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Front Cover: Close-up view of a patch-reef coral head in Grahams Harbor, north of Dump Reef. As shown here, Caribbean shallow-water reefs have declined since the mid-1980s and are now largely overgrown by fleshy green macroalgae and a variety of encrusting organisms. See Curran et al., "Shallow-water reefs in transition," this volume, p. 13. Photograph by Ron Lewis.

Back Cover: Dr. A. Conrad Neumann, University of North Carolina, Chapel Hill, NC, Keynote Speaker for the 11th Symposium and author of "Cement loading: A carbonate retrospective," this volume, p. xii. Photograph by Mark Boardman.

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CEMENT LOADING: A CARBONATE RETROSPECTIVE

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ABSTRACT

I gratefully acknowledge the opportunity in this keynote address to present, in retrospect, some areas of research and observation on a theme that involves the addition of material to an open carbonate sediment on its way to becoming a dense limestone, hence "cement loading." It appears that this can be seen to express itself in a sequence of effects from light to moderate to extreme. For instance, off the Bahamas, we see the effect of incipient cement altering the acoustic velocity within the peri-platform sediment in a finely laminated, seismic sequence associated with sea-level change. On the way to hardground formation, the effects of firmground, brecciation, and nodule formation can be seen. Under certain conditions of flow, lithified build-ups on the hardgrounds can grow into layered mounds called "lithoherms." Ultimately, large sections of carbonate bank margins can break off and fall into deep water as a result of the localized overweighting there due primarily to increased cement content. These internal cements, especially the deeper subphotic ones, when examined petrographically, reveal a sequence from loose micrite (paste) to clotted structure to peloid formation to micro- and then macro-crystalline overgrowths. These cements need an external source of ions and this is provided by diffusion and/or advection of seawater. Advection is enhanced by pressure gradients set up by bottom-water flow over the mounds. This process could explain the coarse bedding seen in the mounds as due more to a diagenetic effect than to a sedimentological episode. Lastly, the recent work Neuweiller suggests than the cement mechanism may be related to the humic fraction remaining in the pore waters. Humates within the micritic cements suggest an intimate association of organic and inorganic reactions.

So, here in a collage assembling bits of recent research with a lifetime of observations, on and underwater, is a keynote kernel of an idea that may hopefully expand our understanding of limestone origin and inspire (or goad!) others to extend the inquiry. Thanks for the opportunity to share these ideas.

INTRODUCTION

It is with pleasure and gratitude that I acknowledge the opportunity to deliver this keynote address, and in keeping with the address, this essay is blatantly retrospective and in no way meant to be a scholarly review. It is rather the exploration of an idea that has been on and off my mind for some time and emerged as a theme while cleaning out the cupboard of a forty-year career in carbonate research. Various observations and investigations seemed to organize themselves around this "cement loading" story.

In the carbonate peri-platform settings that we have studied in the Bahamas, early cementation appears to work in a way that is gradual and sequential. From a barely perceptible stiffening (incipient lithification), it proceeds to distinct induration (lithification). This progression is observed as a series of steps, each with recognizable associated features. It begins with the effect of incipient cement appearing as changes in the acoustic velocity of alternating beds and proceeds to the formation of intra-formational conglomerates and then sometimes to nodule development. It continues with the extensive sheet-like cementation of firmgrounds to hardgrounds. Under the influence of bottom currents, lithified build-ups, or lithoherms, nucleate on the hardgrounds and grow upward by overlapping cemented crusts into mounded structures tens of meters high and hundreds of meters long. The end process of this selective lithification, and thus selective "overweighting," occurs along the shallow shoulders of carbonate margins where gravity-driven collapse results in mega-breccia shedding (Figure 1).

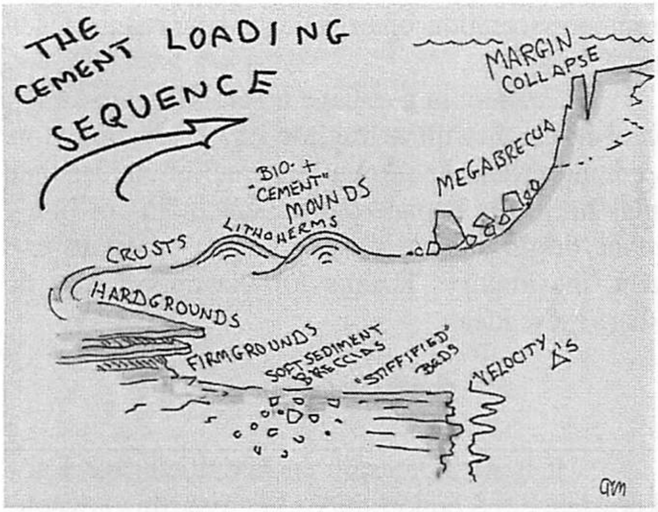

Figure 1. Cartoon of progressive effects of cement loading in carbonate peri-platform settings. Drawn by C. Neumann

