Assessing and Forecasting Natural Gas Reserve Appreciation in the Gulf Coast Basin

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Introduction

Reserve appreciation, also called reserve growth, is the increase in the estimated ultimate recovery (the sum of yearend reserves and cumulative production) from fields subsequent to discovery from extensions, infield drilling, improved recovery of in-place resources, new pools, and intrapool completions. In recent years, reserve appreciation has become a major component of total U.S. annual natural gas reserve additions. Over the past 15 years, reserve appreciation has accounted for more than 80 percent of all annual natural gas reserve additions in the U.S. lower 48 states (Figure 1) (Fisher, 1993). The rise of natural gas reserve appreciation basically came with the judgment that reservoirs were much more geologically complex than generally thought, and they hold substantial quantities of natural gas in conventionally movable states that are not recovered by typical well spacing and vertical completion practices (Fisher, 1991). Considerable evidence indicates that many reservoirs show significant geological variations and compartmentalization, and that uniform spacing, unless very dense, does not efficiently tap and drain a sizable volume of the reservoir (Figure 2) (Levey and others, 1993). Further, by adding reserves within existing infrastructure and commonly by inexpensive recompletion technology in existing wells, reserve appreciation has become the dominant factor in ample, low-cost natural gas supply.

Although there is a wide range in natural gas reserve appreciation potential by play and that potential is a function of drilling and technology applied, current natural gas reserve appreciation studies are gross, averaging wide ranges, disaggregated by broad natural gas provinces, and calculated mainly as a function of time. A much more detailed analysis of natural gas reserve appreciation aimed at assessing long-term sustainability, technological amenability, and economic factors, however, is necessary. The key to such analysis is a disaggregation to the play level. Plays are the geologically homogeneous subdivision of the universe of hydrocarbon pools within a basin. Typically, fields within a play share common hydrocarbon type, reservoir genesis, trapping mechanism, and source (White, 1980). Plays provide the comprehensive reference needed to more efficiently develop reservoirs, to extend field limits, and to better assess opportunities for intrafield exploration and development in mature natural gas provinces. Play disaggregation reveals current production trends and highlights areas for further exploration by identifying and emphasizing areas for potential reserve appreciation (Lore & Batchelder, 1995).

Objectives

It is well known that areas like the northern margin of the Gulf of Mexico Outer Continental Shelf (GOM OCS) have vertically stacked reservoirs associated with growth faults and compartmentalized reservoirs associated with domal salt structures. These producing environments are especially amenable to several new technologies, such as horizontal drilling, directional drilling, and 3-D seismic imaging, and have been major sources of natural gas reserve appreciation. It is also known that plays with little natural gas mobility constraint have achieved high rates of conventional recovery and offer little natural gas reserve appreciation potential. However, there has not been a quantification of natural gas reserve appreciation by play, nor a ranking of those plays with the largest remaining potential.

Detection technology, locational diagnostics, horizontal drilling, directional drilling, hydraulic fracturing technology, measurement while drilling (MWD), advanced drilling bits, 3-D seismic, and amplitude versus offset (AVO) are just a few technological advances that have led to an increase in exploration and development efficiency sufficient to offset the depletion effects of declining field size, particularly in natural gas reserve appreciation of older, large fields. However, neither the impacts of technology by play nor the play-specific amenability of applying advanced technologies have been assessed or quantified.

