Ridges Build Walls

Concept Shakes Mississippi Salt

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A new geologic concept coupled with cutting edge seismic processing techniques has fueled an exploration play in the Central Mississippi Salt Basin that has already yielded several million barrels of oil — and promises to uncover significant reserves in the future.

Over the past 10 years drilling and state-of-the-art 3-D seismic acquisition and processing have proven the validity of the model conceived in 1988 by geologists John J. Morris and Jeffrey S. Requarth.

That model offered a new geologic interpretation for Mississippi Vs deep salt structures.

“From the early 1960s through the early 1970s, when common depth point seismic techniques came into use, operators in the Central Mississippi Salt Basin were able to image low relief salt anticlinal structures,” Morris said. “This touched off activity along the basin margin in the shallower Smackover Formation for structural and stratigraphic traps associated with these low relief salt anticlines, culminating in reserves of about 350 million barrels of oil.”

Following that success, companies moved south into the deeper basin and began exploring deeper, larger, north-south trending linear salt ridges. This round of drilling in the 1970s and early ‘SOS resulted in some discoveries on inter-domal turtle structures at about 18,000 feet, as well as a number of wells on the crest of these large ridges.

“What we ended up with was a grid of wells that did a good job of delineating the crest of the ridges and the intervening areas where the salt has withdrawn,” he said, “but little commercial success,”

Upthrown and Downthrown

By the late l9BOs higher quality 24- to 40-told seismic data were shot in the basin — and for the first time companies were able to begin delineating the flanks of the salt ridges with this high fold 2-D data.

Information gleaned from the new seismic data helped Morris and Requarth develop a new geologic concept of salt walls associated with the salt ridges in the deeper sections of the basin.

“We looked at the significant production found on small salt structures to the north,” Requarth said, “and began to wonder, Why couldn’t the same reservoirs be truncated against much larger salt walls along these ridges?”

The intermediate salt anticlines range in relief from 3,500 to 7,00D feet. Many of the ridges have a dominant normal fault that is parallel or subparallel to the salt crest and divides the ridge into upthrown and downthrown flanks.

On the upthrown side the Smackover Formation has been uplifted by rapid salt movement during the Haynesville deposition and, to a lesser extent, during Cotton Valley deposition. The Smackover on the upthrown flank is truncated updip by the dominant ridge fault or by a subparallel buried fault.

On the downthrown flank, Haynesville depositional loading has forced salt to flow laterally and vertically into the upthrown flank. As a result, the downthrown flank is structurally low due to withdrawal of underlying salt. The dominant normal fault, which transects the ridge, controls the shape of the salt feature.“

On the downthrown flank of some salt ridges, a ‘salt wall’ can develop along the plane of the dominant normal fault,” Requarth said. “Norphlet, Smackover and younger formations are successively truncated against the salt. The thickness of Jurassic strata juxtaposed to salt is dependent on the volume of salt transferred from the downthrown to the upthrown flank.

“A generalized ‘downthrown’ trap model shows the Smackover terminated updip by Louann Salt, with the vertical seal provided by a thick Lower Haynesville section,” he said. “Bed dips in the Smackover should be lower than those found in the ‘upthrown’ trap due to the absence of late salt movement.

“Thick pay columns and large closures may be expected in future ‘downthrown’ fields as a result of excellent lateral and vertical reservoir seals and the lack of late structural movement”

In 1989 the first salt wall field was discovered from high fold seismic in Wayne County. The West Chaparral Field produces from the Smackover and will yield ultimate reserves of about seven million barrels, Morris said.

The Next Dimension

Another important seismic development, however, has been the real impetus in this play.

A major stumbling block in exploring for these “downthrown” Smackover fields is the very high dip of as much as 50 degrees or greater off the flanks of some ridges. These steep dips create very strong lateral velocity contrasts between the salt and the carbonate layers beneath the Haynesville that could not be imaged properly with traditional time migration processing techniques.

“Even a slight increase or decrease in the migration velocities will expand or squeeze the salt wall and ‘move’ it spatially on the seismic data by hundreds of feet,” Requarth said,

Last year, however, CGG acquired the first 3-0 speculative survey over part of the deeper Central Mississippi Salt Basin and is applying depth migration processing techniques, which are yielding significantly higher quality data.
“
These 3-0 seismic data are an exciting development in this play,” Morris said. “We are gaining a better understanding of how the salt ridges grew through time, which greatly affects reservoir and sedimentation patterns of the Smackover, Norphlet and Cotton Valley.

