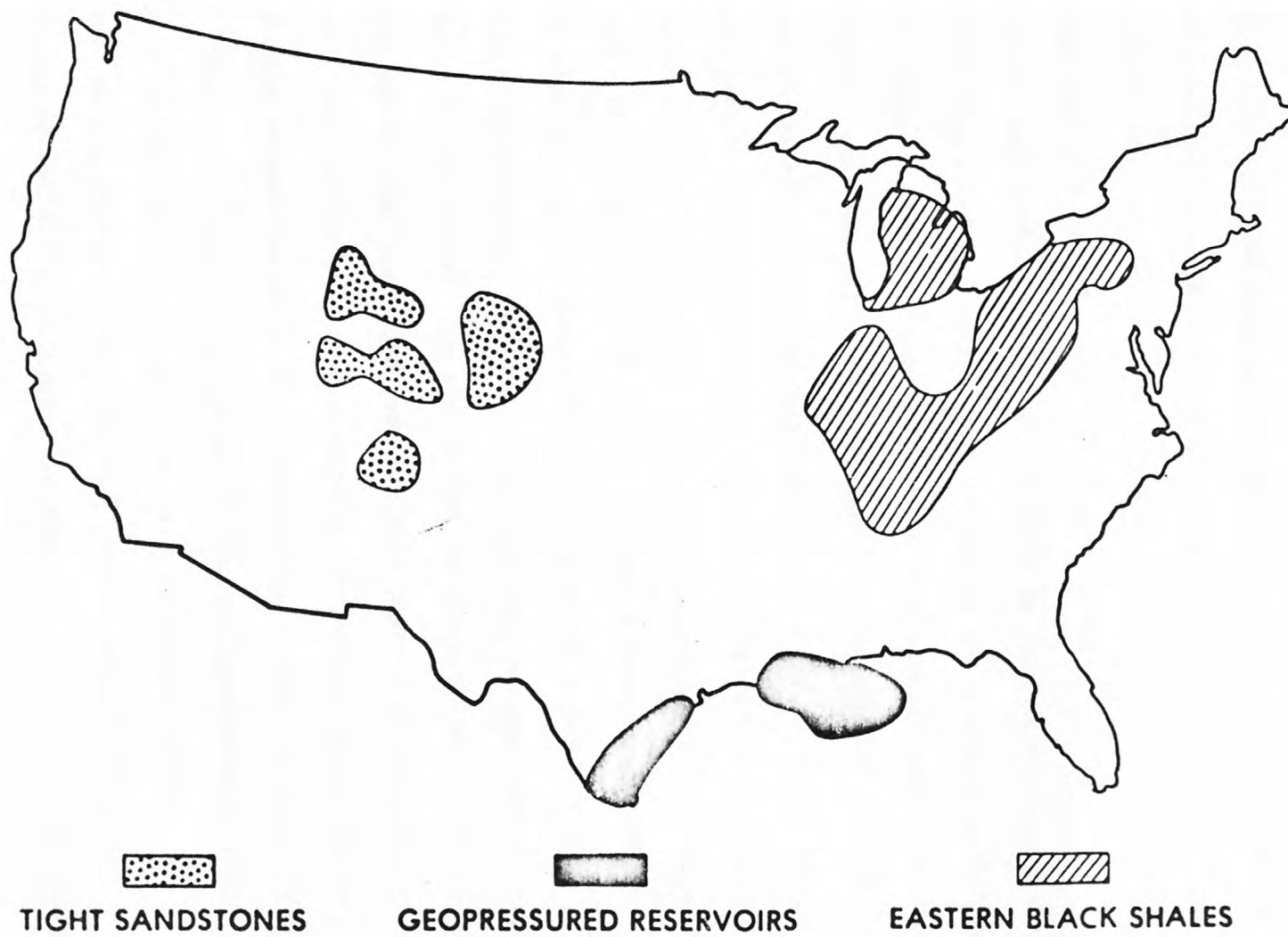


Figure 7.

