higher energy carbonate facies development. Oil and gas accumulations are found on the crestal portions of this paleohigh in structural/stratigraphic traps.

The synthetic sonic program produces a series of synthetic sonic logs from real seismic traces. It is a powerful addition to the conventional seismic section because it monitors additional parameters of seismic continuity and rock properties in what otherwise is a relatively structureless subsurface carbonate terrain.

Detailed studies of seven regional synthetic sonic lines across the North field area indicate that significant decreases in interval velocities occur in all of the studied carbonate reservoir formations. Three factors affect the interval velocities on both a regional and local basis. These are (1) variation of carbonate facies- higher energy wackestone/packstone and possibly grainstones flanked by predominantly mudstones, (2) secondary porosity developed near the top of unconformity surfaces, and (3) the existence of hydrocarbons in the reservoir.

Many local lateral and vertical variations in interval velocities were noted on the synthetic sonic sections that would have otherwise been undetected, such as areas of tight or porous reservoir development, permeability barriers, and subtle faulting. In these studied formations, there are many examples of low interval velocity zones that are known to contain hydrocarbons whereas equivalent higher interval velocity zones on the seismic sections at other well site locations do not contain hydrocarbons. In many places, these variations are of sufficient magnitude to be mapped as intraformational permeability barriers. These variations were useful in explaining the occurrence of different oil-water and gas-water contacts within the same formation that could not be explained solely on structural criteria.

It can be concluded from this field study of the North field, Qatar, that the synthetic sonic technique is a particularly useful exploration tool in carbonate reservoir environments because it is able to delineate areas of higher exploration potential. The geologist can use these data in areas of known well control to project carbonate reservoir variation in areas where log or petrographic information is not available.

BABALOLA, OLUFEMI O., Univ. Texas, Austin, TX

Analysis of Hydrocarbon Potential of Outer Continental Shelf, Slope, and Rise of the Niger Delta, Nigeria, from Seismic and Geological Data

Whereas hydrocarbon potential studies of most parts of the Nigerian sedimentary regions have been documented, no similar assessment has yet been made for the outer continental shelf (OCS), slope, and rise of the Niger delta. The shelf, slope, and rise of the delta are frontier areas in which no wells have been drilled to date.

For this broad evaluation of hydrocarbon potential of the deep-water Niger delta, six published seismic sections were reviewed in conjunction with available geological information and geophysical data.

On the basis of an assumed average velocity of 2.0 km/sec, the seismic data indicate a sedimentary thickness of about 2 km (1.3 mi) in the deeper portions of the rise. This thickness increases shoreward to more than 3 km (1.9 mi) at the foot of the continental slope and 5 to 7 km (3 to 4.3 mi) beneath the outer continental shelf.

The distal relationship of the OCS, shelf, and rise to the sedimentary discharge of the Niger delta have made these areas of essentially deep-water marine sediments. With the high organic carbon content commonly associated with these areas, the thick shales in this distal deltaic environment would be very rich in kerogen. Coarse-grained clastics are identifiable on the seismic sections by their distinct and continuous reflection character. These potential reservoirs are common and widespread on the shelf and rise. The reservoir rocks occur as deep-sea fans, turbidites, canyon fills, and as onlap fills between diapiric intrusions, and are enclosed by shale, thus providing favorable conditions for the formation of stratigraphic traps. The diapirism in the slope and outer shelf provides favorable conditions for structural traps.

The tectonic origin of the Niger delta area implies a history of initially high geothermal gradients which decreased with time as the margin moved farther away from the Mid-Atlantic Ridge. The geothermal gradient map of the Niger delta indicates higher values for the OCS relative to the onshore and shallow-water areas where rapid sedimentation has depressed the geothermal gradients. The general increase of geothermal gradients toward the mid-ocean ridges would also provide gradients much higher than the 1.8°F/100 ft of the shallow shelf and probably approaching the 3.0°F/100 ft of the Anambra basin region. These gradient ranges are sufficient to mature the kerogen of the oldest shale source rocks (more than 40 m.y.) and to generate hydrocarbons within even the thinnest (2 km, 1.2 mi) sediment observed. In the areas of thin sediment, hydrocarbon potential would be appreciably increased in the vicinity of oceanic fracture zones where geothermal gradients are locally high. The hydrocarbon potential increases shoreward as sedimentary thickness increases and is very significant in the upper rise, the slope, and the OCS.

The decline in giant field discoveries in the Niger delta is a pointer to the depletion of Nigeria's onshore and shallow-water oil reserves. The continuing increase in world oil demand in the face of dwindling reserves and the steady improvement in deep-water drilling technology combine to make future petroleum exploration and production economically promising in Nigeria's high-potential deep-water frontier.

BACKUS, MILO M., FILHO NEPOMUCENO, and JING-ZHONG CAO, Univ. Texas, Austin, TX

Reflection Seismogram in a Solid Layered Earth

Current approaches to seismic data processing and interpretation ignore the change in reflection coefficient with incident angle. The justification is typically based on fluid earth models or models in which the ratio of compressional velocity to shear velocity (C_p/C_s) is assumed constant. In clastic basins, normal incidence reflectivity is low, and variations in C_p/C_s can be significant. Under these conditions the change in reflection coefficient with incident angle can be very significant. Replacement of the plane wave normal incidence synthetic seismogram with the point source solid earth synthetic seismogram is likely to lead to important changes in our approach to acquisition, processing, and interpretation of seismic reflection data.

The accompanying figure shows a sample solid earth synthetic seismogram. In this example, a change from brine to gas produces a dim spot on the near traces, a bright spot on the far traces, and a polarity reversal on the stacked section. The CDP stacked trace should be different from our conventional normal incidence synthetic seismogram.

In general, in a clastic basin, we might expect to see a different set of rocks emplasized on partial stacks from different offset ranges. The sensitivity of our solid earth synthetic seismogram to changes in Poisson's ratio is such that we suggest that conventional reflection data in clastic basins should permit the extraction of band-limited shear impedance logs as well as compressional impedance logs. Attempts to work only with the CDP stacked data should yield a "hybrid impedance log;" a mix-