The large, gross estimates of remaining natural gas reserve appreciation and the tremendous increases in these estimates over the past 7 or 8 years support the assumption that reserve appreciation can continue to be a long-term, low-cost component of natural gas supply (Figure 3). There is also substantial evidence that technological advancements have become a major factor in the emergence of reserve appreciation as an important component of low-cost natural gas supply. However, in the case of both the future volume and the role of technology, there are a number of specific elements that should be better defined, better assessed, and more finely disaggregated to facilitate the full combination of reserve appreciation to future natural gas supply. The primary research objectives of this project are developing new concepts in: (1) realistic and play-specific measures of remaining natural gas reserve appreciation potential; (2) assessment of technology necessary and most amenable to realizing natural gas reserve appreciation; and (3) assessing the economic factors of realizing natural gas reserve appreciation in the Gulf Coast Basin. Through such assessment the longer-term potential and economics of natural gas reserve appreciation as a contributor to the future natural gas supply from the Gulf Coast Basin can be determined and quantified. The methodology of such an assessment can be verified and applied more broadly to other natural gas resource areas with significant natural gas reserve appreciation potential.

Approach

An assessment of reserve appreciation potential by play, in terms of drilling effort required, in terms of amenability to technologies, and in terms of economic sensitivity is essential to quantifying the future role of natural gas reserve appreciation. The onshore and offshore Gulf Coast Basin can be a model for such an assessment. For the offshore northwest Gulf of Mexico, 91 oil and natural gas plays have been defined covering approximately 1,100 fields. The onshore Tertiary of the Gulf Coast Basin includes 37 established plays.

Most of the basic data to accomplish an assessment and forecast for onshore and offshore Gulf Coast Basin natural gas reserve appreciation are at hand. The Bureau of Economic Geology (BEG) and others, with support from the Department of Energy (DOE), Gas Research Institute (GRI), and Minerals Management Service (MMS), have defined the major gas plays of the nation in a series of regional atlases, along with an analysis of the main geologic, engineering, and production attributes of the plays. This effort has given BEG researchers considerable experience in addressing the geologic and engineering attributes that control reserve growth. The DOE's Energy Information Administration (EIA) maintains the most comprehensive and reliable historical data on natural gas reserves by field relative to time in its Oil and Gas Integrated Field File (OGIFF). Similar data are maintained by MMS in its Field Reservoir Reserve Estimates (FRRE) and by NRG Associates. Data are available to determine natural gas reserve appreciation relative to drilling activity, and surveys of specific operators can define the kind of technology historically applied in realizing reserve appreciation. The EIA OGIFF contains field-specific confidential data which must be protected through aggregation by play or which must be omitted if one or two fields dominate the play. Also, some operators may choose to hold confidential the nature of any specific technology that might have been applied. Yet, a sufficient data set exists or could be developed to assess reserve appreciation (achieved and yet to be realized) on a play basis and to quantify the role of technology already applied as well as amenability of the specific play to future technology applications. An approach for the assessment and forecasting of natural gas reserve appreciation in the Gulf Coast Basin can be outlined by the following:

1. Select and define natural gas plays.
2. Determine annual natural gas reserve appreciation by field and aggregate to plays.
3. From calculated historical growth rate relative to drilling and time, extrapolate future natural gas reserve appreciation potential.
4. Estimate natural gas reserve appreciation potential by heterogeneity class and determine volume.
5. Determine the most effective kind of technologies deployed to date and define the amenability of plays to the deployment of existing and future technologies.
6. Through an engineering economic evaluation utilizing discounted case flow, sensitivity, risk, and cost/benefit analysis, determine on a play-by-play basis the economic sensitivity of remaining natural gas reserve appreciation potential.

Applications and Benefits

In recent years, reserve appreciation has become a major component of total annual natural gas reserve additions. However, several important scientific contributions remain to be addressed. We do not have a quantification of natural gas reserve appreciation by play, nor a ranking of those plays with the largest remaining potential. We have not quantified the impacts of technology by play nor assessed play-specific amenability of applying advanced technologies. We do not know the economic costs and benefits of reserve appreciation by play. An assessment of reserve appreciation potential by play, in terms of drilling effort required, amenability to technologies, and economic sensitivity is essential in quantifying the future role of natural gas reserve appreciation in the Gulf Coast Basin.

