Charles Lum Drake, known to his many friends as Chuck, died on July 8, 1997 at the age of 72. He is survived by Martha, his wife of 47 years, three daughters and 4 grandchildren.

His professional career began at Lamont-Doherty Geological Observatory of Columbia University where he was one of the founders and finally served as Senior Scientist and Acting Assistant Director. He was chairman of the Department of Geology at Columbia University in 1967-1969. He made major and numerous contributions during the golden years there to the emerging theory of plate tectonics and established a network of colleagues that would be with him for the rest of his life. Many of his early students were instrumental in “solving” the various aspects of plate tectonic theory.

He moved to Dartmouth College in 1969 and had an instant effect on the curriculum. He established himself as an accessible and friendly mentor to students who during his career there numbered over 5000. He was co-founder of the Lake Powell Project to study the newly formed reservoir on the Colorado River. This was a seven-year study of the effects of the impoundment on the Colorado River and on the local biological, political, climatological and social environments. It provided important data to planners on the probable effects of similar dams in the southwest. The research project ended in the late 1970’s, but since then he conducted annual ten-day field trips to the lake for Dartmouth undergraduate Earth Science majors. To do “a little desert oceanography” as he put it. The trips to Utah each year allowed him to remain in contact with his favorite place (after Vermont), the American Southwest and every aspect of it—the geology, its history, and its people. He continued the student trips after retirement, and he was planning one for this fall.

Recently he became actively involved in the controversy over the extinction of the dinosaurs. I suspect that he did so with “tongue in cheek”, because it was fun to “rattle some cages”. Such a whimsical approach was vintage Chuck Drake because his humility and objectivity never let him take himself or our science too seriously. His collaboration with Charles Officer on this subject produced a strong minority hypothesis for a controversy that is still active.
He served unselfishly and tirelessly in a number and variety of leadership positions on national and international science committees and in societies. His advice was much sought after because of his broad background and accomplishments in science; he was a good listener, and his style was one of careful organization, good humor, quiet wisdom, firmness and a gentle touch. One of his friends writes, "in later years, in spite of our geographical separation, I often found myself completing a task and then wondering if I had done so in a manner that would measure up to Chuck's high standards".

Chuck was not only blessed with a fine scientific mind, but the physical toughness that served him well in a profession that was often demanding both mentally and physically. Whether on the tennis court, the high seas or in the deserts of the southwest, he maintained these qualities to the end. He was the kind of friend that you would go over the mountain with or across the river.

Another friend writes "Chuck was an inspiring colleague and a dedicated servant of the earth sciences. But most importantly, he was a dear friend; always willing to listen, always ready to help, always ready to share a good story and a laugh. He will be sorely missed by all of us". It is in a strange way fitting that he died helping a friend, though not surprising, for he did that most of the time.

Robert C. Reynolds
The isolation of the eustatic component of relative sea-level change over significant periods of time is an extremely useful endeavor, because of its potential role in regional and global correlation as recognized by Vail et al. (1977). However, our ability to isolate eustasy in most settings is seriously hindered by the fact that relative sea-level history in any location is multi-variable, comprising the net effects of such components as eustasy, local and regional tectonism, local and global climatic variability and variable sediment supply.

Published eustatic cycle charts commonly call for eustatic fluctuations of more than 40 m every few million years or less. These cycles are interpreted as eustatic, but, so far, waxing and waning of continental glaciation is the only known mechanism which clearly has the ability to drive such large, short-term eustatic fluctuations. High-magnitude (>40 m), high-frequency (<3 my) “glacio-eustatic cyclicality” may be a valid concept for times of continental glaciation, but what about times when such glaciation was absent from Earth? Why do cycle charts have a similar form and style for time periods with and without glaciation? Is it that we have missed the identification of a fundamental driving cause which is as important as glaciation and which might have operated during non-glacial times? Or, is it that there is something in the way we interpret relative sea-level changes from the rock or seismic record that leads to the gross exaggeration of the inferred magnitude of change? Or, is it that we are confusing local and eustatic drivers of relative sea-level change? These persistent questions, and others, continue to cast doubt on the entire subject of sequence correlatability.

