Mud Problem Exposed: Drainage-Path Geometry and the Consolidation Time of Thick Mudrock

M. Nailor [1]
Independent Researchers

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ABSTRACT

Dunn (2024) applies Terzaghi consolidation theory to clay successions on the order of 1,000 m thick and concludes that the mechanical compaction stage of lithification requires timescales far longer than a young catastrophic Flood chronology allows, presenting this as a quantitative barrier to Flood geology. Dunn's arithmetic is correct. This paper examines the single modeling choice that carries the conclusion: the treatment of a thick mudrock succession as one homogeneous, laterally continuous clay column that drains only vertically. Terzaghi's own solution gives the time to ninety percent consolidation as $t_{90} = T_v H^2 / c_v$, so the predicted time scales with the square of the drainage-path length H. The deep-time result is therefore not a fixed property of consolidation physics but a property of the assumed drainage geometry, and it is this sensitivity, not any error in Dunn's numbers, that the analysis develops. Holding Dunn's coefficient of consolidation fixed and changing only the geometry, introducing a permeable parting every 10 m reduces the single-slice ninety percent consolidation time from roughly 134,000 years to about 13 years, a factor near 10,000 that is exactly the H^2 scaling. I show, however, that this reduction is real only under a specific and testable condition: each parting must remain laterally continuous, hydraulically connected to a low-pressure outlet, and able to discharge the expelled pore water without itself becoming overpressured. A parting that merely exists is not a drainage boundary; a parting that carries water to an outlet is. I set out the mass-balance and connectivity requirements this imposes, weigh the roles of early cementation, continuing deposition, and cyclic softening, and distinguish what soft-sediment deformation structures do and do not demonstrate. The result is not a refutation of Dunn but a redirection of the question: the clay consolidation objection is decisive for a homogeneous, vertically draining column, and whether real thick successions consolidated on Flood timescales is an empirical question about drainage architecture that specific, stated measurements can decide.

Keywords: *clay consolidation; Terzaghi theory; drainage-path geometry; pore-pressure dissipation; permeability anisotropy; hydraulic connectivity; early diagenetic cementation; soft-sediment deformation; Flood geology; rapid lithification*

1. Introduction

Lithification of fine-grained sediment proceeds in two overlapping stages: mechanical consolidation, in which pore water is expelled and the grain framework compacts under load, and chemical cementation, in which authigenic minerals bind the framework into rock. Dunn (2024), writing in the Creation Research Society Quarterly, focuses on the first stage and argues that it is the rate-limiting step. Applying the classical consolidation theory (Terzaghi 1943), which Dunn attributes to Terzaghi's foundational work of the 1920s, to clay layers on the order of 1,000 m thick of the kind documented in the North Sea, the Gulf of Mexico, and the Caspian Sea, he obtains compaction times far longer than the months to years a Flood chronology allows, and he adds that there is a ceiling on how fast sediment can accumulate before excess pore pressure destabilizes the pile. He presents this as a quantitative challenge to the assumption that rock can form quickly.

I do not dispute Terzaghi's equation, Dunn's arithmetic, or the conclusion that a homogeneous, kilometer-thick clay column draining only upward would take an enormous time to consolidate. The question I raise is narrower and, I hope, more useful: whether that idealized column is the correct model for the sediments actually preserved in the rock record, and if it is not, what a more realistic model would have to demonstrate before it could claim rapid consolidation. The argument proceeds by isolating the variable that governs the result, the drainage-path length, showing how strongly it controls the predicted time, and then stating explicitly the physical conditions that a short-drainage-path model must satisfy. Those conditions are not rhetorical; they are measurable, and I frame them as such.

2. Dunn's argument, stated fairly

Terzaghi's one-dimensional theory describes how excess pore pressure dissipates from a saturated, compressible layer as water escapes toward a drainage boundary. The time to reach ninety percent of primary consolidation is

$$t_{90} = T_v \cdot H^2 / c_v, \quad \text{with } T_v \approx 0.848,$$

where H is the longest distance a water molecule must travel to reach a drainage boundary, equal to the full layer thickness for one-way drainage or half the thickness for two-way drainage, and $c_v = k / (\gamma_w m_v)$ is the coefficient of consolidation, the ratio of hydraulic conductivity to the product of the unit weight of water and the compressibility. Using c_v on the order of 5×10^{-8} m^2/s, typical of cold, quiescent marine clay, and treating a 1,000 m clay body as a single mass, the predicted ninety percent consolidation time is on the order of 10^5 to 10^6 years. Dunn pairs this with an accumulation-rate ceiling, on the order of 0.1 m per year for clay, above which excess pore pressure would destabilize the pile.