In each case, these progressive effects seem to be due to the increase of the mass of the deposit from the inside out due to the addition of cements precipitated within the body of the sediment or rock. The sediment thus "grows" into a rock, producing a spectrum of external effects due to this internal increase of mass. What begins quietly and steadily in inter- and intra-grain voids ends up as intermittent depositional events of potentially catastrophic consequence.

The complete story of "cement loading" can best be told in terms of the phases of our research and the different ways of looking at the process and its results. Part I is the sequence of observed external effects that appear to be due to the incremental accumulation of internal mineral material as outlined above. Part II is the sequence as seen in the petrography of the cements themselves: it is the "internal" view. Part III is a story of flow. If internal cements are to grow beyond the limits of simple diffusion, ion-bearing fluid must actively move through the sediment in order to supply the accumulating cement. Finally, Part IV is the chemical mechanism of the cementation process.

PART I: OBSERVED EXTERNAL EFFECTS OF CEMENT LOADING

Seismic Cycles

Our first inclination that something akin to cement loading was afoot in the carbonate sediments on the flanks and at the base of the Bahaman platform came from an investigation of the fine, parallel reflectors seen in the high resolution surface seismic sections there. Earlier a horizontal seismic facies transition was sampled and related to the down-slope sedimentary facies transition from sand to nodular carbonates to fine laminated mud (Mullins et al., 1979). This was followed by isotopic studies on cores, which related the observed depositional cycles to the latest glacial episodes (Boardman et al., 1986). The draped tops of interfluves along the gullied northeastern flank of Northwest Providence Channel (NWPC) were then cored and incipient cements were actually observed in a reflecting layer (Burns and Neumann, 1987). The laminated fine mud and muddy sands of the cyclic peri-platform pelagic ooze were further studied in greater detail from a 17-meter-long piston core taken on the sediment-draped top of a turbidite-free, inter-canyon high in the western end of NWPC (Slowey et al., 1989). It was here that the role of incipient cements in producing rhythmic seismic reflections was most apparent. Seismic velocities were measured at 7 cm intervals throughout the length of the core and correlated with observed reflectors (Figure 2). It was further shown that the high-velocity intervals were correlated with beds of low aragonite, high calcite content, low water content, heavy oxygen isotopes and increased "stiffness." The latter was determined qualitatively by feeling with a probe and by microscopic examination for aggregate grains.

Slowey et al. (1989) concluded that the high-velocity layers were deposited during glacial episodes of lowered sea level because of the isotope data and the lack of bank-derived aragonite fines (from calcareous algae) and correlative

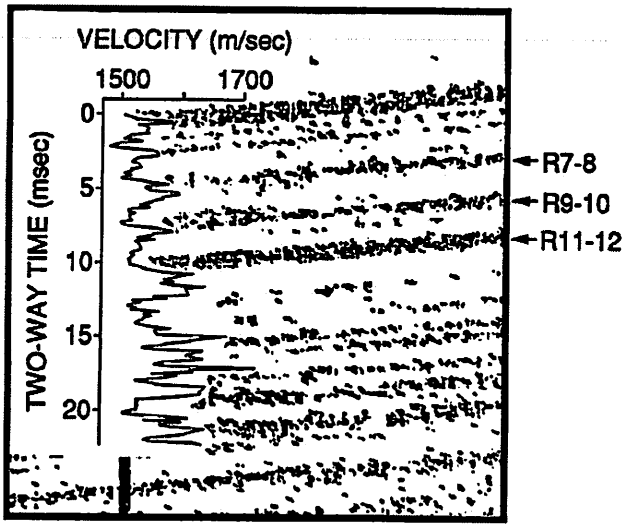

Figure 2. Velocity maxima match reflectors in NWPC. Acoustic velocities measured over 7 cm intervals down-core show peaks that correlate with reflecting horizons, heavy isotope intervals, calcitic bands, and incipiently cemented intervals. From Slowey, et al. (1989).

higher calcite content from pelagic foraminifera. Over the objection of others, we stuck to our conclusion that, at these depths of a kilometer or so, the observed cycles were due primarily to fluctuating sea level, and thus changes in bank-top supply rather than selective dissolution effects of glacial bottom waters.

