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Chronostratigraphy, Sedimentary Facies, and Architecture of Tectono-Stratigraphic Sequences within a Miocene Rift, Gulf of Suez, Egypt

The Miocene synrift stratigraphy of the Suez Rift records the complex interplay between the structural development of the rift and the sedimentary response to tectonics. Along the Sinai margin of the Gulf of Suez (GOS), the Miocene sediments were deposited during the three main phases of rifting: rift initiation, clysmic rifting, and early post-rift. In general, this stratigraphy records the progressive subsidence and drowning of the basin during rift initiation and the clysmic stage, followed by isostatic adjustment and shallowing during the early post-rift stage.

A regional synthesis of the Miocene stratigraphic sections exposed along the Sinai margin of the Gulf of Suez has resulted in a depositional and sequence stratigraphic model for these strata that integrates tectonic history and sedimentary response during the early, clysmic, and post-rift phases of basin evolution. The development of this model was made possible by establishing rigorous chronostratigraphic control based upon micropaleontology and magneto-stratigraphy. Application of this model, along with 3-D seismic, has had a major impact on the ability to recognize stratigraphic and subtle combination traps within this mature basin, resulting in a 75% increase in exploration drilling success (1993–1997) and an increase in production of 164,000 BOPD (IP).

Graphic correlation of paleontological data from wells and outcrops reveals that the Neogene section consists of at least eight biostratigraphic sequences (S10–S80) separated by graphic terraces (T00–T70) or geologic hiatuses (gaps in time). Outcrop analysis of terraces T00 to T30 and their associated fossil assemblages indicates that they represent either regional regressive or transgressive events. The number of depositional sequences (those bounded by regressive erosional surfaces) is therefore less than the number of paleontologically defined sequences. Terraces T00 and T20 are sequence boundaries, and subsurface evidence suggests that T40 is a condensed interval and that T50 is an erosional unconformity (sequence boundary). Field observations of T10 at Wadi Thal in the Sinai indicate that it consists of at least two ravinements and a condensed section within a narrow stratigraphic interval. Similarly, the T30 hiatus associated with the Markha Anhydrite at Wadi Feiran is composed of several stacked flooding and regressive surfaces. These surfaces at both Wadi Thal and Wadi Feiran represent minor time breaks. These small lacunae cannot be individually resolved by graphic correlation, but their sum total within a thin rock (hiatal) interval is detectable as a graphic correlation terrace. Despite limitations in resolution, graphic correlation of paleontological data was crucial for recognizing key surfaces and intervals that allowed us to decipher the sequence stratigraphy of the Miocene synrift section of the Gulf of Suez and to make more precise correlations within the basin.

The key stratal surfaces and intercalated sequences can then be related to the tectonic evolution of the GOS. T00, for example, represents the pre-rift unconformity. The initiation phase of the Suez Rift is recorded by deposition of the Aquitanian Nukhul Formation (S10). Rift initiation was characterized by northerly flowing fluvial systems that occupied the downthrown segments of asymmetric half-grabens. Increased subsidence resulted in a relative sea-level rise that flooded the half-grabens and created

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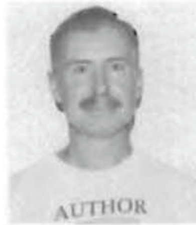
elongate estuaries and, ultimately, shallow marine environments. Nukhul depositional facies include: continental alluvial valley fill, estuarine, tidal flat, tidal channel complexes, and shallow offshore marine. The clysmic phase began with uplift of the rift shoulders and concomitant basin subsidence. This resulted in a period of progressive sediment starvation within the basin (T10) as sediment sources adapted to the new topography. The clysmic stage of rifting is recorded by deposition of relatively deep marine mudstones, basin-floor fan sandstones, and footwall-margin conglomeratic-talus cone and fan delta deposits of the Mheiherrat Formation (S20). Continued extension and crustal thinning resulted in isostatic uplift, shallowing of detachment depths, and increased rotation of fault blocks (T20). The later stages of the clysmic rift were documented in the channelized submarine fan, offshore marine, deltaic, lacustrine, and hypersaline lagoon/sabkha deposits of the Hawara, Asl, and Ayn Musa formations (lower S30). The early post-rift phase is recorded by open marine mudstones and delta front deposits of the Lagia and Ras Budran members of the Ayun Musa Formation (upper S30 and S40).

Within the subsurface of the Gulf of Suez, seismic data are generally poor because of energy attenuation by shallow evaporites, multiple reflections, and complex structure. These conditions make traditional seismic sequence stratigraphy techniques difficult to apply. However, the tectono-sequence stratigraphic model developed from outcrops and the paleontologically-defined chronostratigraphic framework provides tools that allow for better subsurface correlations by systematically mapping stratal geometries using sequence boundaries and flooding surfaces defined by high-resolution biostratigraphic data. The stratigraphic picture that emerges from application of these concepts creates a profound change in quantification of fault throws and recognition of stratigraphic and combination traps. In addition to revealing new plays, application of the tectono-stratigraphic model also results in a better understanding of reservoir geometry and distribution.



Biographical Sketches

William (Bill) Krebs received his B.S. (geology) from UCLA in 1970. He did dissertation research in Antarctica and in 1977 received his Ph.D. (geology) from UC Davis. He joined Amoco Production Co. in Denver in 1978 as a biostratigrapher for west coast and Great Basin exploration. In 1987, Bill was transferred by Amoco to Houston where he worked as a chronostratigrapher and paleontological coordinator for international exploration. He has had project experience in numerous foreign countries, and in recent years has worked extensively in Egypt and Turkey. Bill retired from BP Amoco in 1999 and now consults. He has published 27 articles on paleontology and stratigraphy.

Bill Wescott received his undergraduate degree in geology from Franklin and Marshall College in Lancaster, Pennsylvania. After serving in the U. S. Army, he continued his geological education, earning an M.S. degree from Southern Illinois University at Carbondale and a Ph.D. from Colorado State University. From 1979 until 1984 he worked a series of domestic exploration projects for Amoco Production Company. In 1984 he transferred to Amoco's international new ventures group and spent the next 15 years engaged in a variety of world-wide exploration activities, predominantly in Africa and the Middle East. He is presently a consulting geologist specializing in sedimentology and sequence stratigraphy.

Bill Wescott has authored or co-authored more than 75 papers, abstracts, book chapters, and field guides. His present research interests are the evolution of depositional systems and development of stratigraphic sequences in extensional settings and imaging paleo-depositional systems using 3-D seismic. Bill Wescott can be contacted by e-mail atwwescott@flash.net. □