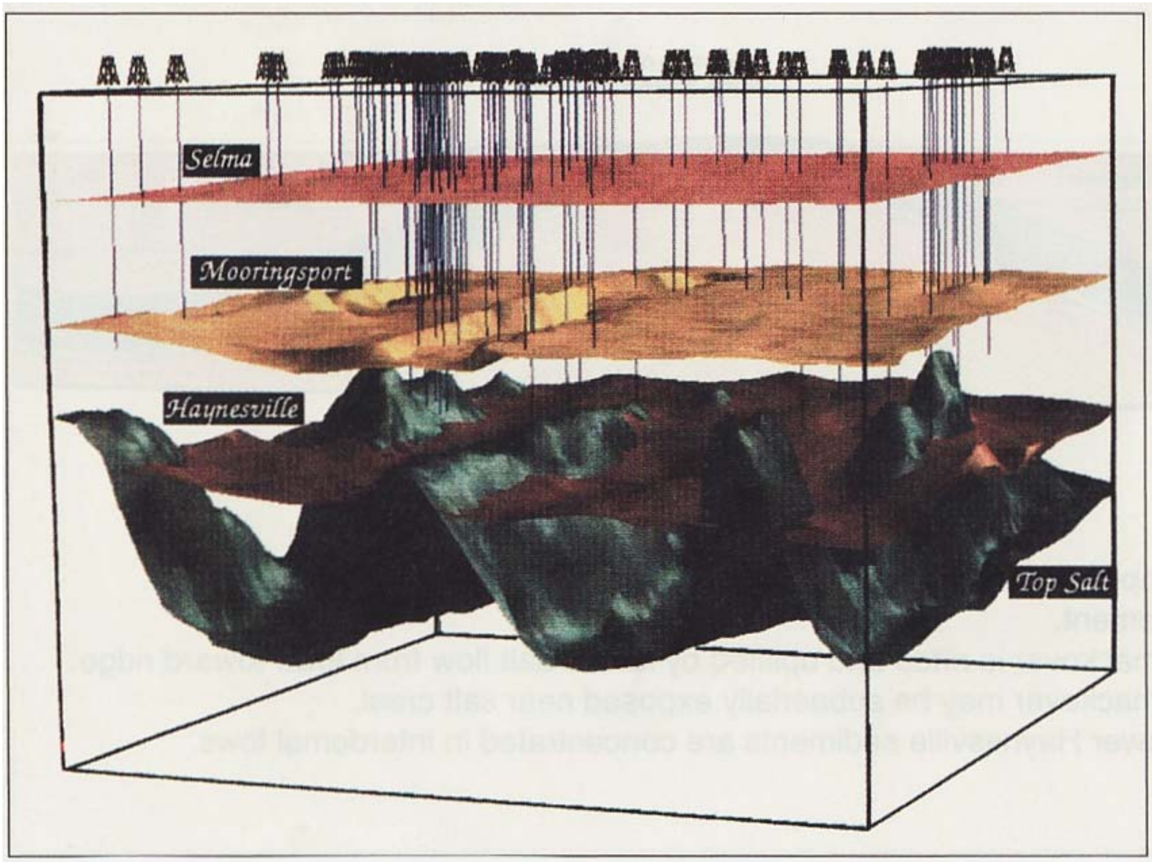
“The major risks in searching for deeper salt wall fields,” he continued, “is defining the seal rock, sedimentation patterns and defining the flanks of the salt ridges. Depth migrated 3-D seismic data speak to each of these risk categories.”

True Lies

David Kessler is manager of depth processing services for CGG Data Processing Services, the division that was assigned the task of applying the newest processing technology to the basin due to the challenges of the high velocity Haynesville formation and the steeply dipping salt bodies in the play.

“In order to correctly image the subsurface at depths of over 15,000 feet, depth processing techniques were needed,” Kessler said.

Historically, be added, seismic data processing has been applied in the time domain — the data are recorded as a function of time, and therefore are typically processed and interpreted in this domain. Time-to- depth conversion is applied by geologists as the final part of interpretation.