Two features of Dunn's treatment should be stated plainly, because a fair reassessment must engage the argument at its strongest. First, Dunn does not model the load as a single end load applied to a finished column; his numerical treatment adds sediment in increments and allows the deposit to consolidate as it grows, comparing deposition spread over widely different durations. Second, Dunn acknowledges that a layered profile with horizontal flow may require a fuller two- or three-dimensional treatment than his one-dimensional model provides. The argument below is therefore not that Dunn overlooked layering, but that the quantitative weight of his conclusion still rests on the drainage-path length assigned to the operative model, and that this length is the pivot on which the whole result turns.

3. The decisive variable is drainage-path length

Because t_{90} is proportional to H^2, consolidation time is governed more strongly by drainage geometry than by any other term in the equation. Halving H quarters the time; reducing H by a factor of 100 reduces the time by a factor of 10,000. The coefficient c_v enters only linearly, so even a generous tenfold increase in c_v buys far less than a tenfold reduction in H. The most consequential physical question is therefore not how warm or saline the pore water was, but how far that water actually had to travel before it reached an escape route, and whether that route could carry it away. Dunn's model answers the first half of that question with the largest defensible value: water in the interior of a thick clay body must migrate through hundreds of meters of intact clay before reaching the top surface. That is the slowest boundary condition available. It is also the condition that civil engineering deliberately inverts. Prefabricated vertical drains, descended from the sand-drain theory of Barron (1948), are installed through soft clay precisely to shorten the drainage path, giving pore water a permeable route every one to two meters and consolidating in a single construction season a deposit that would otherwise take centuries. The physics is Terzaghi's throughout; only H changes. That engineered analogy is instructive, but it also carries a warning that I take up next: those drains work because they are connected at the top to a drainage blanket that removes the water. A drain that leads nowhere consolidates nothing.

4. When a permeable parting acts as a drainage boundary

This is the pivot of the whole argument, and it deserves to be stated exactly. Terzaghi's two-way solution assumes that both surfaces bounding the clay layer remain at essentially zero excess pore pressure for the duration of consolidation. A silt, sand, or ash parting becomes such a surface only if it can accept the water expelled from the adjacent clay and carry it away fast enough that its own excess pore pressure stays near zero. Shortening the modeled drainage path from the formation scale to the parting spacing is legitimate only when that condition holds.

The condition is not automatically satisfied, and the reason is a matter of mass balance. Consider a 10 m mud layer compacting from a porosity of 0.90 to 0.50. Its solid fraction is conserved, so the layer thins to about 2 m and expels on the order of 8 m^3 of water for every square meter of area. A thin parting cannot simply store that volume; it must transmit it laterally to an outlet, a basin margin, the sediment surface, an open fracture, or another connected permeable body held at low pressure. If the parting is laterally discontinuous, pinches out, is sealed by cement, or is loaded by the same overburden that is pressurizing the clay, then water entering it raises its pressure, and it ceases to behave as a drained boundary. In that case the operative drainage path is not the parting spacing at all; it reverts toward the distance to the nearest true outlet, which may be the formation scale after all.

The reassessment therefore splits into two calculations, only one of which the geometry argument by itself performs. The first is the local journey, clay to nearest parting, and it is genuinely fast when the parting is close. The second is the export journey, parting to outlet, and it depends on the lateral continuity, transmissivity, storage, and outlet distance of the parting network. A defensible claim of rapid consolidation requires both. What the H^2 sensitivity establishes is that the first journey can be short; what it does not by itself establish is that the second journey exists. The remainder of this paper is organized around that distinction, because it is precisely the distinction that separates a valid sensitivity result from an overstated one.