Previous resource assessments generally do not include the technology and economics required to incrementally develop and produce potential resources. It is not enough to characterize resource potential only in terms of quantity of natural gas that is available. It is equally important to characterize the technology and economic structure associated with its development. Resource estimates without associated technology and economics provide little information for a planner in addressing long-term natural gas supply. Volumetric and statistical estimates such as how much natural gas remains to be discovered and produced in the Gulf Coast Basin are meaningful only when they are coupled with technologic and economic information. Moreover, reserve appreciation has not been addressed in detail, although it is a dominant contributor to annual natural gas reserve additions. The scientific contributions and benefits to the field of resource assessment of this project are the development of a methodology incorporating technology and economics to resource assessments to improve resource estimates. It will provide a critical resource information base that can be incorporated into existing and proposed natural gas databases. Moreover, this project will provide one of the first play-level natural gas reserve appreciation models for the Gulf Coast Basin. Play-level natural gas reserve appreciation models provide guides for frontier exploration, such as in the ultra-deep-water areas in the GOM OCS, maximize field development efficiency by delineating opportunities for field extensions and intrafield development, and specify current and innovative technologies amenable to reserve appreciation. The methodology of such an assessment can be verified and applied broadly to other natural gas resource areas with significant reserve appreciation potential.

Accomplishments and Future Activities

Reserve appreciation is an important component of U.S. natural gas supply. However, very few reserve appreciation studies have been conducted, and it is still poorly understood. As stated recently by the researchers of the U.S. Geological Survey, “Much work remains to be done on the phenomenon of reserve growth, which is arguably the most significant research problem in the field of hydrocarbon resource assessment” (Schmoker & Attanasi, 1997). Through disaggregation by plays and incorporating the effects of technology and economics, this project intends to develop a methodology to better understand and forecast natural gas reserve appreciation.

To date, most of the research effort has focused on literature surveys, gathering and review of data, and database construction. Past resource assessment and reserve appreciation studies have been reviewed and compared in order to delineate the current state of research and problems needed to be resolved. EIA’s OGIFF data for the GOM OCS have been obtained and analyzed, and a field database and corresponding play-level database have also been constructed and integrated with BEG’s play databases. Preliminary analysis has revealed that natural gas reserve appreciation in the GOM OCS has steadily occurred along with an increasing number of fields within the 17-year time frame (Figure 4). Although natural gas reserve appreciation in the GOM OCS shows no correlation to price, a relatively good correlation is seen with technology advancements as represented by 3-D seismic permits issued.

Different trends in natural gas reserve appreciation according to BEG-defined plays have also been indicated by initial research. As seen in Figure 5, fields within the same play exhibit relatively similar patterns in reserve appreciation as represented through cumulative growth factors (Arrington, 1960, Marsh, 1971, Root, 1981, Megill, 1989a, 1989b, 1989c, EIA, 1990, NPC, 1992, Root & Mast, 1993, Root & Attanasi, 1993, Attanasi & Root, 1994, Lore and others, 1996). Cumulative growth factors represent the ratio of the size of a field n years after discovery to the initial estimate of its size in the year of its discovery. The two fields within the Middle Miocene Combination Sandstone - Southern Corsair Trend (MM7RAP1A) show relatively higher rates of natural gas reserve appreciation compared with the two fields in the Upper Pleistocene Progradational Sandstone (UPLP1). Whether these trends exist for all the fields within the same play and using drilling rather than time as the dependent factor remains to be resolved. The controls on natural gas reserve appreciation, such as technology, geology, and economics, on a play-level basis requires further detailed studies. Future activities involve continued data gathering and database construction, operator surveys, play selection, and determining reserve appreciation by plays on the basis of both drilling and time.

