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**Ben D. Hare**  
Chief Geologist

March 11, 1999

Lyle Baie  
Executive Director  
American Association of Petroleum Geologists  
P.O. Box 979  
Tulsa, Oklahoma 74101-0979

RE: Endorsement of World Assessment Methodology Used by the USGS

Dear Lyle,

At the Annual Meeting of the Committee on Resource Evaluation (CORE) on May 16, 1998, held at the annual AAPG Convention in Salt Lake City, the committee discussed the United States Geological Survey's (USGS) Assessment of Worldwide Energy Resources. The committee unanimously agreed that a project like this is very significant and any figures published by the USGS for worldwide energy resources will have profound implications for domestic and international policy as well as for the geoscience community. Therefore, the full committee asked Naresh Kumar and Earl Ritchie to form a subcommittee to carry out an assessment of the methodology being utilized by the USGS for this project.

Consequently, a subcommittee consisting of Naresh Kumar, Earl Ritchie, Glenn Buckley and Bill Stanton was formed. Messrs. Kumar and Ritchie met with the USGS assessment team on May 27, 1998 and the full subcommittee met with the team on September 18, 1998. Both of these meetings took place in Denver at the USGS office.

The World Energy Project was initiated in 1995. The USGS has divided the world into eight regions and the regions have been further subdivided into 954 provinces, of which 406 are petroleum bearing. These provinces have been ranked by their known oil and gas resources and the survey has selected the top 76 non-U.S. provinces, which along with 21 provinces in the United States, contain 95% of the known oil and gas resources of the world. Each of the provinces may contain one or more "assessment units". A team of 25 to 30 Survey and contract employees is working on the project. An "Assessment Team," consisting of senior scientists with long-standing experience in resource assessments, provides a measure of comparison and standardization among various provinces and assessment units. Although the USGS and others have published worldwide resource assessments in the past, this is the first effort in the public domain based on geologic

data and petroleum system evaluation. This is probably one of the most data intensive worldwide resource assessments undertaken.

The subcommittee presented its finding to the full CORE at its meeting on January 21, 1999. The full committee concluded that the assessment project team has done a very thorough job synthesizing regional and local data on petroleum systems. The geologic expertise has been well balanced with expertise in data analysis, statistics, and probability methods. The assessment team has also utilized peer-review processes effectively through formal and informal contacts with the industry. A few interim products, a series of CD-ROMs containing regional geologic maps and displaying various province outlines and locations of significant oil and gas fields, have already been released. These products alone constitute a significant contribution to the profession. Summary results of all the assessments will be released sometime in the middle of year 2000.

The Committee on Resource Evaluation is satisfied with the scientific methodology, rigor and consistency being applied to the World Oil and Gas Assessment by the USGS World Energy Project. The results of this project, sizes and volumes of undiscovered oil and gas accumulations in various parts of the world, will address matters of significant national and international interest and will be a great data resource for policy makers and those engaged in strategic planning. The geologic maps generated during the assessment will be of value to AAPG members worldwide for years to come.

After the CORE voted to endorse the methodology at its January 21, 1999 meeting, it submitted its recommendation to the Executive Committee. At the AAPG Executive Committee meeting in February 1999, the Executive Committee also voted to endorse the methodology as well. The figures, when they are released, will form the basis for many policy decisions of domestic and international interest. The AAPG Executive Committee, by its endorsement, has signaled that it is satisfied with the scientific approach utilized in this study.