5. The field geometry of thick mudrock, and its limits

Thick mudrock successions in the geologic record are not, in general, the homogeneous clay masses that Dunn's simplest model assumes. They are commonly interbedded at the centimeter to decimeter scale with silt, very fine sand, and volcanic ash laminae, and they are cut by joints, faults, and fluid-escape structures. Where a permeable parting is laterally continuous and connected, it functions as an internal drainage boundary, and the operative drainage path is then set by the spacing between partings rather than by the gross thickness of the formation. Two further features can reinforce this. Layered muds are typically anisotropic, with horizontal permeability commonly exceeding vertical permeability by one to two orders of magnitude, so water tends to escape sideways toward the nearest permeable bed. And fracture or fault-damage zones can act as vertically continuous conduits that link the horizontal partings into a three-dimensional network resembling an installed field of vertical drains.

Each of these features, however, carries a condition, and honesty requires stating them rather than assuming them. Partings drain only where they are continuous and connected to an outlet, not merely where they are present. Anisotropy speeds lateral escape only toward a bed that can itself discharge. And fractures are not uniformly drains: a fault zone may act as a conduit, a barrier, or a combined conduit-barrier system depending on its core, damage zone, clay smear, cementation, and the effective stress acting on it (Caine, Evans, and Forster 1996).

Whether a given fracture network drained a given succession depends on whether the fractures were open under hundreds of meters of overburden, whether they intersected a low-pressure boundary, and whether they were later sealed. These are empirical questions about a particular formation, not properties that can be assumed for mudrock in general. The correct reading of this section is therefore conditional: thick mudrock frequently possesses the architecture that would shorten drainage paths, and whether that architecture was hydraulically effective in any given case is a matter for measurement.

Table 1. *Modeling choices that carry the long-age result in the homogeneous limit, their effect, and the field-realistic alternative with the condition each requires.*

Modeling choice (homogeneous one-dimensional limit)	Effect on the predicted time	Field-realistic alternative and its condition
Single homogeneous clay column	Sets H to hundreds of meters, the largest possible drainage path	Continuous partings set H to meters, provided they connect to an outlet
Drainage treated as vertical only	Ignores lateral escape, though horizontal permeability is usually higher	Anisotropic flow drains laterally, toward a bed that can itself discharge
Constant c_v at cold laboratory value	Fixes properties at their slowest	c_v rises modestly with temperature and salinity, a linear effect only
Load approximated as applied to the full thickness	Treats the pile as simultaneously undrained	Event beds consolidate during deposition, but only where per-bed paths are short
Cementation strictly after consolidation	Separates processes that in fact overlap	Early cement adds strength in parallel, at a mass-balance cost

6. Quantitative sensitivity analysis

The reassessment requires no new physics. It applies the same equation, $t_{90} = 0.848\ H^2 / c_v$, with the drainage path set by parting spacing rather than by formation thickness, and it isolates the effect of geometry by holding c_v fixed at Dunn's cold-clay value in the upper rows before allowing modest, physically defensible increases in the lower rows. Table 2 should be read as an illustrative single-slice sensitivity calculation, not as a reanalysis of any specific cored succession; it shows what the drainage-path length does to the predicted time, on the explicit assumption that each modeled boundary is a working outlet in the sense of Section 4.

Table 2. *Time to ninety percent consolidation for a single mud slice from $t_{90} = 0.848\ H^2 / c_v$ as the drainage path is shortened. The upper three rows retain Dunn's coefficient of consolidation and vary only the geometry; the lower two add modest increases in c_v. Every row assumes the bounding partings act as working drainage boundaries in the sense of Section 4.*

Drainage path H	c_v (m^2/s)	t_{90}	Setting and drainage condition
500 m (two-way)	5×10^{-8}	~134,000 yr	Homogeneous kilometer-scale clay; a hardened base makes drainage one-way, giving ~537,000 yr at H = 1,000 m
10 m	5×10^{-8}	~54 yr	Working parting every 20 m, Dunn's own c_v
5 m	5×10^{-8}	~13 yr	Working parting every 10 m, Dunn's own c_v
1 m	3×10^{-7}	~33 days	Decimeter to meter interbeds, modestly raised c_v
0.3 m	1×10^{-6}	~0.9 day	Thin event beds, elevated c_v near arcs and vents

The central entry is the third row. Retaining every number Dunn uses, including his coefficient of consolidation, and changing only the assumption of homogeneity so that a working permeable parting occurs every 10 m, a drainage path of 5 m under two-way drainage, the predicted ninety percent consolidation time for a single slice falls from roughly 134,000 years to about 13 years. That four-order-of-magnitude reduction is not a rescue device; it is the exact H^2 scaling built into Terzaghi's own equation. The result is also, however, exactly as strong as its premise: it is the consolidation time of one clay slice draining to bounding surfaces that are assumed to hold at low pressure. It becomes a statement about a whole succession only when the partings that bound every slice are shown to form a connected, outlet-linked network..