regions. Our understanding of shale gas distribution is at present based on only a very few samples, and we really don't know whether the properties of the rocks in the area have a uniform distribution or not. In each case, however, programs of geologic characterization are well under way, and in a very few months or years we will have good rock data for you engineers to work with. I guess my view at this stage is that these sources of gas will supply to us what is in effect a different commodity because they will come on line at such a relatively slow rate of production that we will likely put them to work in quite a different way from so-called conventional gas. For example, in a recent symposium at Morgantown, it was suggested that 100,000 cuft/day would be a high average production for shale-gas wells, and that we might look forward to as many as 15,000 producing wells. If such a development effort were to come to pass for such a resource, we might expect 1/2 TCF annually of production. This is not trivial, but neither will it turn our energy future around. To add further to the problem, prices in the vicinity of \$3-5/MCF were suggested for such a level of reserves, which is, let's say, 10 TCF at a 20-1 reserve to production ratio; who can say whether or not the society will sustain that level of basic energy cost. The massive gas quantities quoted for the geopressed areas suffer from similar limitations--that is, a dispersed target. On average, we can probably expect no more than 50 cuft of dissolved gas/barrel of water. If we wanted to produce 1 TCF/yr, that multiplies out to moving over 2,000,000,000 gallons of water/day, which is over

twice as much as the consumption of the city of New York and four times that of Houston. Possible? Who knows. Fantastic, certainly! But once again, even a prodigious effort will not markedly alter the energy picture.

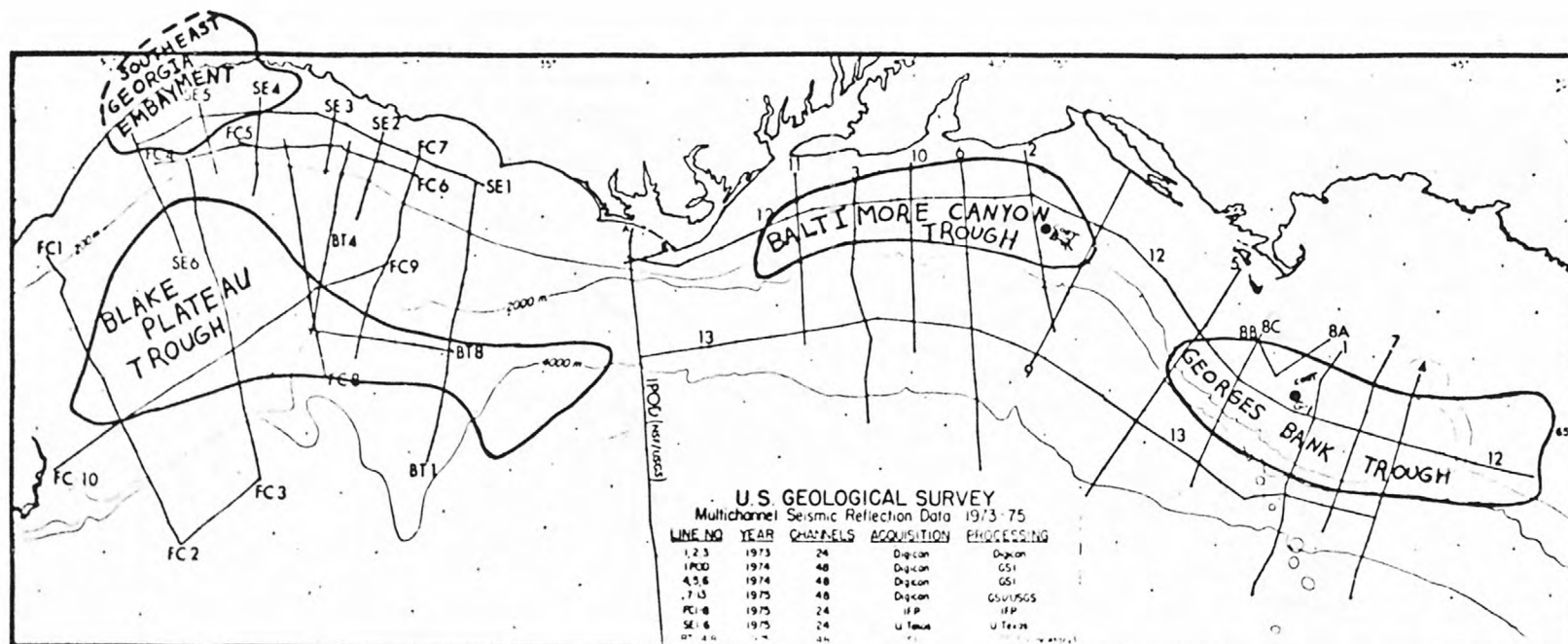
Figure 8 near here.

And finally, enter the knight in shining armor, the Atlantic OCS. This figure shows the locations of the three major offshore basins. The lines represent publicly available multichannel seismic profiles on which, along with other data, our assessment of Atlantic petroleum potential is based. Our estimates range from 0-22 TCF of gas for the Atlantic OCS within the 200 m isobath. Gas estimates will probably increase only slightly with deeper water because the area becomes increasingly oil prone. For analogy, we have only the Canadian Nova Scotian basin to compare with and of course, as you know, they did not discover commercial production after approximately 100 exploratory tests. We can argue, however, that Baltimore Canyon, the biggest and best of our three basins, has a thicker section and bigger structures, therefore higher hopes.