It was further concluded that it was the incipient cement and resultant density increase that produced the higher seismic velocities. For each volume of cement produced, an equal volume of pore water must be expelled. The result of this earliest cementation is to thus "de-water" the sediment and change its physical and consequently its seismic properties. These intervals are more dense, more "dry" and more cohesive, or "stiff." The incipient cementation thus results in a "stiffification" that occurs well before final lithification. Later, this rhythmic variation in incipient cement was to be actually observed in outcrop during Alvin dives in NWPC where steeper scarps of more lithified beds alternated with terraces of less cohesive sediment (Slowey et al., 1999). See Figure 3.

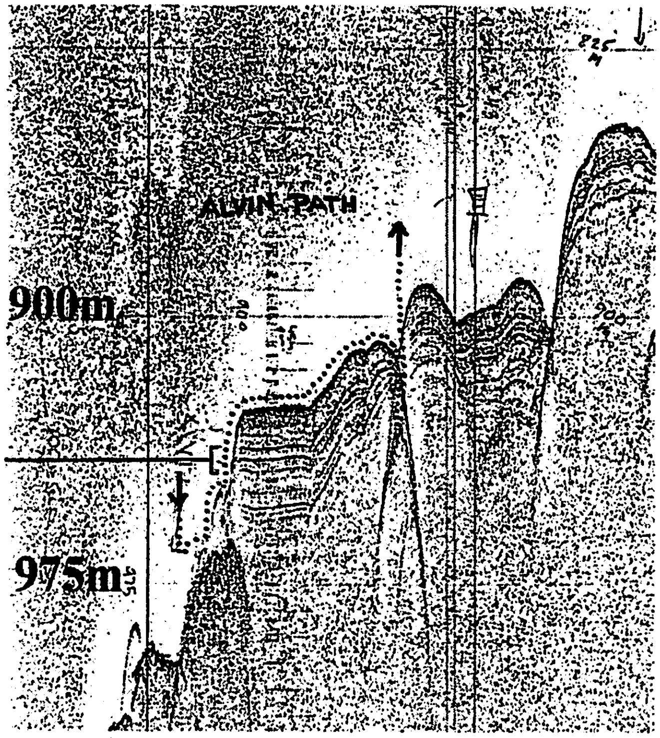

Figure 3. The path of Alvin dive 1276 in Northwest Providence Channel, Bahamas, overlain on 3.5 kHz section of dive traverse. Reflecting horizons correlate to low cliffs of firmer (slightly cemented) material, whereas inter-areas form short, low terraces of less consolidated material. (Slowey, et al., 1998).

Intra-formational Conglomerates and Nodules

The occurrence of intervals of relatively fluid sediment alternating with zones of relatively cohesive beds lays the groundwork for the formation of intra-formational conglomerates. A disturbance such as slumping would mix these two intervals of different cohesiveness, with the more cohesive lithology appearing as clasts within the less cohesive matrix of the other sediment. This is what we believe to be the case in the sediment observed on a slope dive in ALVIN (Figure 4). Elsewhere, what appeared to be a nodular sediment surface was found to be the continuous, cemented top of an extensive nodular hardground. Thus, there appears to be a gradation of effects of cement incorporation from slightly stiffened sediment, to intervals of intra-formational breccia-tion, to nodules, to nodular hardgrounds, and to planar non-nodular hardgrounds.

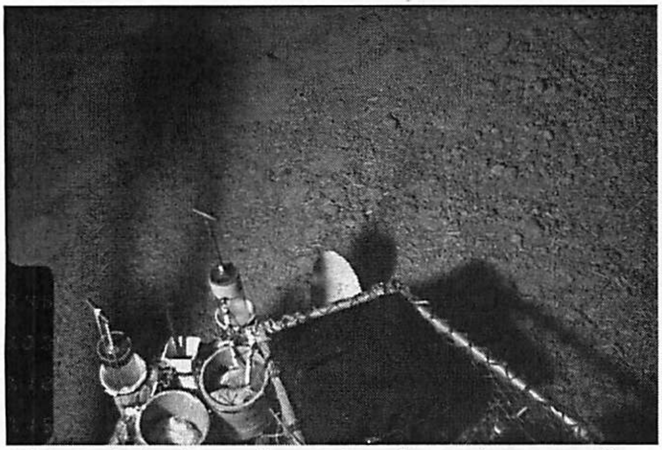

Figure 4. An intra-formational conglomerate from ALVIN dive 848 on the flanks of Northwest Providence Channel at 658 m deph. The solid looking fragments are only slightly firmer than the surrounding sediment. The deposit is being covered with underlying sediment brought up by the action of burrowers.