A note on the drainage condition is needed for the top row. Dunn's Flood scenario treats the substrate as hardened, which makes drainage one-way for the full column; under that condition a 1,000 m column has H = 1,000 m and a ninety percent time near 537,000 years, larger still than the 134,000 year figure that corresponds to a 500 m two-way path. I use the 500 m, 134,000 year case as the reference point because it is the more conservative of the two for this argument, not the less; nothing in the reassessment depends on inflating Dunn's baseline.

7. Continuing deposition: what staged loading does and does not do

Because deposition is not instantaneous, it is sometimes argued that staged loading further shortens the time, since lower beds begin consolidating before upper beds arrive. Whether this helps depends entirely on the relation between the deposition rate and the per-bed consolidation time, and the honest answer is that at slow accumulation rates it helps a great deal and at the rapid rates a Flood model requires it does not, unless the per-bed drainage path is very short.

The arithmetic makes this concrete. Take the favorable case of a 10 m bed with a 5 m drainage path and Dunn's c_v, for which t_{90} is 13.4 years. If the overlying 10 m of section arrives at a rapid, compacted-equivalent rate on the order of several meters per day, the next bed is emplaced in little more than a day. In that time the Terzaghi solution gives only about two percent average consolidation of the underlying bed, and even after a hundred days of continued deposition the earliest bed has reached only about fifteen percent, assuming ideal two-way drainage throughout.

At rapid deposition rates, therefore, the lower beds are not well advanced when the next beds arrive, and staged loading cannot be claimed as an independent accelerant. Where staged loading does earn its place is in combination with genuinely short, well-connected drainage paths at the individual event-bed scale, thin graded beds bounded by their own coarse bases and tops, for which the per-bed consolidation time is days rather than years. The defensible statement is thus specific: staged loading matters only in the thin-bed, short-path, connected-outlet regime, and it should not be invoked as a general rescue of a thick, undivided pile.

8. Complementary processes and their limits

Mechanical consolidation is not the only route to load-bearing strength, but each additional process carries a cost that must be stated alongside its benefit.

Early cementation. Carbonate and silica cements can precipitate into pore space during or shortly after deposition and stiffen a sediment before mechanical consolidation is complete. The clearest natural calibration is beachrock, in which loose beach sand is bound into coherent rock by carbonate cement on timescales of years to decades (Vousdoukas, Velegrakis, and Plomaritis 2007). Two limits apply.

Beachrock cements permeable sand in a specialized coastal geochemical setting; it is empirical proof that the chemical step can be fast, not a direct analog for dewatering a thick claystone. And delivering enough dissolved carbonate or silica to cement a thick, low-permeability pile quickly requires moving large volumes of supersaturated fluid through the very sediment whose permeability is in question, while early cement forming along partings can reduce their permeability and impede later drainage.

Early cementation is therefore best treated as a secondary, locally important process requiring geochemical mass-balance modeling, not as a demonstrated general accelerant.

Modest increases in the coefficient of consolidation. Warm, saline pore water lowers viscosity and promotes flocculation, both of which raise hydraulic conductivity and therefore c_v. The honest magnitude is a factor of a few, not orders of magnitude, which is why the argument does not rest on it; it is a linear term layered on top of the quadratic geometric effect.

Cyclic loading and the behavior of clay. It is sometimes supposed that seismic shaking could pump water from clay by liquefaction. Plastic clays do not liquefy in the sand-like sense; their permeability is far lower, so shaking accelerates dewatering chiefly in the silt and sand interbeds and by generating fractures, not by liquefying the clay. The distinction is not simply that clays never fail cyclically: low-plasticity, clay-bearing silts can display sand-like liquefaction, while plastic clays undergo cyclic softening and strength loss, and the appropriate criteria distinguish these regimes (Boulanger and Idriss 2006). The argument advanced here deliberately does not depend on liquefying clay; it depends only on shortening and connecting the paths through which the clay drains.