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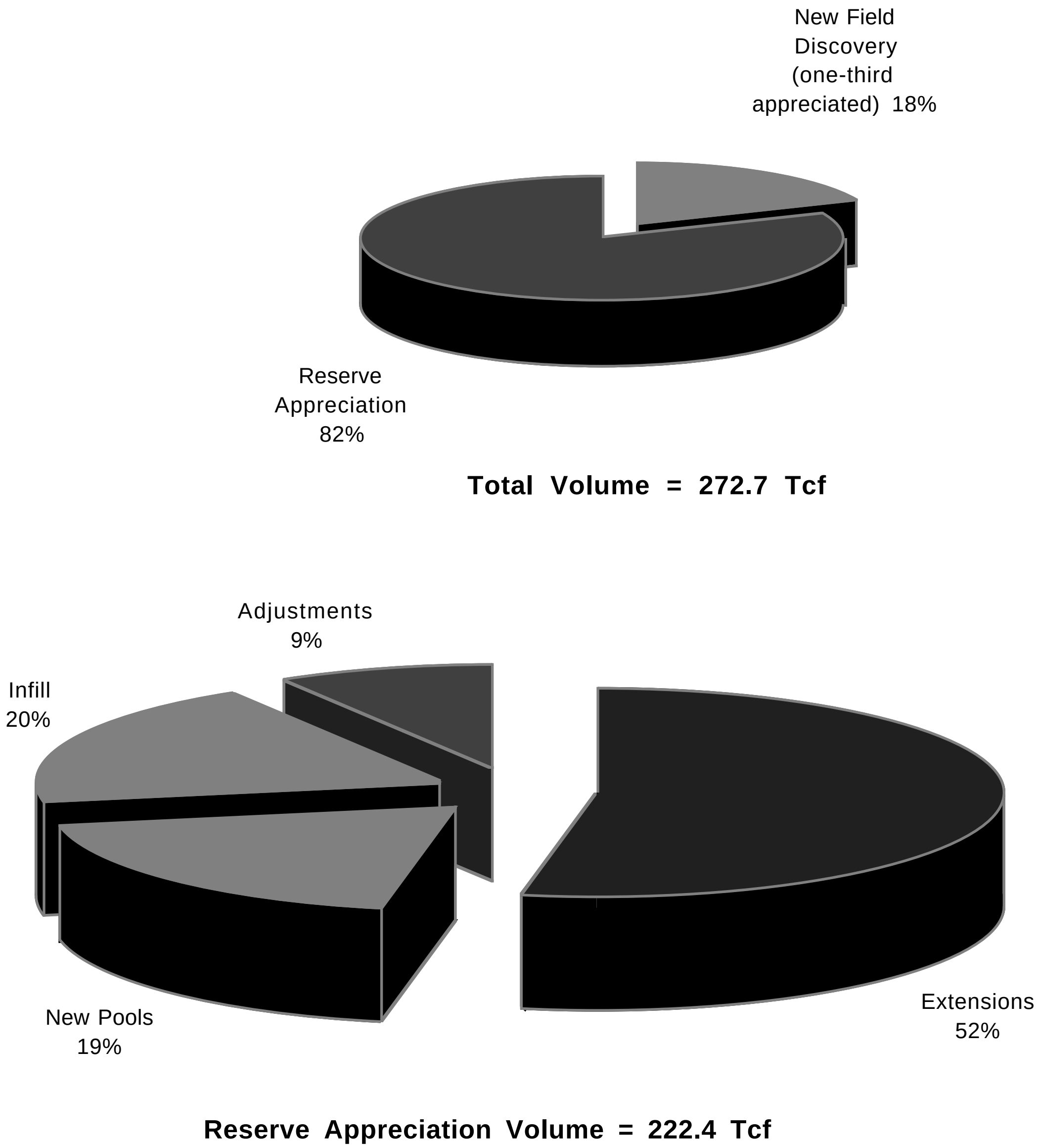

Figure 1. U.S. lower 48 states natural gas reserve additions from 1977 to 1992 (Modified from Fisher, 1993)