Graphics courtesy of CGG

Figure1: A geological model used in depth processing

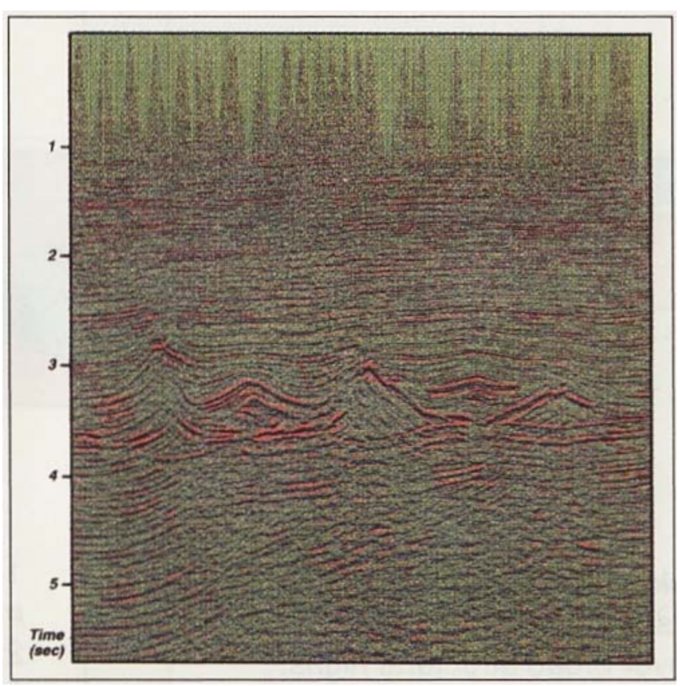


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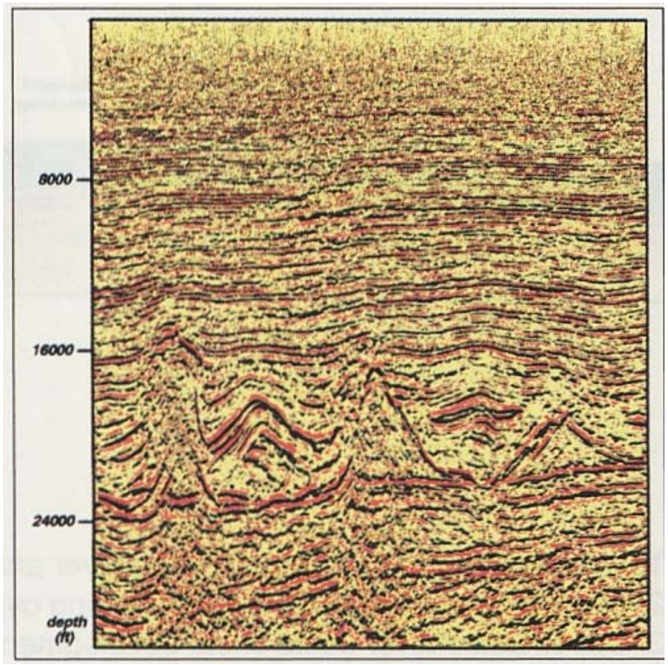
Figure 2: A time migrated section from the 3-D volume of the Waynesboro south survey, the result of classical time processing



Graphics courtesy of CGG

Figure 3: A depth migrated section showing improved imaging quality

“However, with depth processing the depth conversion is done as part of the processing sequence. We still start with time processing aimed at gaining, scaling and cleaning the data, but then switch to depth processing.”

Kessler said the objective of depth processing is to create a seismic volume in depth rather than time that represents the true geology of the subsurface.

Seismic events on the depth seismic volume are positioned in their true locations.

“Time-to-depth conversion is achieved by applying depth migration,” he continued. “Depth migration is a process in which we map seismic reflections from where they are recorded at the surface to the subsurface locations where they were generated.

“To do this job correctly, a geological velocity model needs to be used in the seismic migration process,” he said. “We build a velocity model layer-by-layer, matching the seismic volume to well data in each layer.

“Due to the integration of geologic and well data during the layer-by- layer building process of the velocity model, much of the interpretation work is done along with processing. Once the velocity models are constructed, the only additional interpretation work necessary is adding fault planes or layers not associated with velocity boundaries.”

Kessler said that four formations that are associated with velocity changes were selected for the Waynesboro South survey in Mississippi. Each layer was added to the model and calibrated using well data.

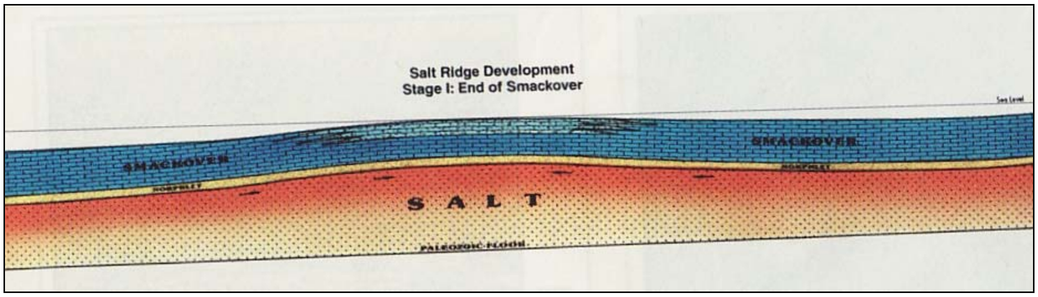


Figure 4: 1. Initial salt movement during Smackover and Norphiet deposition.
2. Slight Smackover and Norphlet thinning over salt crest.
3. Upper Smackover oolite shoal development over broad structural highs.