9. What soft-sediment deformation demonstrates

Sedimentary successions preserve abundant features that form while sediment is still soft and water saturated: flame structures, load casts, dish-and-pillar structures, sand volcanoes, clastic dikes, and convolute folds. These features are real evidence, and it is important to state precisely what they establish. They demonstrate localized deformation and rapid escape of pore fluid before lithification, frequently under conditions of high excess pore pressure, and they are concentrated particularly in silt, sand, and gravel-grade sediment (Lowe 1975). What they do not by themselves demonstrate is that a thick mudrock succession reached ninety percent consolidation rapidly.

Indeed, many of these structures are produced by exactly the overpressure and instability that Dunn's rapid-deposition scenario predicts, so their presence is consistent with both a slow-consolidation and a fast-consolidation reading and cannot adjudicate between them on its own. The correct use of this evidence is therefore modest but genuine: it confirms that these sediments experienced vigorous, localized early dewatering, which is a necessary condition for the short-path drainage argued here.

The argument of this paper is deliberately bounded. It establishes that the deep-time result of the clay consolidation objection is a property of an assumed drainage geometry rather than a fixed consequence of consolidation physics, and that under Terzaghi's own equation and Dunn's own coefficient, a succession whose operative drainage paths are meters rather than hundreds of meters would consolidate locally on timescales of years rather than geologic ages.

It does not establish that any particular formation possessed such paths, and it should not be read as dating any specific kinds of rock. The objection is decisive against a homogeneous, vertically draining column.

10. Conclusion

Dunn (2024) is correct that a homogeneous, kilometer-thick clay column draining only upward would take geologic time to consolidate. That conclusion is a property of the assumed geometry, because Terzaghi's equation makes the time scale with the square of the drainage path, and thick mudrock in the actual rock record is frequently layered and fractured rather than homogeneous. Substituting a field-scale drainage path into Dunn's own equation, with Dunn's own coefficient, reduces the single-slice consolidation time from roughly 134,000 years to about 13 years, an effect that is the H^2 scaling and nothing more.

That reduction is real, and it is also conditional. It is the consolidation time of a clay slice draining to boundaries that hold at low pressure, and it becomes a statement about a whole succession only when those boundaries are shown to form a connected network that carries the expelled water to an outlet. The clay consolidation objection, properly analyzed, is therefore not a fixed barrier imposed by soil mechanics, but neither is it dissolved by arithmetic alone. It is decisive for the homogeneous column in Dunn models, and open for the layered, fractured successions the rock record preserves.

