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Oil and Gas in Offshore Tracts: Inexactness of Resource Estimates Prior to Drilling

The report of Uman *et al.* (*1*) illustrates that the estimation of oil and gas resources prior to drilling is a very inexact process. Uman *et al.* compare the resource estimates made by the U.S. Geological Survey (USGS) for a series of tracts on the federal outer continental shelf (OCS) prior to leasing and drilling with the estimated reserves discovered after drilling. They also compare the current estimation procedures with those that have been used in the past. The most important conclusion that can be drawn from their report is not that the present procedures are significantly better than earlier procedures (they are not) but that both procedures are ineffective. As Uman *et al.* point out, there is a significant positive correlation between prelease sale estimates and postdrilling estimates, but the correlation for the current Monte Carlo estimation procedure (*2*) is only $r = .45$. This means that only 20 percent of the variation in postdrilling estimates can be associated with the predrilling estimates; 80 percent of the variance is independent of the prior estimates. The standard error of the estimate is very large, and there is thus a wide confidence interval about the regression (Fig. 1). Figure 1 also shows the confidence bands of the forecast, which exceed two orders of magnitude at the means. These results suggest that current estimation procedures are very imprecise at best. Figure 1 of Uman *et al.* (*1*) shows a line having a slope of $y = x$, or perfect agreement between presale and postdrilling estimates; however, the slope of the regression between presale estimates and postdrilling estimates is significantly less than 1.0, and the intercept is significantly greater than 0.0. Therefore, there is a tendency to overestimate resources in advance of drilling when the presale estimates are less than about 10 million barrels of oil equivalent (MMBOE) and to underestimate resources when the presale estimate is greater than 10 MMBOE.

Perhaps it is most critical to note that Uman *et al.* are dealing with a censored data set, because they consider only those tracts that were leased and from which hydrocarbons were subsequently produced. They did not include tracts for which presale estimates were made although no commercial quantities of oil or gas were found. Since approximately 38 percent of Gulf Coast lease tracts that have been drilled have failed to produce (*3*), there must be about 18 additional points that should have been plotted in figure 1 of (*1*) for sales 33 to 44. Since these additional points would all lie below any values shown, it is quite possible that these additional tracts would cause the correlation between prelease estimates and postdrilling estimates to become zero or even negative.

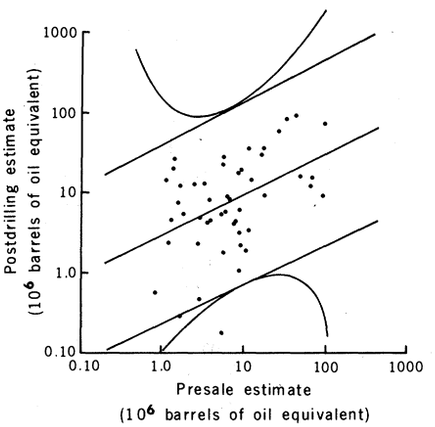

Fig. 1. Presale and postdrilling estimates of recoverable hydrocarbons for 49 tracts of lease sales 33 to 44 on the federal outer continental shelf. The central straight line is the regression of postdrilling estimates on the presale estimates; the outer straight lines are the upper and lower 95 percent confidence limits for the regression. The curved lines are the upper and lower 95 percent confidence limits for the estimates made prior to leasing.

The USGS prelease evaluation procedure is an extension of widely used reservoir analysis methods for economic appraisal (*4*), but this procedure is applied under conditions of extreme uncertainty when used in advance of drilling. By using this method, one can calculate the volume of recoverable oil or gas in place in lease tracts on the basis of a consideration of 17 diverse geologic parameters such as reservoir thicknesses, volumes of closure, porosities, water saturations, and ratios of oil to gas (*5*). Since these reservoir characteristics are not known prior to drilling, they must be estimated from seismic data and from logs and production histories of wells drilled elsewhere in the region. In an attempt to account for uncertainty, the parameters are given as distributions and the volumetric calculations are performed by Monte Carlo methods. The results are distributions of possible resources, which then are tempered by the analyst's assessment of the probability that no recoverable hydrocarbons exist at all in the tracts. The presale estimates given by Uman *et al.* (*1*) are the expected values of these distributions. In tract evaluation, further analysis is performed to yield expected monetary values, which can be used to establish fair market values and minimum acceptable bids set by the Bureau of Land Management.

The effort required to obtain the input distributions of geologic and reservoir properties required by the Monte Carlo analysis is substantial. The imprecise results reported by Uman *et al.* suggest that alternative estimation procedures should be investigated to determine if improved forecasts can be made or if estimates of equivalent precision can be obtained with substantially less effort. We have suggested (*6*) that it may be possible to make effective resource forecasts for tracts in the Louisiana OCS by regressing the oil and gas volumes of known reservoirs onto seismically perceivable variables, such as the apparent areas, heights, and volumes of closure of the structures which contain these reservoirs. A wealth of data are available in the Louisiana and Texas OCS that would permit these seismic properties, which are established in advance of drilling, to be statistically compared with the results of drilling. The regression could then be used to estimate the resources that may

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be contained in undrilled seismic prospects. Unfortunately, this simple statistical procedure, as well as other possible alternatives to the Monte Carlo simulation procedure, remain untested because it is not possible to obtain access to the necessary geophysical and production data. The procedures described by Uman *et al.* are not effective from a statistical standpoint, and it remains to be determined whether more effective procedures can be devised.