The papers in this book collectively address these questions by assessing the tectono-depositional evolution and relative sea-level history of exposed sections of northern South America. Despite its being an active plate boundary zone between the South American and Caribbean Plates today, northern South America was, in Cretaceous times, a passive margin facing the Proto-Caribbean Seaway (Pindell, 1985; 1993; Pindell and Erikson, 1994; Pindell and Tabbutt, 1995) with little known structural deformation in the passive, thermally subsiding (Erikson and Pindell, 1993), autochthonous basins. Furthermore, continental glaciation is generally not recognized for the Cretaceous period, which makes sections of that age ideal for assessing non-glacial relative sea-level behavior in the absence of the glacio-eustatic driver. The Cretaceous northern South America margin, unlike most other passive margins which developed following the breakup of Pangea, is especially suitable because Tertiary tectonism associated with the relative eastward translation of the Caribbean Plate has brought the Cretaceous strata to the surface for direct and detailed field study. Elsewhere, in the western hemisphere at least, exposed Cretaceous passive margin sections basinward of the coastal onlap zone are extremely rare, possibly including only that of northern Cuba.

With this most favorable setting of northern South America in mind, a four year, industry-sponsored, multi-faceted program was undertaken at Dartmouth College with important contributions from other collaborating institutions. The papers herein represent much of this program and question not the basic premises of the original (Vail et al., 1977) and evolving sequence stratigraphic models, but, rather, the extrapolation of only locally determined relative sea-level histories to the global (eustatic) scale, especially when pieced together from different locations to cover all of time, and the common application in poorly known areas of cycle charts as a time scale and dating tool, particularly for non-glacial (e.g., Cretaceous) times. Results from the Colombian and Venezuelan Cretaceous sections suggest a surprisingly stable short-term relative sea-level behavior, in either or both magnitude and frequency, implying correspondingly stable short-term Cretaceous eustatic behavior. If short-term, regionally correlative cycles of relative sea-level change did occur here, then they must have been of far smaller magnitude than is commonly inferred. For a given frequency, smaller amplitudes are achievable by slower rates of change: slower and smaller changes are easily accomplished in most settings by allo- and autoecyclic factors, especially if the various feedback interrelationships of such drivers are considered.

The relative sea-level changes which are apparent in field sections and correlateal across northern South America at the regional scale occurred over time intervals significantly longer than those associated with “short-term cycles”. Because they are regionally correlative and occurred more slowly, at rates explained by known processes, it is our cautious belief that these “regional sequences” (and associated sequence boundaries) stand a realistic chance of being truly eustatic and therefore possibly recognizable at other Cretaceous passive margins.

Implications are significant: this passive setting shows far fewer regionally correlative Cretaceous sequence boundaries than do most “global” cycle charts, with correspondingly fewer sequence boundaries with which to date sections of poorly known age and with which to predict reservoir facies associated with certain systems tracts. It is therefore implied that the degree of local/regional tectonic control is highly significant in syn-tectonic Cretaceous stratigraphies such as the tectonically-loaded foredeep basins of the Cretaceous US Western Interior Seaway, the volcanically active Cretaceous US Gulf Coast, the syn-rift and then syn-compressional Cretaceous of most of continental Europe, all Cretaceous magmatic arc/active margins, the Jurassic-Cretaceous transcurrent margin of South Africa, and other areas of known Cretaceous tectonism which have been used to develop “eustatic” curves.

One of this book’s prime conclusions, therefore, is that the eustatic component of short-term relative sea-level changes during non-glacial times cannot be confidently isolated in most settings. The inability to isolate short-term eustatic changes will preclude genetic correlation of short-term cycles and the use of short-term cycles on cycle charts as time scales or predictors of reservoir horizons in most basins. Furthermore, for non-glacial times, we question the value of the concept of “orders” of cyclicality. For these times, we envision a “history” of eustatic change of variable magnitude and rate, driven by changes in global seafloor spreading, rifting, continental shortening, etc.

So, we start off with a paper by Dewey and Pitman, who show us that short-term cycles of large eustatic change are ex-
tremely unlikely for non-glacial times, suggesting that short-
term cycles of relative sea-level change in a given basin are
likely because of more local events, especially for non-glacial
times. Next, Markwick and Rowley conduct an exhaustive sur-
vey of the evidence for glacioation in the rock record, and con-
clude that episodes of continental glaciation have occurred
since the Oligocene and possibly the Late Eocene, but, prior to
this, not after the Permian. Thus, older Cenozoic and Mesozoic
cycles of relative sea-level change in a given basin are likely
not because of the eustatic effects of continental glaciation.