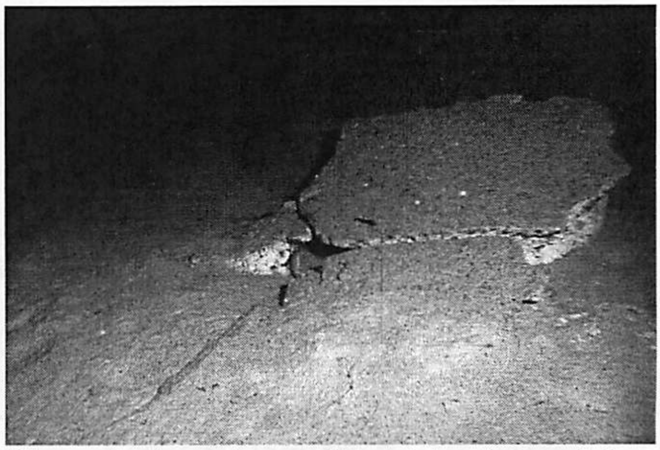

Figure 5. A semi-consolidated hardground fragmented by gravity slumping in Agassiz canyon, southwestern Florida margin, at a few hundred meters depth. The block is about one meter across. Photo provided by G. Keller and J. Kofoed from 1972 ALUMINAUT dive.

Firmgrounds and Hardgrounds

A rare glimpse of an incipient hardground that was apparently exposed by down-slope disturbance was seen on an early ALUMINAUT dive on a canyon floor off the southwest tip of Florida (Figure 5). Carbonate hardgrounds are diverse in character and are commonly observed in all of the deep circum-platform and basin settings we have studied (Neumann and Ball, 1970; Neumann et al., 1977; Mullins et al., 1980; Slowey et al., 1999). Just how these common features form is not completely understood, despite an extensive literature. They can form at critical chemical zones within the sediment as a result of oxygen utilization or methane production. Diffusion from seawater above may also play a role, as would advection of pore waters due to flow over irregularities at the surface. At any rate, the firmgrounds/hardgrounds appear to form below a few cm of sediment and come into view when regional erosion strips off this sediment cover.

Lithoherms and Mud-mounds

A fortunate moment of my career came when I was invited by colleagues at the NOAA laboratory in Miami to take part in a dive series in the northeastern Straits of Florida in the 1970s. It was on these dives, at depths near 500 to 800 meters, under the northerly flowing Gulf Stream that we first observed the dense field of elongate, lithified build-ups of concentric, carbonate crusts that we later dubbed "lithoherms" (Neumann et al., 1977). These rocky mounds, a few building, others eroding, are populated by attached organisms. A thicket of branching hard corals grows at the up-current end. A stand of large sea fans occupies the center, and rows of crinoids cling to the eroded down-current terminus (Messing et al., 1990). More recently, we have visited similar mounds on the Florida-Hatteras Slope at similar depths via the Navy's nuclear submersible, "NR-1." However, at this locality on the western end of the Blake Plateau, the bottom currents are not as strong or as regular, and the ecological zonation is not as distinct. Clusters of branching coral, living and dead, are the main faunal element observed. However, the same internal structure of layered crusts is apparent in places where erosion affords a look inside the mounds (Paull et al., 2000). Most recently, a side-scan survey of the mounds of the northeastern Straits has been conducted on the NR-1 that reveals an extensive field, several miles long, with closely spaced ridges and mounds oriented north-south parallel to current flow (Slowley and Brookshire, pers.comm; Figure 6)

In the sequence of increasingly dominant cementation effects, the question is just how do