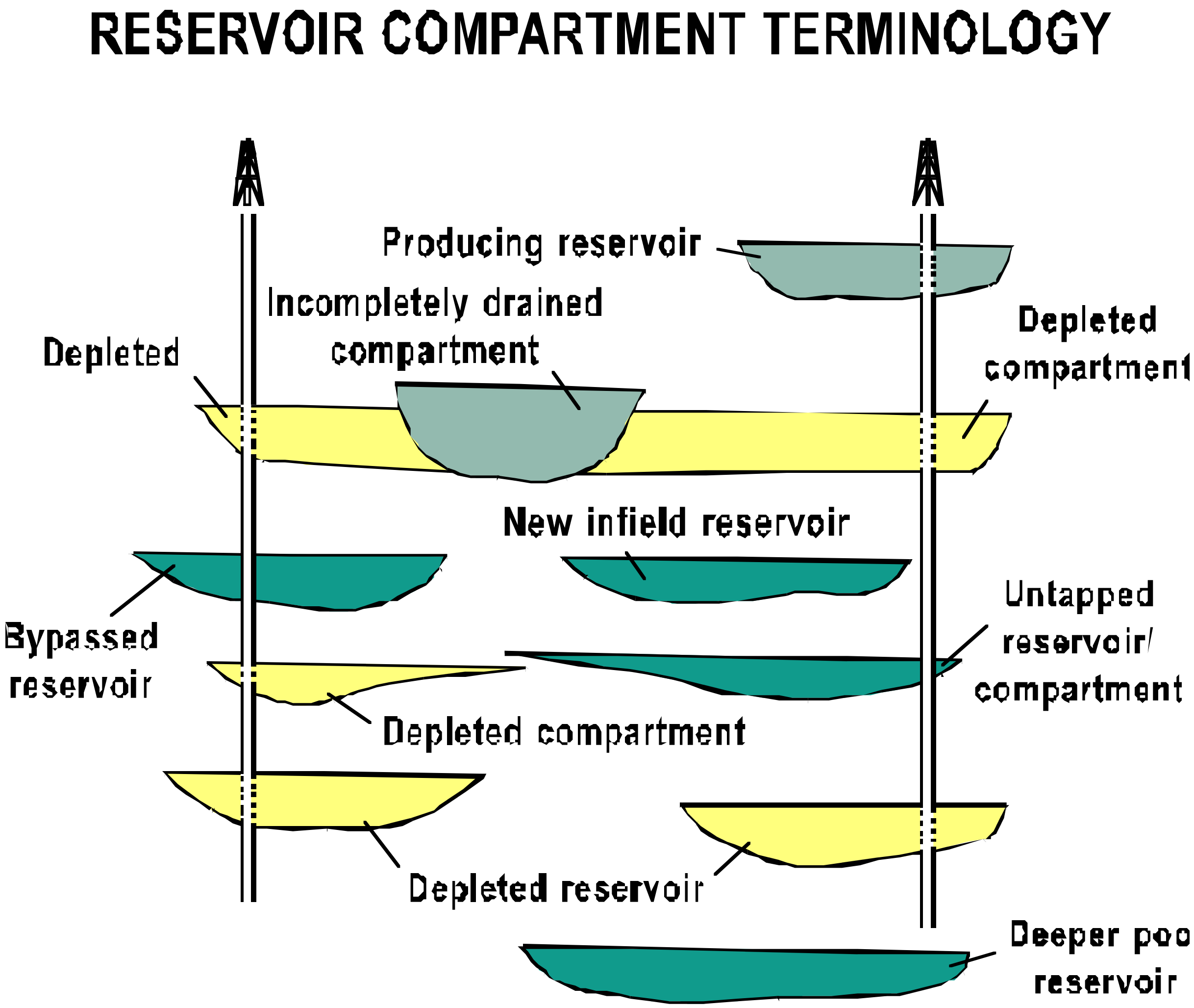

Figure 2. Major types of reservoir compartmentalization (Levey and others, 1993)

