Carbonate Sequence Stratigraphy–Future Directions for Exploration and Development

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The introduction of the seismic tool and the depositional sequence concepts derived from it have revolutionized the way sedimentary geologists view carbonate stratigraphy. Seismic analysis of carbonate strata has most recently concentrated on the generation of more accurate and robust stratigraphic frameworks, and has provided the means to study large-scale carbonate platform architecture. New insight into carbonate platform evolution has been gained from outcrops by describing subseismic geometric and facies relationships within these larger frameworks. Carbonate platform systems are dynamic and react rapidly to global changes in sea level and local structural subsidence. In addition, sediment supply and type, basin margin relief, and slope declivity all play major roles in controlling sequence architecture. Current and future work in the stratigraphy of carbonate systems is focused on gaining a more complete appreciation of the origin of sequence defining surfaces and their accompanying stratal units.

Many workers have observed that sequences often depart from the original published models. This is mostly because of differences within their lowstand systems tracts. Lowstand systems span a continuum of depositional geometries. Relief and slope-angle constitute spatial variations in accommodation space. These spatial factors are especially important in carbonate sequences where the organic growth potential of platforms can generate a range of depositional slopes from near vertical escarpments to ramps of less than 1°. The thickness and volume of carbonate lowstand systems are dependent on the accommodation potential on the slope, and on the existence of shallow, normal marine environmental conditions conducive to carbonate growth (i.e., a healthy carbonate ‘‘factory’’). Where slopes are steep, the carbonate ‘‘refugia’’ are limited and deposition is diminished. The lowstand is recorded in subaerial features on the shelf, erosion at the platform margin. Deposition occurs in the form of debris wedges at the toe-of-slope and/or small, in-situ carbonate banks perched at or below the platform edge. The isolated platforms of the Pleistocene of the Caribbean and the Miocene of Southeast Asia show this type of sequence geometry. At the other end of the spectrum, low-angle depositional slopes provide an opportunity for larger, more widespread "refugia" and significant carbonate deposition. The Paleozoic and Mesozoic-aged ramps and low-angle banks of the continental interiors (e.g., Devonian of western Canada, Permian of west Texas, Mesozoic of the Arabian platform) provide examples where significant downslope lowstand deposition occurs. Reservoir, source, and seal lithofacies are distributed systematically within sequence architectures. Pore systems within carbonate reservoirs are complex and record both depositional and diagenetic controls. The sequence framework provides a predictive way to map lithofacies that are reservoir prone (e.g., grainstone shoals, reefal rudstones and floatstones, etc.), and to qualitatively delineate the early diagenetic history of a platform (e.g., subaerial exposure at sequence boundaries). Future development of 2-D and 3-D numerical process-response models, physical sediment models, combined with outcrop dimensional data, and forward seismic models will help quantitatively populate geometrically

constrained stratigraphic models, and validate seismic predictions of stratigraphy and lithofacies.

In addition, the sequence framework provides constraints for geologic modeling in exploration and production settings. The introduction of 3-D seismic, seismically-derived attributes (e.g., amplitude, frequency, phase), and visualization technology integrated with rock physics, core, and outcrop lithofacies dimensions provide new opportunities to delineate meter to decimeter-scale stratigraphy. Attribute and seismic facies are mapped as 3-D volumes and give a detailed view of individual stratal bodies.

Efforts to significantly improve seismic imaging of carbonate sequences are critical to any advances in the area of volume and attribute interpretation. Unique aspects of carbonates, including high impedance, lack of bedding in reefal lithofaces, the chaotic character of karsted carbonate terrains, and their intimate association with mobile evaporites in many basins all present challenges to seismic acquisition and processing. In particular, carbonates are, in many places, interbedded with much slower siliciclastics, and the seismic is susceptible to severe multiple problems. Advances in imaging will be followed by advances understanding carbonate platform development.

Future breakthroughs in analysis of carbonate strata will focus on methods to populate geologic and flow-simulation models with integrated well- and seismic-derived rock property data. Volume interpretation techniques using seismic attributes, coherency, impedance, and image attributes will assist in the prediction of pore systems in carbonate reservoirs. Calibration of seismic attributes with reservoir rock properties will provide a more quantitative approach to geologic and flow-simulation modeling. Three-dimensional visualization of seismic will provide constraints for diagenetic and 3-D numerical modeling, and for imaging fracture systems.