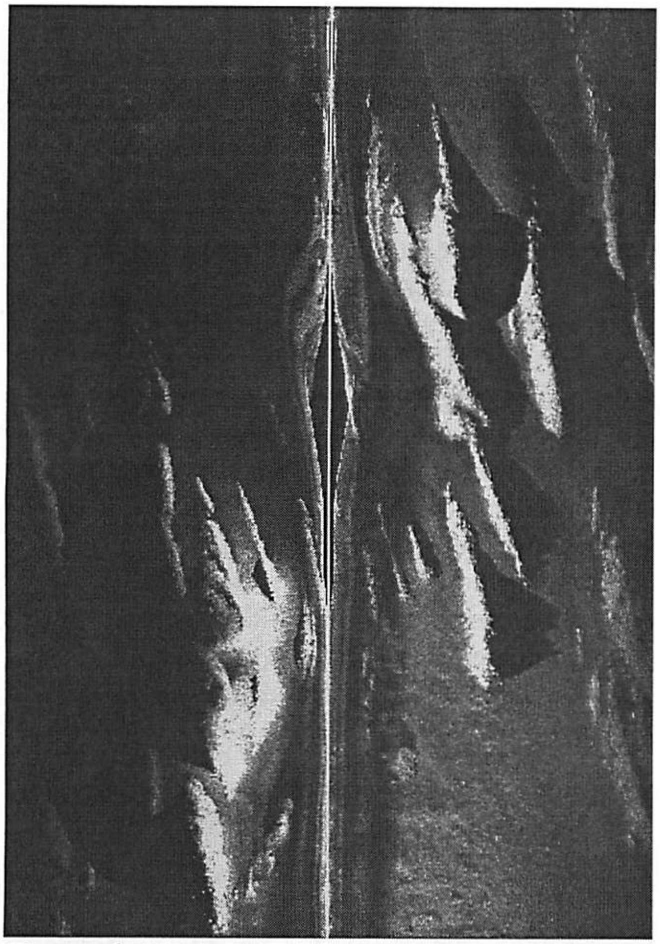

Figure 6. NR-1 Detail from side-scan survey of lithoherms in the northeastern Straits of Florida. The mounds are tens of meters high and hundreds of meters long. They are oriented north-south with the current flow: North to top. (Image courtesy of N. Slowey and B. Brookshire)

horizontal hardground crusts build up as concentric shells into structures over 30 meters in relief like a stack of inverted elongate bowls (Figure 7). Not having been able to drill into one of these mounds or dissect one in detail, we can only conjecture on the exact origin. They appear to nucleate and grow upward as well as outward into the current by the trapping and baffling action of the coral thickets. These grow on the up-current front and extend the mound by sediment accretion and thicket growth. We say this because fossil coral is found imbedded in all crusts sampled everywhere on the mound even though the living coral colonies grow only at the up-current nose. Observations from submersibles indicate that the mounds grow at the up-current nose and erode at the

Figure 7. ALVIN view of an outcropping of overlying crusts (~30 cm thick) on the side of a lithoherm. Dive 365. Depth is 620 meters. Northeastern Straits of Florida near Memory Rock.

down-current end. Just down-current of the growing nose, on the top of the mound, a rocky surface is exposed. Here the current is the strongest (three knots and more) and the sea fan community holds on by holdfasts on the rock surface. The down-current (north) end of the lithoherm is an irregular rocky erosion surface with crinoids clinging to the lithified surface by means of the cirri that extend from the stalk. Most of the lithoherms in the northwest Straits appear to be in various stages of erosion (Messing et al., 1990). The main process appears to be bioerosion, largely by clionid sponges.

"Paleo-lithoherms?"

Are lithoherms confined to the Recent? It appears not. Today's lithoherms may provide clues to the ubiquitous "mud-mounds" of the geologic past. Mud-mounds are found throughout the geologic column since the late Precambrian (Figure 8), whereas reefs come and go in geologic time depending on the evolutionary occurrence of reef-building communities. This supports the contention that mud-mounds, like lithoherms, are due mainly to some non-biological process such as submarine cementation.

The asymmetrical mounded shape of mud-mounds and their general dimensions also agree with those of lithoherms. Like lithoherms, mud-mounds commonly reveal fine-grained cement

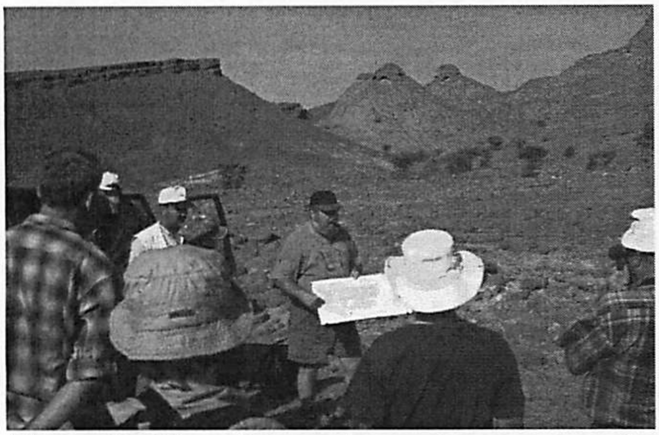

Figure 8. Devonian mud-mounds seen near Erfoud, Morocco. Field trip leader Pierre-Andre Borque with map. Mud-mounds are similar in many respects to modern lithoherms.