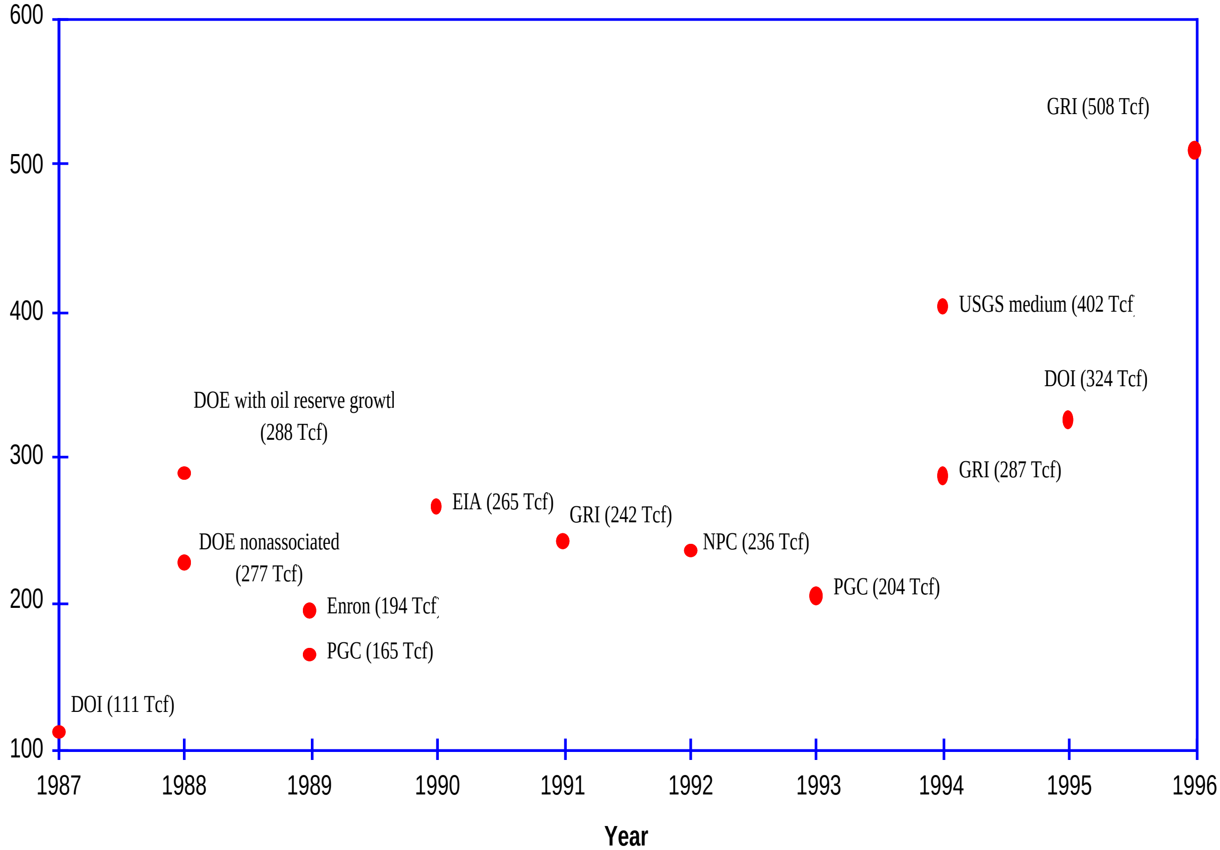

Figure 3. Recent estimates of future natural gas reserve appreciation from existing fields, U.S. lower 48 states (Updated from Fisher, 1994)