Yours very truly,

Ben D. Hare, Chairman  
AAPG Committee on Resource Evaluation

BDH:pd

cc: T. Ahlbrandt  
S. Weedman

attachment: Subcommittee Report

**American Association of Petroleum Geologists  
Committee on Resource Evaluation (CORE)  
Subcommittee to review the World Assessment Methodology used by the USGS**

**Report Submitted by**

**Glen Buckley (Exxon Exploration Company), Earl Ritchie (Enron Oil and Gas),  
Bill Stanton (Mobil Corporation), and Naresh Kumar (Growth Oil and Gas)**

*Recommendations*

1. The subcommittee recommends that the full Committee on Resource Evaluation (CORE) endorse the methodology being used for assessing undiscovered oil and gas resources by the United States Geological Survey in its World Energy Project. If the Committee approves this recommendation, we also recommend that the Executive Committee be advised of this approval.
2. Because of its national and international significance, and the potential usefulness of the products coming out of this project, we recommend that the Committee ask the AAPG Executive Committee to support publicity for the project by the *AAPG Explorer*.
3. Because the final results of this assessment are going to be announced only in June 2000, we believe that our review is a progress report. We recommend that the Committee consider another review prior to the release of the final results during the early part of the year 2000. This revisit is necessary because some of the procedures are still being refined/clarified.

**American Association of Petroleum Geologists  
Committee on Resource Evaluation (CORE)  
Subcommittee to review the World Assessment Methodology used by the USGS**

*Background*

At the Committee Meeting on May 16, 1998, held during the national AAPG Convention, Naresh Kumar and Earl Ritchie were asked to review the United States Geological Survey (USGS) assessment methodology for worldwide energy resources. Earlier, USGS had requested a review of its assessment methodology utilized for the 1998 report on undiscovered oil and gas resources in the Arctic National Wildlife Refuge (ANWR). A subcommittee chaired by Richard Nehring reviewed the ANWR methodology and reported to the Committee on Resource Evaluation (CORE) that the USGS approach to assessment was technically and scientifically sound. The AAPG Executive Committee later endorsed this USGS methodology.

The World Energy Project is another major resource assessment project being carried out by the USGS. Although periodic estimates for worldwide undiscovered oil and gas resources have been published by the USGS at least since the mid 1980s, the current World Energy Project is utilizing a very different approach. Therefore, the USGS wanted an industry panel to review the methodology being utilized and provide comments and suggestions to the assessment team. Because of the importance of this type of project to the AAPG membership, CORE approved its involvement.

Earl Ritchie and Naresh Kumar carried out the review during one visit to the Survey's offices in Denver on May 27, 1998 and another by the full subcommittee on September 18, 1998. The agenda for the September 18, 1998 meeting is attached as Enclosure 1. Besides Ritchie and Kumar, the other two members of the subcommittee were Glenn Buckley (Exxon) and Bill Stanton (Mobil). This report summarizes the committee's observations, comments and recommendations.

*USGS World Energy Project*

For the current project, which was initiated in 1995, the USGS has divided the world into eight regions. These regions are similar to the economic regions used by the U.S. State Department. The eight regions have been further subdivided into nine hundred and fifty four provinces out of which 406 are petroleum bearing. These provinces have been ranked by their known oil and gas resources and the Survey has selected top 76 non-U.S. provinces, which along with 21 provinces in the United States, contain 95% of the known oil and gas resources of the world (tabulation released in a CD-ROM). In addition, the Survey has selected 26 "boutique" provinces among the rest which deserve detailed studies either because of their strategic location or because they have the potential of becoming major petroleum provinces. Detailed resource evaluation of undiscovered oil and gas in these 76 "priority" and 26 "boutique" provinces are planned to be released by June 2000.

The Survey has assembled a team consisting of 25 to 30 Survey and contract employees to undertake this project. A senior Survey scientist acts as "Regional Coordinator" for each of the eight regions. In addition, an "Assessment Team" consisting of senior scientists with long-standing experience acts as the final reviewer for each of the individual assessment units. This assessment team will see each of the 102 province assessments to ensure consistency.

### *Sources of Information and Data Bases*

This is one of the most data-intensive resource evaluations undertaken by the Survey. All the assessments will be based on local and regional geology. Hence, the project team has compiled regional and local data, maps, charts, publications, etc. from a wide variety of sources. Many of the Survey scientists have intimate knowledge of specific parts of the world and this knowledge has been incorporated into the regional analysis. The mapping has been done through Geographic Information Systems (GIS) and the team has already released base maps for Africa, Arabian Peninsula and South Asia in CD-ROM formats. Two additional CD-ROMs, one for South America and another for the former Soviet Union, will be released shortly. These maps display surface geology and individual province boundaries. In addition, center points of oil and gas fields have been plotted using the Petroconsultants database.