and often show no evidence of shallow-water fauna (Neuweiler et al., 2000). They are built up of the same irregular, coarsely bedded crusts that are seen in the lithoherms. It appears that, in the Recent, as in the geologic past, the common co-occurrence of bottom currents, carbonate sediments, and cementation work together to form build-ups that contain biological material but are basically chemical in their structural development, i.e., they consist of overlapping sub-sea cemented crusts. The 5-10 cm crusts accrete by organism attachment, baffling, sediment accumulation, more cementation, and so on. Formation of the cement requires the interaction with diffusing ions and/or advecting seawater. The crusts are more cemented on the top and progressively less cemented below. The cementation and sediment accretion is in some way episodic, as is obvious from the stacked crusts revealed in outcrop. It is not apparent what controls these episodes. In the absence of dates and isotopes on sampled crust sequences, the inclination is to assign the lithoherm cyclicity to glacial/interglacial events. Formation and erosion of these modern mounds seems to co-occur, and their ultimate fate in preservation is a question. The mud-mounds of the past appear to have formed in somewhat lower energy environments and are often floored and/or capped by black shales. The process of early seafloor cementation below the photic zone seems to be the main factor linking these look-alike mounds of the present and the past.

Margin Collapse

The leap from lithoherms to shallow carbonate margin collapse may appear abrupt, but it follows from submersible observations along upslope traverses in the northwestern Bahamas. On one traverse, the lithoherms abruptly disappeared at about 635 meters. However, at a depth of 402 meters we encountered the severely eroded concave remains of a few lithoherm noses of "band-shell" shape (Figure 9). We have no idea why they are there. The bioerosion seems to be concentrated on the embayed down-current (concave) end, and cementation seems to be densest on the south-facing, up-current, convex end. It would appear that there is a driving force into the rock due to the pressure of the on-coming current that tends to cement the surface exposed to it. Turbulence on the rear side of the feature seems to favor bioerosion.

Figure 9. Eroded fragment of a lithoherm at 402 m on Northwestern slope of Little Bahama Bank. ALVIN Dive 764.

This same "drive" of wave and current impinging upon the larger scale, shallower bank margin has been inferred to be the cause of the concentration of cement there. It is the final stage in the cement loading sequence. The exposed shoulder of the bank or margin becomes heavier by virtue of the cement concentrating there. The material in the lagoon behind and deeper on the slope below does not appear to be as well cemented. Thus, the shoulder becomes relatively over-weighted by cement and potentially unstable. Shallow margins thus become a victim of "cement loading." Vertical, pull-away fissures are seen on bathymetric traverses and also observed on land where an island, such as Andros, sits close to an abrupt bank margin. We dove into one of these large pull-away features on the Miami terrace on the ALUMINAUT back in 1970 (Neumann and Ball, 1970). The collapse of carbonate margins forms scalloped embayments along the margin edge (Mullins and Hine, 1989).

Our most recent work on the geology of the last interglacial in the northeastern Bahamas suggests that the shallow eastern shelf, which once was the source of the oolitic sands that built the eolianite islands of the present margin, is missing. The islands, such as Eleuthera, now sit on the seaward edge of a steep drop-off into the deep Atlantic. We can only conclude that the shallow margin that bore the oolite shoals has calved away in the interim and its brecciated remains lay buried within the flanking basinal sediments some four thousand meters below (Neumann and Hearty, 1996; Hearty and Neumann, 2001). At the base of platforms on the Nicaraguan Rise, these aprons of breccia are particularly obvious, as are the pull-away joint openings along the platform margin (Hine et al., 1992). Figure 10 is a close-up shot from ALVIN of part of a collapse block. It was encountered in a gulley at about 400 meters depth in the northeastern margin of NWPC.

Thus, it appears that something is causing a spectrum of effects from incipient stiffening of peri-platform pelagics to the collapse of carbonate margins. We relate these features to an increase in accumulated internal cement, or "cement loading." It now remains to be seen how this cement gets into the rock, what it looks like, and why it precipitates.

Fig 10. A partial view of a large collapsed block in a marginal gully on the northeastern margin of the Northwest Providence Channel. The block is at least 10 meters in diameter. The depth is about 400 meters.