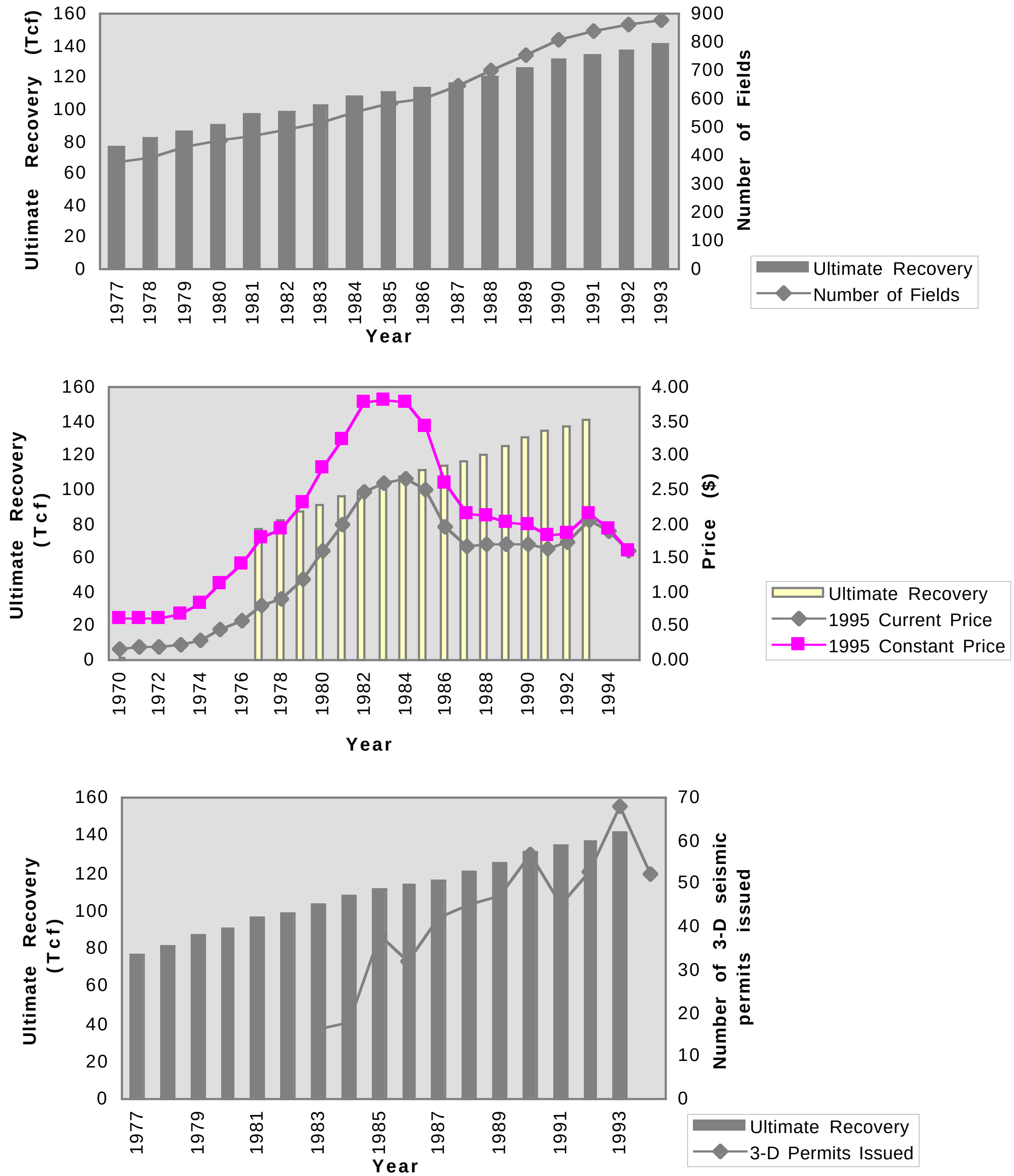

Figure 4. Natural gas reserve appreciation in GOM OCS versus field number, price, and 3-D seismic permits (Data from EIA, 1995 & Francois, 1995)