Attention then focuses on northern South America. Three
papers help build the case for passive margin conditions there
for most of Cretaceous time. Pindell et al. define a palinspastic
reconstruction of northern South America which restores the
effects of Cenozoic tectonism and which outlines in a series of
paleogeographic reconstructions a fairly detailed model for the
Cenozoic tectono-sedimentary evolution of the margin which
accounts for the majority of the margin's known post-rift tec-
tonism. The palinspastic reconstruction provides a paleoge-
ographic framework for assessing Cretaceous stratal develop-
ment in Venezuela, Colombia and Trinidad in subsequent
papers. The evolutionary synthesis for the Cenozoic provides a
framework for understanding the petroleum habitat and systems
in those same countries which embraces the dynamic tectonic
history in detail. Complementing this paper, Algar follows with
a discussion of the evolution of Trinidad which also supports
the concept of passive margin conditions for Cretaceous times,
contrary to most earlier studies in Trinidad which have assumed
Cretaceous deformations for various reasons. Results and sys-
tematics of supporting geochronological fission-track work util-
ized in Algar's study are then presented separately in Algar et
al.

The remaining five papers then address the Cretaceous of
northern South America in some detail, integrating detailed
field analyses and regional stratigraphic development to derive
relative sea-level histories for periods of Cretaceous time. These
studies address two regions which have considerable continu-
ous field section, the Upper Magdalena Valley/Eastern Cordil-
lera of Colombia and the Serranía del Interior Oriental of east-
ern Venezuela. Trinidad and the Mérida Andes are not
addressed at this level of detail: Trinidad's Cretaceous is insuf-
ficiently exposed, and the Cretaceous of the Mérida Andes was
found to be too brittle/internally deformed.

Villamil and Arango critically examine the Cenomanian-Tu-
ronian boundary interval in Colombia, concluding that the
widest condensed section of that age is because of eustatic
rise. Villamil then expands this work and develops an inter-
pretation of the Albian to Santonian relative sea-level history
for much of Colombia. Addressing eastern Venezuela, Erikson
and Pindell develop in two companion papers a methodology in
which independent assessments of four sub-areas within the
Serranía del Interior are compared, in order to identify which
relative sea level changes in each of the four sub-areas might
only be local, and why. The remaining correlatable changes in
all four sub-areas then become candidates for more regional
correlation. Finally, Villamil and Pindell use the palinspastic
reconstruction of Pindell et al. to integrate the bulk of known
information on Cretaceous depositional systems for northern
South America and to create a series of paleogeographic maps
which show changes in Cretaceous depositional patterns as a
function of time. Regionally observed relative sea-level
changes and sequences that appear to be correlatable across the
northern South American "passive margin" are considered as
candidates for inclusion in an as-yet conceived Cretaceous (i.e.,
non-glacially controlled) "global" cycle chart in which the ef-
fects of local tectonism and other processes are minimized. The
style of the inferred eustatic behavior for this time interval (i.e.,
lacking large magnitude, short-term cycles) is suggested to typ-
ify eustatic behavior for non-glacial times in general. This in-
ference seriously reduces our confidence in the use of short-
term cycles on many cycle charts as a basis for dating sequences
in unknown areas.