PART II: THE PETROGRAPHY OF THE CEMENT SEQUENCE

The lithoherm crusts and the associated inter-mound hardgrounds were sampled via ALVIN or dredged up using surface ships. The general petrography of the rocks and the nature of the cements were described by Neumann, et al. (1977). More exhaustive work later recognized that there was a paragenetic sequence in the character of the cements (Wilber and Neumann, 1993). It was apparent from Jude Wilber's painstaking petrographic work that what was originally ascribed to clastic infill by very fine material from the outside was instead a spectrum of cement types produced *inside* the rock or sediment. The mineralogy was wrong for external pelagic material. It was calcite high in magnesium for which there is no common pelagic or bank-top source. Furthermore, it appeared to Wilber that these cements were not of different specific types produced at different times but were part of a gradational occluding sequence that occupied entire cavities between and within the constituent grains. The rock, it should be mentioned at the outset, is a foram/pteropod ooze with an associated fine fraction of largely Mg-calcite micrite. It appeared to Wilbur that the fine material in the spaces within and between skeletal grains was largely "homegrown." It originated within the rock. It is thus at the core of the "cement loading" story.

It seems the term "cement" may be too general. As a result of later petrographic and geochemical work on mud-mounds and lithoherms, it was found that the term "cement" has come to mean different things to different workers. Thus, we now refer to these materials, which have been added to the rock since deposition, as "organomicrites," or authigenic micrites (Neuweiller et al., 2000). I will complete the discussion here continuing to use the more general term of "cement," meaning any chemical precipitate added to the rock since deposition (this excludes clastic fines filtered in after deposition).

The sequence observed by Wilber and Neumann (1993) is seen throughout the rock but is best captured in the geopetal ("spirit level") infill of partially filled voids commonly seen within the rock (Figure 11). Numbering the steps, it starts with (1) a **mix** of clastic (allogenic) fines and precipitated fines. The clastic fines are bright flecks, usually consisting of skeletal remains, whereas the micritic matrix is high-Mg calcite, as seen in microprobe imaging. As the clastics are filtered out by passing through progressively finer voids, only the water-borne cement remains. The cement seems to have been precipitated as a loose **paste** (2) within the cavity and not as growth on the cavity wall. This conclusion is based on impressions of the adjoining wall molded by the sedimentary cement. It is interpreted to be a rapidly precipitated, unconsolidated infill. Aggraded centers of finer material then appear within the paste giving it a clotted structure. The clots (3) become more closely spaced and develop rounded outlines at the surface of the clotted mass. These individual spherical bodies are fine within and coarsen to a microspar on the surface. These are the common cement structures of phase 3 and are called "**peloids**." They characterize a large volume of the internal cement. As the spacing of the peloids increases, the micro-spar exterior becomes more obvious. Finally, there is a phase of **epitaxial overgrowth** (4) on the exposed void wall by sparry cement. The whole sequence seems to reflect a slower and slower rate of precipitation. The flow becomes slower due to the gradual cutting off of the conduits by the increased addition of cement.

In this way a rock of fifty percent porosity can occlude to become a dense rock with little void space. Here in microcosm is the step by step petrographic path of the infilling of an open sediment to a closed rock. It represents the phrase "cement loading" better than any observation so far.

PART III: FLOW OVER/FLOW THROUGH

This part is by necessity brief because it deals with work in progress and thus is incomplete. In order to bring about extensive infilling of internal voids by cement, the ions of the cementing material must be delivered via diffusion or advection, or more probably both. Diffusion is so slow that it is suspected that actual flow (advection) must also play a significant role.

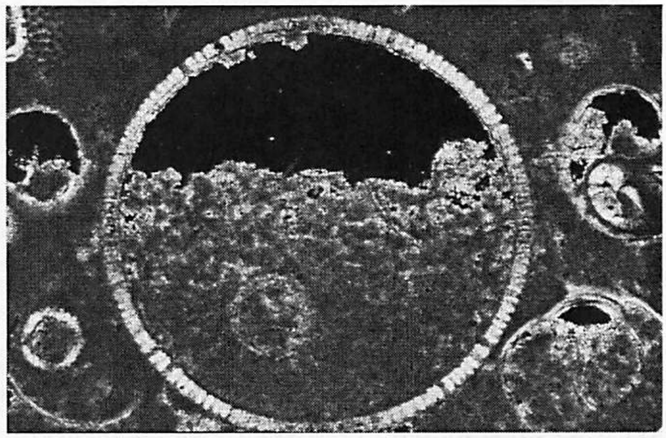

Figure 11. The sequence of textures in micritic cement in most lithoherm rocks and intervening hardgrounds as seen in thin section and described by Wilber and Neumann (1993). In this field , inside a foram test, homogeneous micrite grades upward into a clotted texture followed by peloidal development and then encrusted by calcitic microspar. The foram test is about 220 microns across.

