Geologic and Economic Risk Factors in OCS Lease Sale Evaluations: MMS Perspective

Gary L. Lore, Minerals Management Service

There is an important distinction between geologic success and economic or commerical success (Downey, 1988). The Minerals Management Service (MMS) asseses these probabilities sequentially, first geologic success and then economic success via Monte Carlo discounted cash flow simulation.

The assessment of geologic success is approached by considering key goelogical components necessary for an accumulation and estimating their probability of existence. These probabilities are often called chance factors. From three to seven critical factors are typically considered (Rose, 1987; Duff and Hall, 1996; Murtha, 1996). The MMS Gulf of Mexico Region in its lease sale evaluations considers three factors: hydrocarbon fill, reservoir, and trap and has modified accordingly the number of factrs and associated guidelines of Duff and Hall (1996). We have also adopted their concept of process and corresponding chance domains and the utilization of risk tranches.

In its simplest form, a single horizon, singl trap prospect, the individual geological components are considered independent, and the probability of geologic success is the product of the adequacy factors for each component:

$$P(S_{hc}) = P(\text{hydrocarbon fill} \times P(\text{reservoir}) \times P(\text{trap}).$$

In reality, the majority of prospects in the Gulf of Mexico consist of multiple traps and/or multiple horizons. In these situations the assumption of indpendence is nearly always inappropriate; e.g., different traps on the same horizon may hsare a common seal, migration pathway, or reservoir rock. Likewise, different horizons may share some of the same risks with respect to timing of trap formation, seal, source, or migration pathways. As a result, knowing the outcome of a well drilled in one trap or horizon influcences the probability of succes on others.

A special case of dependency is one in which the prospect (horizon) is dependent upon the best horizon (trap), in terms of probability of $P(S_{hc})$, being successful. All combinations not involving the best horizon (trap) are impossible; therefore, if this horizon (trap) is unsuccessful, so is the prospect (horizon). This represent one endpoint of a continuum, with the other being total independence-knowing the result on the best horizon (trap) does not affect the probability of

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succes for the prospect (horizon). Both of these siutations are realistic. However, a more typical scenario is that the individual traps within a horizon share many commonalities; e.g. separate closures against the same fault,same source and reservoir sands, or the same digenetic and burial history. Thus, a great deal of interdependence exists in terms of shared risks among traps, but not enough that the assurance of success or failure of the prospect (horizon) can be determined by the reslts from one horizon (trap). As a generality, traps within a horizon probably have more commonality (interdependence) than horizons within a prospect (these commonalities will generally be more structural in nature). This is the sencario that we attempt to model.

Newendrorp (1975), Gehman *et al*. (1980), Rose (1992) and Murtha (1996), among others have addressed the treatment of various cases of geologic dependence. These solutions quickly become unwieldy with only a few traps on several horizons. MMS's appraoch allows for the simultaneous evlaution of three horizons, each with as many as 25 traps. It also permits assumptions concerning independence and dependence as described above, but in its more genral form considers partial dependence among individual traps at a specific horizon as well as multiple horizons in a prospect:

$$P(S_{hc}) = \psi\, \{P(S_{hc})_I - P(S_{hc})_D\} + P(S_{hc})_D$$

Where subscripts I and D refer to the independence and total dependence cases as described above and ψ is a fraction greater than 0 and less than or equal to 1.00. Table 1 shows the calculationof horizon $P(S_{hc})$.

The conditional probabilities for each possible state of nature, assuming independence, dependence, and partial dpendence among the three horizons, are shown in table 2. In practice this calculation is performed first among traps to determine the appropriate estimate of $P(S_{hc})$ at the horizon level and then at the prospect level. The MMS resource economic evlaluation model, MONTCAR, actually uses the absolute values of $P(S_{hc})$ at the trap, horizon, and prospect levels to determine geologic states of nature for each trial. Notice in the table for the partial depdnency case, event C8 all horizons dry, the calculated probabilityis 0.1032, while the independence and dependence cases correctly show a value of 0.000. MMS has developed a solution using surrogates, successive approximations, and convergence algorithms to determine the appropriate probaiblities for each event.

The probability of economic success, $P(S_{hc})$, is determind from MONTCAR's simulation of the assumed geologically successful states of nature and is calculated from the following:

$$P(S_e) = 1 - \{(1 - P(S_{hc}) + P(S_{hc})N_{ne} / N\}$$

Where N_{ne} is the number of noneconomic trials and N the total number of trials. A noneconomic trial is one in which the calculated net present worth at the specified discount rate was not positive.

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Table 1. Horizon Probability of Geologic Success Matrix

Horizon	Hydrocarbon Fill	Reservoir	Trap	Probability Geologic Success
1	0.80	0.60	0.50	0.24
2	0.80	0.50	0.35	0.14
3	0.50	0.50	0.20	0.05

Table 2. Conditional Probability Matrix for Horizons and Combinations [(1)]

Event	Independence[(2)]	Dependence[(3)]	Partial Dependence[(4)]
C1. Horiz. 1 only	0.5173	0.3299	0.3561
C2. Horiz. 2 only	0.2666	0.0000	0.0852
C3. Horiz. 3 only	0.0862	0.0000	0.0199
C4. Horiz. 1&2 only	0.0842	0.4618	0.2940
C5. Horiz. 2&3 only	0.0410	0.000	0.0164
C6. Horiz. 1&3 only	0.0272	0.0868	0.0686
C7. Horiz. 1,2&3	0.0044	0.1215	0.0566
C8. All horiz. dry	0.0000	0.0000	0.1032
	1.0000	1.0000	1.0000

Horizon 1	0.6331	1.0000	0.7753
Horizon 2	0.3963	0.5833	0.4523
Horizon 3	0.1319	0.2083	0.1615

[1] Given propsect is a geologic success

[2] P(Sg) = 1 – (1 – 0.24) (1 – 0.14)(1 – 0.05) = 0.3791

[3] P(Sg) = P(sg)1 = 0.24

[4] P(Sg) = 0.5(0.3791 – 0.24) + (0.24) = 0.3095