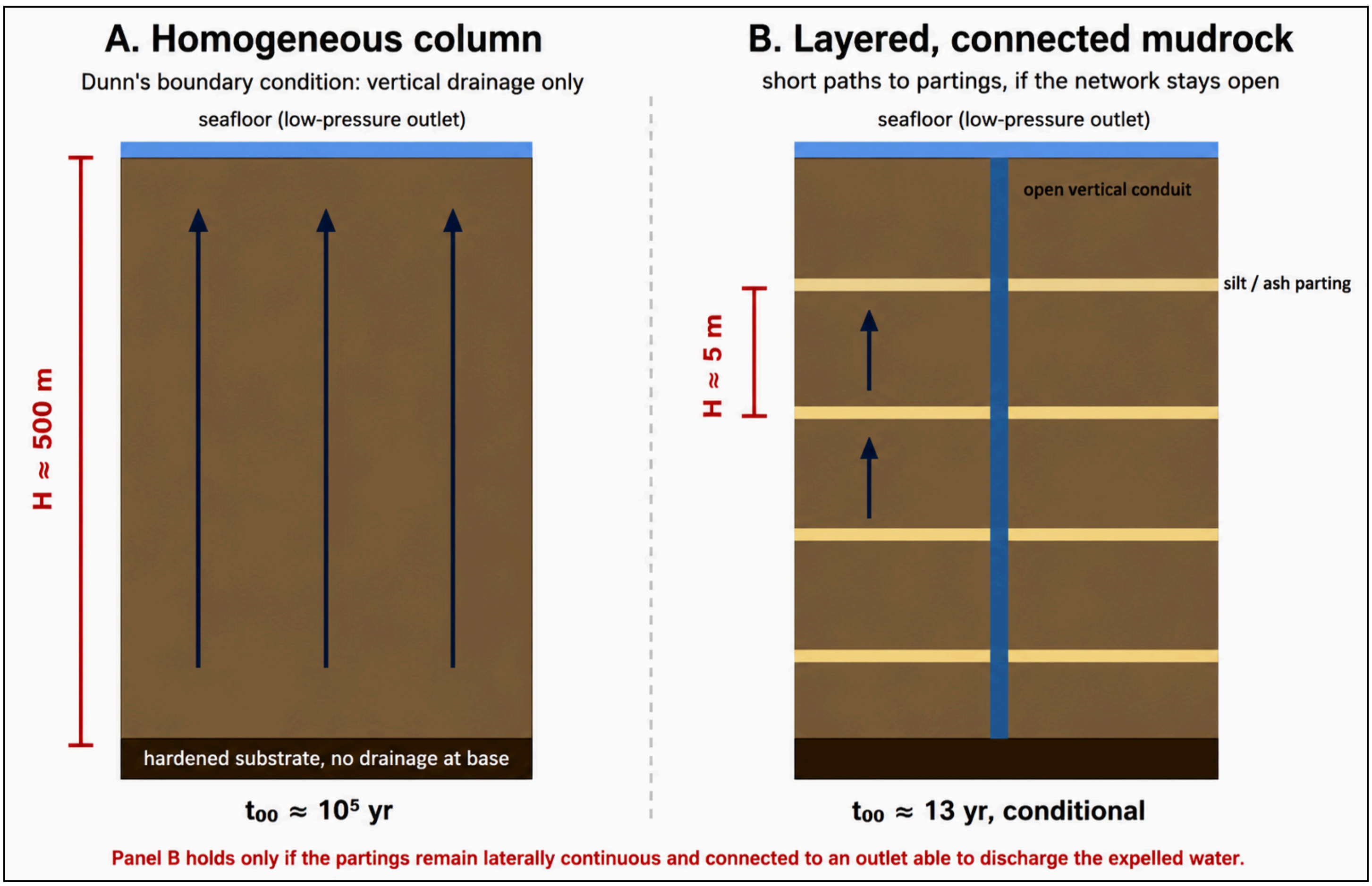

Figure 1. *Conceptual schematic (not to scale). (A) The homogeneous column of Dunn's boundary condition: water drains only upward over a path of hundreds of meters, giving a ninety percent consolidation time on the order of* 10^{-5} *years. (B) A layered succession in which continuous permeable partings shorten the local drainage path to a few meters, giving a single-slice time near 13 years. Panel B is valid only under the condition printed on the figure: the partings must remain laterally continuous and connected to an outlet able to discharge the expelled water, as set out in Section 4. The figure is an author-drawn conceptual illustration, not a depiction of a specific locality.*

References

Barron, R. A. (1948). Consolidation of fine-grained soils by drain wells. Transactions of the American Society of Civil Engineers, 113(1), 718-742. https://doi.org/10.1061/TACEAT.0006098

Boulanger, R. W., & Idriss, I. M. (2006). Liquefaction susceptibility criteria for silts and clays. Journal of Geotechnical and Geoenvironmental Engineering, 132(11), 1413-1426. https://doi.org/10.1061/(ASCE)1090-0241(2006)132:11(1413)

Caine, J. S., Evans, J. P., & Forster, C. B. (1996). Fault zone architecture and permeability structure. Geology, 24(11), 1025-1028. https://doi.org/10.1130/0091-7613(1996)024<1025:FZAAPS>2.3.CO;2

Dunn, S. L. (2024). The clay consolidation problem and its implications for Flood geology models. Creation Research Society Quarterly, 60(3).

Lowe, D. R. (1975). Water escape structures in coarse-grained sediments. Sedimentology, 22(2), 157-204. https://doi.org/10.1111/j.1365-3091.1975.tb00290.x

Oard, M. J., Reed, J. K., & Klevberg, P. (2023). Lithification of clastic sediments, Part I: Significance, processes, and modeling. Creation Research Society Quarterly, 60(1), 11-28.

Terzaghi, K. (1943). Theoretical soil mechanics. John Wiley & Sons.

Vousdoukas, M. I., Velegrakis, A. F., & Plomaritis, T. A. (2007). Beachrock occurrence, characteristics, formation mechanisms and impacts. Earth-Science Reviews, 85(1-2), 23-46. https://doi.org/10.1016/j.earscirev.2007.07.002