In a paper by Heuttel et al. (1996) an interesting model experiment was described wherein water flowing over a ripple of sand drew a dyed interval of interstitial water upward into the small mound. With the collaboration of Thomas Shay here at UNC, we asked whether the flow of water over the lithoherms was enough to draw water through the mound as a result of pressure changes created by the flow over the feature (the Bernoulli effect). It became apparent that, using the dimensions of the entire mound (over 30 meters high and hundreds of meters long), the values required for flow through the mound were unreasonable. But, when this effect was scaled down to a relief of a few centimeters, the effect of flow-over producing flow-through became quite reasonable.

This is an interesting and encouraging result because a few centimeters is the same order of magnitude as the thickness of the crusts of the lithoherms as well as the bed thickness in the ancient mounds. In both cases, the modern crusts and the ancient beds are discontinuous and irregular as if they might well be controlled by local cm-high surficial irregularities. The subject of "flow over/flow through" remains at this stage of development, but it promises to bring modern lithoherms even closer to the mud-mounds of the past by revealing hydrodynamic processes common to both.

PART IV: THE HUMATE/CARBONATE MECHANISM OF ORGANO-MICRITE FORMATION

The end chapter in the cement loading story is provided in the ongoing work of others (Neuweiler et al., 2000). It is included here with their permission as it seems to provide a very nice and convincing "last word" to the cement-loading story. In the study of the complex post-depositional changes that have affected ancient mud-mounds, a close association between inorganic and organic processes emerges that promises to have significant consequences for the way we view carbonate diagenesis. In the studies by Neuweiler, et al. (2000) the internal micrite from ancient mud-mounds was sampled and ground down to finer and finer fractions, each fraction being washed and then dissolved and analyzed for organic constituents. Flourescence techniques were also employed. The organic fraction that persisted through all the size reductions was the broad group of refractory organic compounds termed humates, or humic substance. The working conclusion is that the humates are in intimate association with the carbonate micrite and may well be *co*-precipitates. It is well accepted that a threshold of activation energy needs to be reached in order to precipitate calcium carbonate inorganically. It appears from these analyses that that energy may well be contributed in these environments by the incipient precipitation of humates. Both energy and substrate are contributed. The result is a micrite that may be considered to be of both inorganic and organic origin. Indeed, they are termed "organo-micrites".

These findings seem to agree with the nature of the sequence of occlusion by micrite seen in the lithoherms in thin section. The rapidly precipitated paste could be related to the initial reaction when humates are in greatest concentration and precipitation of carbonate micrite is the most rapid. As flow slows and humates are used up, the reaction slows; the clotted structure and peloids represent this slower reaction, when precipitation is centered around fine nuclei in this long, final phase. The coarser microspar that encrusts the peloids and cavity surfaces may well be physicochemical and may originate from pore-waters basically stripped of the organic fraction. The petrography and the chemistry may be telling the same story.

CONCLUDING REMARKS

It all seems too good to be true, and anything so conjectural is probably stretching the truth. But the story that emerges and seems to fit is that these micritic Mg-calcite cements (organo-micrites) grow within the sediment. On the way to becoming a rock several obvious changes take place in the sediment host. Reflectors reflect incipient cementation in peri-platform ooze sequences. Internal breccias and intraformational conglomerates result from layers of alternating density. Firmgrounds, nodules, nodular hard-*grounds* and regular hardgrounds form and are exposed on the sea floor. Layered mounds (lithified mounds, or "lithoherms") are nucleated from hardground bases. Finally, cement loading concentrates at platform margins, which, as a result, break off and fall into the adjoining basin as mega-breccia blocks.

The ions and fluids move into the sediment or rock by diffusion and/or advection. The movement of current over a mound increases the effect of advection and explains the character of the coarse bedding observed. The micritic cements in deep peri-platflorm settings follows a sequence that suggests rapid to slow micrite occlusion. Humates appear to supply the energy and substrate needed to precipitate the micrites, now considered "organo-micrites." All this seems to have an ancient counterpart in the mud-mounds of the phanerozoic.

So there it all is, the rock that grows within a rock as sediments "stiffify" and then lithify. In so doing, the mass of cement is added to the mass of the host material. The cement weights the rock, hence "cement loading."

Now it is time to put "cement loading" back into a box and back into the carbonate closet; or better yet, it is time to explore the idea with some more doing and lots more data.

ACKNOWLEDGEMENTS

Thank you all, and thanks to all the students over the years and all the friends and colleagues that have lent an ear or bent one. The making and swapping of ideas has been fun, and the sights out the viewing port or at the outcrop have been thrilling (even if we were not always sure of just what we were looking at!). The answers always lie with the next generation, the young. Us old folks seem to be better at supplying the questions. Thanks for asking me to ask these.

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