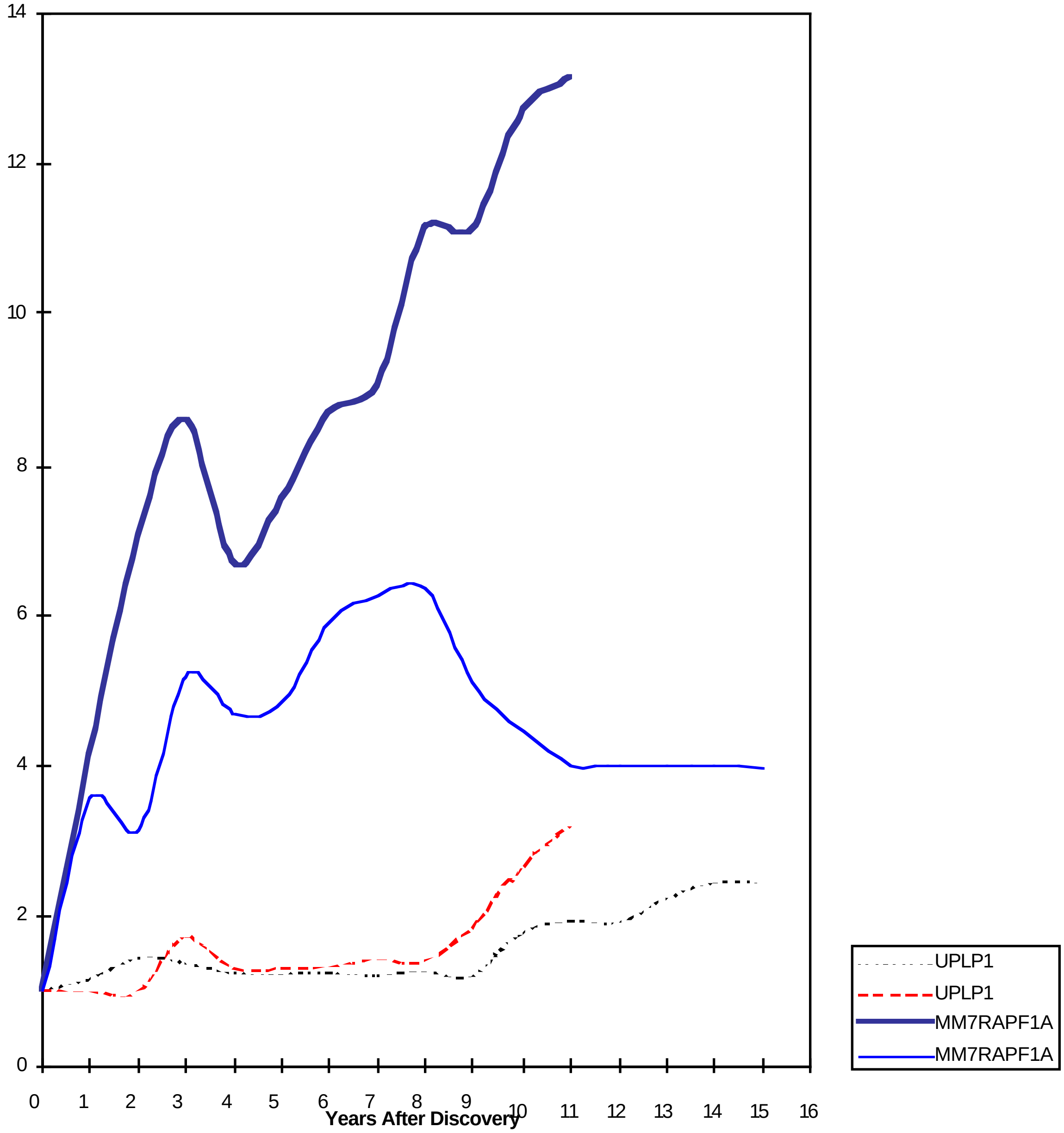

Figure 5. Natural gas reserve appreciation in GOM OCS disaggregated by plays (Data: BEG, in press)