The oil and gas industry has participated in the regional geologic studies actively. The project team has been working collaboratively with some of the majors from the inception of the project. In addition, an industry consortium consisting of majors and independents has been meeting in Denver with the project team once every quarter. Informal discussions during these meetings have been very helpful to the project team. In several cases industry sources have provided country, trend or field-specific data to the project team.

### *The Assessment Methodology*

This assessment is geology and data driven. The form used for this exercise is attached (Enclosure 2). For each of the provinces, one or more "Total Petroleum Systems" have been defined. This is the first time an attempt to characterize the petroleum systems in 102 non-U.S. provinces is being carried out. For each of the Total Petroleum Systems, one or more "Assessment Units", defined as a mappable volume of rock within the total petroleum system that encompasses petroleum fields (discovered and undiscovered) which share similar gross geologic traits and socio-economic factors, have been mapped. At this time it is anticipated that within the priority and boutique provinces, a total of as many as 300 assessment units may be defined.

Upon definition of Assessment Units for a particular Total Petroleum System (within a given province and region), the task of assigning numbers and sizes of undiscovered fields begins. Although, the assessment units are not "plays" as used in many of the domestic resource evaluation projects, an attempt has been made to define them in such a way so that all the fields (discovered and undiscovered) represent a reasonably homogenous population and can be assigned a single probability for charge,

rocks (reservoir, trap and seal), timing of geologic events, and accessibility. An assessment unit with the probability of finding at least one accumulation of certain minimum size has a unit probability of one, whereas those with no known accumulations are hypothetical units with varying degrees of probabilities for undiscovered fields. Geologic analogs across province and region boundaries are used for assessing areas of no known discoveries. It is anticipated that almost one-third of the assessment units might be hypothetical.

Based on all the literature and data available, the assessment geologist for each of the assessment units assigns a probability distribution for number and sizes of undiscovered fields. In some cases there is enough published data available to attempt prospect counting. In most cases, geologic trends, total unexplored area, discovery history, success rates, analogs from other areas, etc. have been considered to estimate the number and sizes of undiscovered fields. These probability distributions do not try to capture every possible accumulation. In fact, a minimum size cut off which varies depending on the characteristic of the assessment unit but is usually from 1 to 10 million recoverable barrels of oil or gas equivalent, has been applied to these distributions.

The project team has carried out considerable research on reserve growth. Using the Petroconsultants data, they have reviewed the reserves (proven and probable) reported for various size fields over a fifteen-year period. During this period (1981-1996), the reserves have "multiplied" by a factor of 1.25 to 1.5. Because the project is attempting to quantify fields that may be discovered during the next 30 years, the estimated probability distributions are "grown" reserves. All the final reported numbers would be "grown" reserves on known and undiscovered fields.

Another area for considerable research has been on the probability function that would best depict the sizes and numbers of undiscovered fields. The team has experimented with normal, log normal, shifted log normal and triangular distribution functions. After much trial and error and experimentation, they plan to use "Shifted Truncated Log Normal" distribution for field sizes and "Triangular" distribution for all other distributions.

The assessment team attempts to estimate gas/oil ratios to assess NGLs in gas fields and associated gas in oil fields. In addition other considerations such as drilling depth for undiscovered fields, oil quality, etc. are also estimated as distribution functions. As mentioned earlier, the Assessment Team, consisting of the same individuals, plans to review each of the expected 300 or so assessment unit evaluations to maintain consistency.

Our review team discussed a few specific areas where this methodology is being applied. Areas discussed were Niger Delta, Trias/Ghadames, and to some extent the Sirte Basin and the Campos Basin. Because our task has been to review the methodology, specific numbers for any of the areas were neither requested by us nor were presented during our discussions.