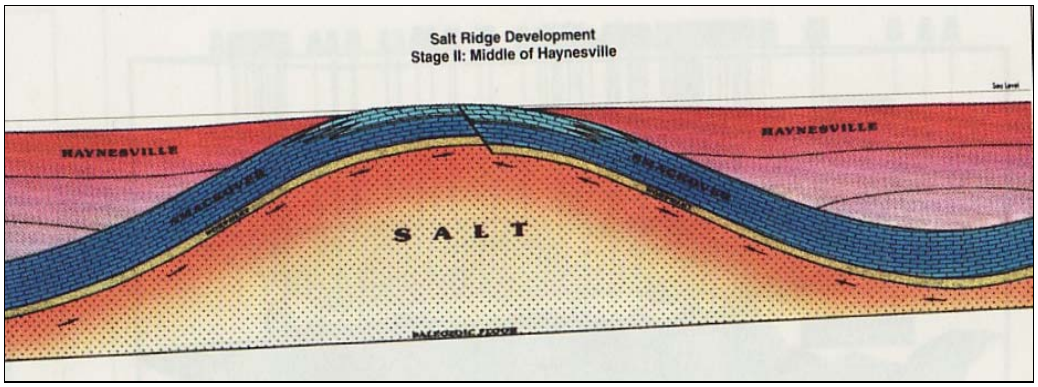


Figure 5: 1. Deposition of high density Haynesville anhydrites accelerates salt movement.
2. Smackover is rifted and uplifted by lateral salt tlow from lows toward ridge.
3. Smackover may be subaerially exposed near salt crest.
4. Lower Haynesville sediments are concentrated in interdomal low

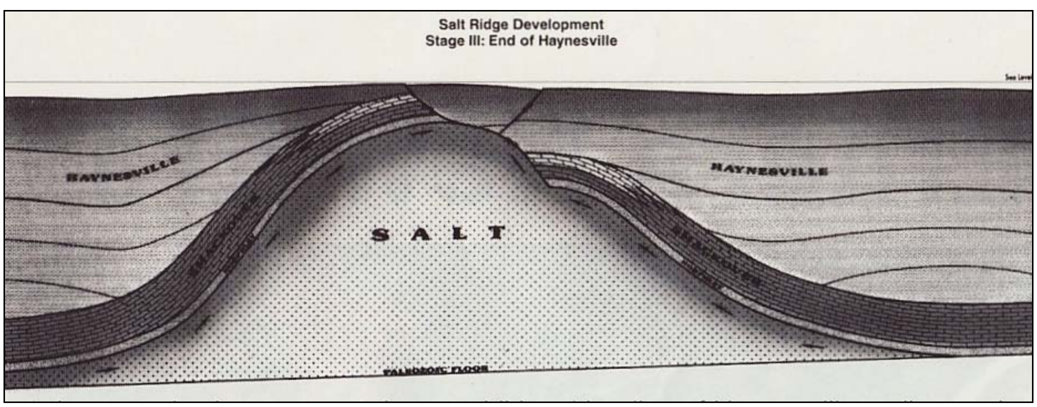


Figure 6: 1. Increased salt movement due to additional loading of Haynesville sediments in interdomal
2. Haynesville turtle structures form as salt is squeezed toward ridge.
3. Central graben develops over salt crest.
4. Upthrown and downthrown hydrocarbon traps are established on each flank of the salt feature.
5. During growth history the ridge crest may migrate laterally. Migration occurs away from downthrown flank due to depositional downbuilding.