JOHN C. DAVIS
Kansas Geological Survey, University of Kansas, Lawrence 66044

JOHN W. HARBAUGH
Department of Applied Earth Sciences, Stanford University, Stanford, California 94305

References and Notes

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2. Data were extracted from a larger version of figure 1 of (*1*).
3. This percentage is based upon an earlier but much larger set of Gulf Coast lease tracts described in "Some basic statistical studies on federal offshore oil and gas lease well drilling and production: Leases issued in 1962 and prior years (LPR-19B data base)" (Applied Research and Analysis Section Report No. 78-24, U.S. Geological Survey Conservation Division, Lakewood, Colo.,1978).
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We agree with Davis and Harbaugh that the estimation of oil and gas resources prior to drilling is a very inexact process. In (*1*, p. 490) we concluded "that the ability to predict the volume of recoverable resources under OCS [outer continental shelf] tracts (if any is discovered) appears to be limited to within a factor of 10." Whether this degree of ability is ineffective, as Davis and Harbaugh suggest, depends on how one defines what is required to be effective. The purpose of our report (*1*) was to indicate the limitations of current procedures so that policy analysts might determine if this level of performance is good enough for the uses intended.

We did not conclude or even suggest, as Davis and Harbaugh imply, that the present procedures for presale estimation of resources are more accurate or precise than earlier procedures. The procedural changes occurred as a historic fact, and we reported a short-term perturbation in accuracy which accompanied these changes (sales 30 and 31). The reasons for the procedural changes had, in fact, nothing to with the degree of inaccuracy of the earlier methods in estimating resources but attempted to address the more obvious problems associated with assigning monetary value to tracts based on single-value estimates of the geological variables. (Statisticians and economists would qualify this problem as "nonlinear.") This point is very relevant to the alternative method suggested by Davis and Harbaugh, and we shall return to it after we make brief rejoinders to two misleading statements in their comment.

Contrary to the statement of Davis and Harbaugh, the presale estimates of (*1*) are unrisked estimates. Our study was concerned with only one of the three steps of the U.S. Geological Survey (USGS) evaluation process. Comparing risked presale estimates with postdrilling results would not separate the volumetric component of the appraisal from the risk assessment. We compared the discovered volumes where drilling resulted in discovery with the volumes expected in the event that drilling proved successful. Thus, no additional points should have been plotted in figure 1 of (*1*).

Davis and Harbaugh attach significance to their finding that the regression slope of postdrilling estimates on presale estimates (the latter used as the independent variable) is less than unity, pointing out that small finds were overestimated and large finds underestimated prior to drilling. This is true but not surprising, and not in any way a feature unique to USGS evaluation procedures [see, for example, the discussion in (*2*) of the problem of "vanishing tonnage" in the mining industry]. Any appraisal method (including the one that Davis and Harbaugh propose) that deviates from absolute accuracy will have an expected value less than unity for the slope of the regression of discovered on predicted values. Regression analysis can be misleading when there are error components in the independent variables, which is why we avoided it in our study.

Davis and Harbaugh suggest an alternative method for making presale resource estimates. The method consists of developing regression equations relating oil and gas volumes in known reservoirs to seismically perceivable variables and using these regressions by analogy in untested areas. This method is less direct than the conventional approach but potentially less expensive in the long run. It also appears to have two serious deficiencies. First, in addition to the usual problems of selecting an analog and finding the necessary data, the method does not allow for directional shifts off the regression line, which are based on known differences between the evaluation target and the analog. In present practice, analogs are used as general guides and can be mixed. For example, reservoir rock properties may come from one analog, hydrocarbon richness and maturity from another, and success ratios from yet another, each selected for its similarity to the evaluation target in different aspects of the geology. Basing the evaluation on a single analog would severely restrict the geologist's ability to incorporate geologic knowledge into his evaluation.

Second, if the basic requirement is to estimate something beyond the potential volume of hydrocarbons in a prospect, such as the net present worth of the property, the suggested method will be inadequate. The value of the property depends on extraction costs and the timing and rate of production, as well as the quantity of recoverable hydrocarbons in the ground. Analysis of these factors requires estimation of basically the same suite of geologic properties used to make the volumetric appraisal in the conventional manner. Using the suggested alternative in support of determinations of fair market value, or in setting bid levels, would result in more analytical effort, not less.

MYRON F. UMAN
National Academy of Sciences, Washington, D.C. 20418

WILLIAM R. JAMES
Houston, Texas 77096

HOLLY R. TOMLINSON
U.S. Geological Survey, Reston, Virginia 22092

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