### *Conclusions*

1. Our group feels that the project team has done a very thorough job of synthesizing regional and local data on petroleum systems. The team consists of very

experienced regional geologists who have long-standing record of oil and gas assessments. The geologic expertise has been well balanced with expertise in data analysis, statistics and probability methods. In addition the team has utilized peer review process effectively through formal and informal contacts within the industry. The focus has remained on the geology as the basis for the organization of the historical data and the final volumetric assessment.

2. There has been well planned and coordinated effort to ensure that all maps and data are recorded and analyzed in digital format. Just the CD-ROMs containing regional maps, province boundaries and oil and gas field locations represent a significant contribution and service to the geologic community. The format is such that additional data can be easily plotted on any desired area at any scale.

3. We saw an outline and a rough draft for the assessment of one of the provinces. The format is quite thorough. In addition to the numbers on undiscovered oil and gas fields, each of the assessment papers will contain background geology, information on oil and gas occurrences and pertinent literature references. Again release of this information represents a significant contribution, especially considering that 102 such papers are expected to be released within the next two years.

4. We spent considerable time discussing the definition and ramifications of the term "assessment unit". As applied in this project, it is at a more general level than a "play" but allows for multiple reservoir, trap, seal, and geographic heterogeneities within a petroleum system. We felt that the team has spent considerable effort in ensuring consistency in defining and mapping these units.

5. Reserve growth has been a question of considerable concern and uncertainty while performing assessment studies. Because the project takes a 30-year forward look, it is especially important that they consider the reserve growth issues in existing and undiscovered fields. We felt that the team has handled this issue appropriately. The project team has addressed the shortcomings of the Petroconsultants database correctly and applied appropriate modifiers that are driven by data from foreign and U.S. fields.

6. Although an economic analysis on the data will not be performed, a minimum size has been used for each of the assessment units to avoid accounting for large number of volumetrically insignificant fields.

7. Our subcommittee is comfortable with the trial and error method the project team has used to define the shape of the probability distributions for the undiscovered field numbers and sizes. The shifted, truncated log-normal distribution starts at the minimum size as defined for each assessment unit, yet maintains the median size as defined by the assessment geologist. The project team has also performed experiments with the effects of using binned data (step functions, such as field size classes). They have found that in highly skewed populations, binned data can provide highly optimistic results. Hence such data will not be used for estimating the sizes of undiscovered oil and gas fields.

### *Suggestions*

1. Our group would like to see the purpose of the project clearly stated. Because of the international political, military, and economic ramifications of undiscovered oil

and gas volumes in various parts of the world, it is important to mention the limitations imposed by the data available and to state that the study is not attempting to count every possible undiscovered accumulation.

2. We do understand that although an attempt has been made to define each assessment unit such that the oil and gas populations in each form a homogeneous population, there is a built-in heterogeneity because of lack of data and the need to generalize. As was discussed during the meeting, a definition of risks assigned to individual attributes, consistent through all the assessment units, will relieve some of these concerns. U.S.G.S. has already taken steps in this direction. Enclosure 3 is a draft for definitions of probabilities used in assessing the risks for charge, rocks, timing and access. Definitions range from  $P=0$  to  $P=1.0$  with intermediate values for  $P= .10, .25, .50, .75$  and  $.90$ . Once these definitions are refined and uniformly applied to all the assessment units, a comparison of individual elements of risks for various assessment units can be made on a worldwide basis.

3. There appears to be a need to document the use of analogs in assessment units with known oil and gas as well as the hypothetical assessment units. What analogs were used where, and were they consistently applied in similar geologic settings needs to be documented. It would be a significant contribution to develop a scheme for defining analogs based on geology and associating a particular geologic setting to certain field sizes, numbers and risks.

### *Summary*

The sub-committee is satisfied with the scientific methodology, rigor and consistency being applied to the World Oil and Gas assessment by the USGS World Energy Project. The maps and background information alone resulting from this project provide a significant contribution to the AAPG membership. Of course, the results of this project, sizes and volumes of undiscovered oil and gas accumulations in various parts of the world, will address a matter of significant national and international interest. Our recommendations and suggestions are described at the beginning of this report.

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