Beyond the above stated authors, it is a great pleasure to
thank the following who have not otherwise contributed di-
rectly to the papers in this book, but whose encouragement,
ideas, assistance and various contributions are gratefully
acknowledged and appreciated. In so doing, I will take this op-
portunity to set many of these acknowledgements in an his-
torical perspective on our collective studies thusfar in northern
South America. First of all, in 1983 Dr. Steven Cande and Dr.
Walter Pitman, at Lamont-Doherty Geological Observatory,
taught and helped me to unravel circum-Caribbean plate kine-
matics to the point where it was clear that Cretaceous arc-con-
tinent collision in northern South America could not have hap-
pened; hence, our first serious suspicions of, and kinematic
constraints upon, the concept of the "Cretaceous passive mar-
gin" of northern South America, for the entire Cretaceous pe-
riod (pre-Late Maastrichtian). In addition, this work, combined
with early subsidence analyses along the margin, produced the
associated development of the hypothesis of an eastwardly
migrating oblique collision between the Caribbean Plate and
northern South American (previously passive) margin, which
spanned the Tertiary and diachronously drove the creation of
eastwardly-younging, foredeep basin clastic sections ahead of
the point of collision, in which the region's best reservoirs occur
and in which thermal maturation of the Cretaceous source rock
section occurred shortly after deposition of the reservoirs. Much
of the existing literature was contrary to this model; specifically,
the model predicted that (1) rifting from Yucatán was of Middle
Jurassic age and the exposed Cretaceous section was deposited
well into the history of mainly thermal subsidence, despite the
fact that the Jurassic is rarely seen; (2) strata deposited upon
the true South American autochthon were not involved in Cre-
taceous plate-boundary type deformations, and (3) Late Creta-
ceous ages derived from certain flysch units indicative of orogen-
y such as the Gárrapata and Paracotos Formations in central
Venezuela must be due to reworking, and that the true deposi-
tional age, as well as the actual allochthon-autochthon collision
in central Venezuela, was Paleogene. These realizations and
suspensions had tremendous implications for oil exploration in
northern South America: (1) that the Cretaceous source rocks
such as La Luna and Querecual Formations were deposited re-
gionally in a blanket fashion across a north-facing passive mar-
gin without an outer high 2 that one of the best source rock
fields such as La Luna and Querecual Formations were deposited
in central Venezuela was Paleogene; (3) Late Creta-
ceous ages derived from certain flysch units indicative of orogen-
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suspensions had tremendous implications for oil exploration in
northern South America: (1) that the Cretaceous source rocks
such as La Luna and Querecual Formations were deposited re-
gionally in a blanket fashion across a north-facing passive mar-
gin without an outer high 2 that one of the best source rock
sections in the world was omnipresent across the margin and
entirely immature at the onset of Cenozoic tectonism; and (3)
that the source rock section was wholly viable for charging the
Cenozoic reservoirs, which were deposited in the eastwardly
younging Tertiary foredeep sections produced by the diachron-
ous migration of the leading edge of the Caribbean Plate along northern South America. Hence, the continued refinement of Cenozoic Caribbean evolution would determine the important models for petroleum exploration in all of northern South America.

In 1987, Dr. Krishna Persad first invited me to come and work in Trinidad, with some late evening help from the attributes contained within a bottle of Royal Oak® rum, which Krishna claimed was the best rum in the Caribbean. I could not contest this, and on my first visit to Trinidad, Mr. Philip Farfan of Amoco (Trinidad) showed me some alligators and then took me swimming in “Shark River” in the Northern Range, where he then advised me to watch out for three or four kinds of very poisonous snakes. But he also showed me some flat-lying Maasticthian beds in the Northern Range, which had been interpreted in the literature as a little-disturbed overlap assemblage upon metamorphic rocks whose protolith was a series of Jurassic and Lower Cretaceous strata. At that time, the variably metamorphosed rocks were believed to represent the effects of Late Cretaceous arc-continent collision in northern South America. But Mr. Farfan had a mission that he knew I would not ignore: although flat-lying, the Maasticthian beds were completely overturned, thus providing an important clue that not ignore although flat lying the Maastrichtian beds were Late Cretaceous arc continent collision in northern South America. Hence the continued refinement of of Cretaceous non-glacial sequence stratigraphic development in the Cretaceous early Paleogene Serranfa del Interior soon began his thesis studies on stratal architecture and development in the Cretaceous-early Paleogene Serranfa del Interior Oriental, also from Dartmouth College. In addition, Tomas Villamil and Claudia Arango, then working toward postgraduate degrees at the University of Colorado at Boulder on Cretaceous sections in Venezuela in terms of direct observation of Cretaceous (non-glacial) sequence stratigraphic development. Armed with the potential significance of this area of research, as described above, I followed Gordon Young’s very wise advice and eventually contacted Dr. Hans Krause, then Manager of Intevip, who, in conjunction with Drs. Nelly and Alirio Bellizzia at the Venezuelan Ministry of Energy and Mines, made our work in Venezuela possible. Johan Erikson soon began his thesis studies on stratal architecture and development in the Cretaceous-early Paleogene Serranfa del Interior Oriental, also from Dartmouth College. In addition, Tomas Villamil and Claudia Arango, then working toward post-graduate degrees at the University of Colorado at Boulder on Cretaceous sections of Colombia, eventually joined our team to help bring in Cretaceous sequence stratigraphic assessments of western Venezuela and Colombia for the important tasks of regional synthesis and correlation with Eastern Venezuela. To Drs. Young, Krause, and Nelly and Alirio Bellizzia in particular, but to many other colleagues throughout PDVSA and the Ministry as well, Johan, Tomas, Claudia, and I remain extremely grateful.