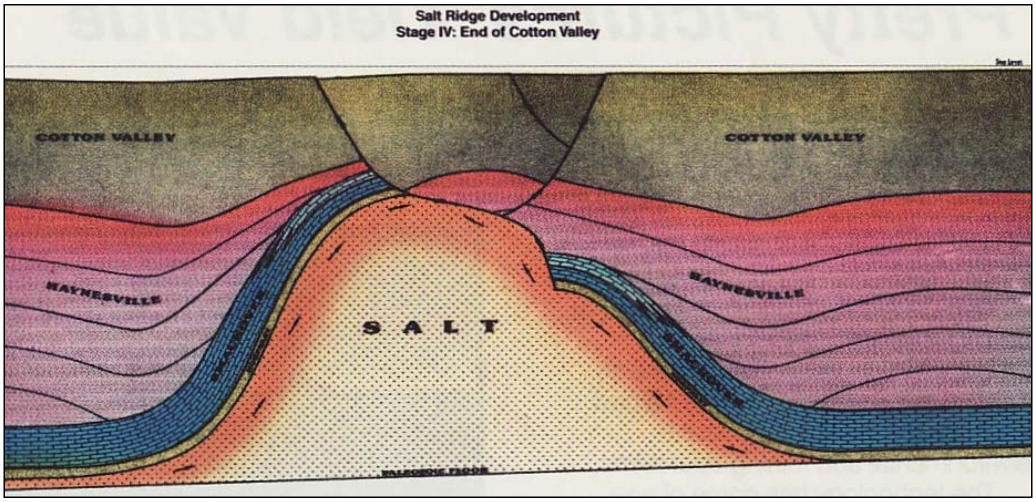


Figure 7: 1. Continued salt movement during Coffon Valley deposition uplifts, defines ridge.
2. Central graben extended and compensating faults may develop.
3. Interdomal turtle structures become well defined.
4. Downthrown Smackover trap sealed vertically by Haynesville, laterally by salt.
5. Upthrown Smackover trap may leak if juxtaposed to Cotton Valley sands.

About 90 wells were drilled in the area, giving us great control when constructing the depth velocity model?" he said, "The resulting depth volume gives the geologists that work the Wayne county (Mississippi) area a 'true' look at the geology of the subsurface.

"In the past, well locations could only be confidently selected for targets that were identified above the salt layers," he said. "Today, with depth processing, well locations can be selected near the salt flanks. enlarging the exploration depths from about 15,000 to 20,000 feet."

Cost Considerations

If depth processing is so superior to the traditional time domain processing, why is it not the universal technique for seismic processing?

Jeff Codd, project manager for the Waynesboro South survey, said the evolution of depth processing has been a function of cost and computer technological advances.

"Depth processing is more expensive and time intensive and requires very powerful computers. It has only been in the last five years that computer technology and the cost of that technology has become widely available to the industry."

For example, he said, 10 years ago supercomputers capable of doing one to two gtlops ("gigaflop"), or one billion floating point operations per second, cost around $20 million. Today $1 million will buy a machine capable of doing nearly 10 gflops, "so depth processing is now coming into its own."

“I think depth processing will be the standard for virtually all 3-D seismic data processing in the near future — particularly in areas like the central Mississippi Salt Basin, where a great deal of aberration in velocity and structure make traditional time domain processing less meaningful.”

Other Activity

CGG originally shot a 200-square- mile 3-D survey in Wayne county, 90 miles northeast of Mobile, Ala., and the data has been delivered to participating companies. Morris said five exploratory tests are planned over the next six months based on the new seismic data by companies such as Anadarko Petroleum, Aviara, PetroCorp. and Jack Phillips, all seeking fields that are 15,000 to 20,000 feet deep with five to 30 million barrels of oil equivalent, he said.
Several “salt wall” fields have been discovered since the initial success at West Chaparral:

*****In 1994 Jack Phillips discovered the Crawford Creek Field, which is currently under development. The field has estimated reserves of eight to 10 million barrels of oil, according to Morris.
***** Last year the Reedy Creek Field Smackover was discovered.
*****In the fourth quarter of 1996 Apache Corp. drilled a deeper pool discovery at the Tiger Field while Amerada Hess and Spooner developed the Stringer Field.

The Tiger Field was first discovered in the early 1970s and produced from the Lower Hosston Formation at about 14,900 feet. Apache drilled down to 15,900 feet and discovered new field pay in the Cotton Valley Formation. The firm plans to drill eight additional wells in the field this year.

CGG is now shooting two additional surveys contiguous to its original acquisition area. Other seismic companies also have proposals to acquire 3-D seismic along the trend. There is plenty of room, according to Morris.

‘We have just scratched the surface,” he said. “This trend extends for about 120 miles west-northwest and the next two years will be a watershed for the play.

‘The new generation 3-0 seismic data produced in depth domain is taking us to the next level of structural definition we need, increasing the chances of uncovering large fields.”