Figure 9 near here.

The geologic interpretation in figure 9 of a seismic cross section through the Baltimore Canyon shows some of the kinds of hoped-for traps. The dominant feature is the great stone dome, an igneous intrusion resulting in a structural closure the dimension of Prudhoe Bay, some 225 square miles. Associated with that feature, one can also visualize unconformity traps, and within the basin there are other fault and

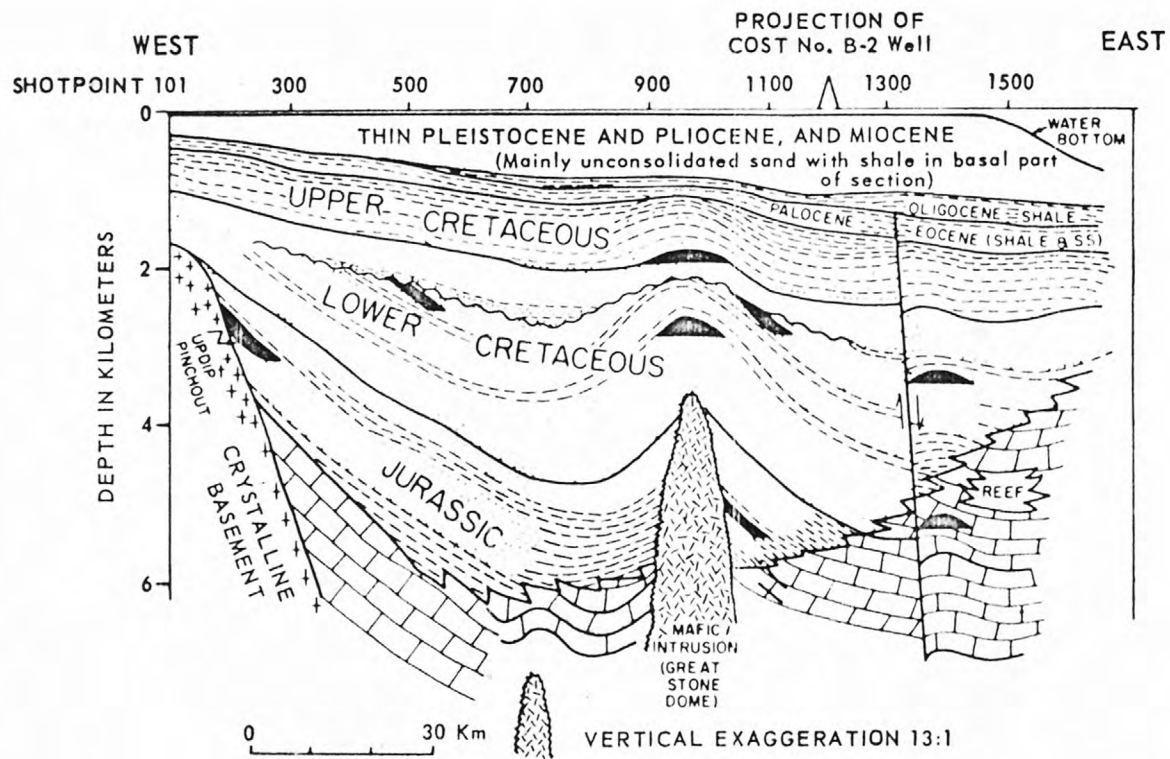




## UNITED STATES ATLANTIC CONTINENTAL MARGIN

Figure 8.





Diagrammatic cross section illustrating potential traps in the Baltimore Canyon trough area. The figure is based on an interpretation of seismic reflection line 2.

Figure 9.

reefoid traps. So the traps are there, but the one well drilled so far in the basin indicates limited source rock, dominant nonmarine section, and poor reservoir rock at depth owing to compaction and resultant crushing of unstable grains. It's always easy to see things wrong with a basin. Needed badly at this time are several good test wells to remove a few layers of wild speculation, including our own, which suggest the possibility of some 5 trillion cubic feet of gas to be discovered in Baltimore Canyon. Until that time, I personally am going to bet on the Stone Dome; it's the best target in town.

The picture I have painted for natural gas is not a pretty one from the point of view of maintaining present production, but at lesser rates of production we have long-term discovery potential, and it's high time we got after it. Maybe Amoco's Tuscarora well signals a rebirth of the Appalachians and an increased contribution by you, the petroleum engineers, to the national energy picture. Good luck.



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