Eventually, our interest in Venezuela progressed to a number of outstanding problems of the Tertiary, in order to refine models of Caribbean evolution and basin development along the margin. Dr. Roger Higgs joined our research team as a sedimentologist in 1994—1995. Roger worked with us throughout Venezuela, but focused in most detail on western Venezuela where we benefited from the kind and much appreciated assistance of Dr. Oscar Odreman, Manager of the Mérida office of the Ministry of Energy and Mines. We also had the pleasure to work at this stage to some extent with Dr. Oliver Macsotay, who, despite my own repeated failures to collect samples containing any Paleogene fauna in the matrix, deserves enormous credit for [independently] coming up with the true, Paleogene depositional ages of the Garrapata, Paracotos, and other flyschoid formations.

For making this program possible, I would like to acknowledge and thank the following industrial sponsors for their support through Dartmouth College: AGIP, Amoco, Arco, BHP Minerals, BHP Petroleum, BP, British Gas, Canadian Occidental, Chevron, Conoco, Elf, Exxon, Home Oil, JNOC, Lasmo, LLE, Marathon, Maxus, Mobil, Nippon, Norcen, Norsk-Hydro, Occidental, Phillips, Talisman, Texaco, Total, Triton, Union Texas, and Unocal.

Moving now to the nuts and bolts of this book, it is with great pleasure that I thank Dr. Dana Ulmer-Scholle for her dedicated efforts at the critical and essential editorial level, and for putting up with the time-consuming fact that few of the authors in this book have stayed put in one place for long enough to bother recording their addresses. We also are thankful to SEPM for their patience and for not losing faith that, some day, the last few papers would arrive.

In addition, I would like to acknowledge numerous individuals of the academic Caribbean ranks for their various roles in the ongoing refinement to models of Caribbean tectonic evolution, with whom I have enjoyed many years of association, and from whom I have learned much. In particular, Sam Algar, Claudia Arango, Stephen Barrett, Alirio and Nelly Bellizzia, Richard Buffler, Kevin Burke, Steve Canid, Jim Case, Cal Cooper, John Dewey, Jim Dolan, Nick Donnelly, Gren Draper, Neal Driscoll, Terry Edgar, Johan Erikson, Francea Galea, Mark Gordon, Stuart Hall, Roger Higgs, Rob van der Hilst, Keith James, Claudia Johnson, Jim Joyce, Garry Karner, Erle Kauffman, Kim Klitgord, John Ladd, Dave Larue, Hans Ávila Lamant, Paul Mann, Florentin Maussasse, Bill McCann, Fred Nagle, Oscar Odreman, Walter Pitman, Ted Robinson, Eric Rosencrentz, David Rowley, John Saunders, Alan Smith, Art Snook, Bob Speed, Lynn Sykes, Ken Tabbutt, Tomas Villamil, and Graham Westbrook have impacted in many different ways whatever contributions I myself may have made, and I thank them all, this proud core of “Caribbean Geologists”.

But my deepest regards go to the late co-editor of this book, Professor Charles L. Drake, to whom I personally shall forever be indebted. Chuck was without question, during his years at Columbia University and then Dartmouth College, one of the few primary driving forces of the most exciting and progressive years of geoscience will probably ever know. Chuck made this program possible, helped to guide its students, and forced us to continuously assess our perspective on what we were doing. He was a model for all of us; we thank him, and we miss him.

James L. Pindell, September, 1997
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