

INTRODUCTION

When present, taxa having aragonitic shells are more likely to be preserved as open molds (following dissolution), recrystallized to coarse calcite, or replaced by other minerals (such as silica), especially in the older fossil record (no original aragonite is known from rocks older than the late Paleozoic; *S1*). This qualitative pattern is primarily attributed to the lower thermodynamic stability of aragonite in natural waters (*S1-2*). However, dissolution kinetics can clearly be affected by a number of environmental (e.g., ionic poisoning, biofilm growth) and intrinsic biological factors (e.g., particle grain size and microstructural surface area; *S2-3*).

For example, in lab experiments using similarly sized grains that had first been cleaned of organic matrix, actual dissolution rates of biogenic aragonite and high-Mg calcites were shuffled relative to thermodynamic expectations, with the particular order at a given water saturation state determined by the microstructural surface area available for reaction (*S4*). Although low-Mg calcite never dissolved faster than the other mineral forms, differences between its dissolution rate and that of high-Mg calcite and aragonite were reduced, minimizing the mineralogic effect (*S4*). In addition, experiments on fresh aragonitic molluscan shells (not cleaned or heated) indicate that the organic matrix that sheathes mineral crystallites initially protects them from dissolution in undersaturated water, but overall accelerates destruction of high-organic microstructures in non-sterile waters, regardless of saturation state, probably owing to low-pH microenvironments created by microbial decay of matrix along crystallite surfaces (*S5*). The magnitude of effect of microbial maceration of organic matrix on shell destruction is such that shells disintegrate in microbially active saturated and supersaturated waters as fast or faster than they do in sterile *undersaturated* waters (*S5*). A similar experimental comparison of both aragonitic and calcitic molluscan microstructures corroborates these patterns: crystallite size outweighs mineralogy in determining the dissolution rate of molluscan microstructures in sterile undersaturated water, and is compounded by organic matrix in non-sterile undersaturated water (*S6*).

The quantitative impact of differential preservation of shell types on large-scale evolutionary patterns remains largely unexplored. Harper's (*S7*) two tests had contradictory qualitative outcomes that were not evaluated statistically. Whereas the fraction of living bivalves having fossil records is consistent with taphonomic expectations (only 6% of genera with calcite in their shells versus 18% of wholly aragonitic genera have no fossil record; $p \ll 0.01$, my G-test), her gap analysis at the family level found that calcite-bearing pteriomorphs have a significantly *less* complete record than the entirely aragonitic heteroconchs (81 versus 90%; $p < 0.05$, my G-test), and a record not significantly different from entirely aragonitic lucinoid bivalves.

MATERIALS AND METHODS

I. Construction of database on shell composition

Bivalve shells are composites of mineral crystallites (either aragonite or low-Mg calcite; first-order crystallites have dimensions ranging from 1-200 μm) which are sheathed by a

refractory organic matrix of fibrous protein (0.02 to 8 microns thick; S8). Microstructures (nacre, foliated, etc) are differentiated on the basis of the shape and arrangement of these crystallites and by the quantity and disposition of intercrystallite organic matrix. Although operational definitions for microstructures mostly follow the terminology of Bøggild (S9), subsequent refinements from SEM and from examination of a broader array of living and extinct taxa have led specialists to recognize new types and to subdivide the full array into a large (e.g., S10) or small number of categories (e.g., seven in S8). Thus merging information from multiple workers – and particularly transforming their descriptive categories into ordinal scales appropriate for quantitative analysis -- requires synonymizing and somewhat simplifying specialists' original observations. Data were compiled from the original observations of many authors (S8, S10-20), and from the original observations and extensive literature compilations of Carter (S21-27).

The composition of outer, middle and inner shell layers – each typically has a different microstructure and not uncommonly a different mineralogy – are used to characterize overall shell composition. A fourth myostracal shell layer, which forms internal muscle scars and the pallial line, is always composed of a distinctive low-organic form of prismatic aragonite and constitutes only a minor part of total shell volume (S8), and thus is ignored here. External organic coatings (periostracum) are also ignored, as these are rarely preserved in the fossil record.

Scoring mineralogy.— A given shell layer may be either aragonite or calcite; the presence of calcitic patches in the outer shell layers of some temperate-water specimens of otherwise entirely aragonitic taxa (S26) is ignored as ecophenotypic. Depending on the mineralogic composition of the 3 primary shell layers, the overall shell might be entirely aragonite (score 1), entirely calcite (score 3), bimineralic (score 2), or bimineralic but dominantly aragonite (score 1.5, e.g. calcite limited to a single, exceptionally thin or patchy (usually outer) shell layer) or bimineralic but dominantly calcite (score 2.5; aragonite limited to a single, exceptionally thin or patchy (usually inner) shell layer). Observed values range from 1 (virtually all Heteroconchia) to 3 (mostly ostreids).

Scoring intercrystalline organic content. -- Based on published determinations of weight loss on ignition (Table S1, Figure S1), bivalve microstructures are either (a) high-organic (>0.5 to 5 wt.-%), comprising nacre, simple prismatic, finely prismatic or fibrillar (calcite), and laminated homogeneous microstructures; or (b) low-organic (<0.5 to ~0.05 wt.-%), comprising composite prismatic, foliated, homogeneous, crossed- and complex crossed-lamellar microstructures. Finer subdivision of this spectrum is unwarranted due to the variability in organic content that is commonly observed within the microstructure of a single shell layer and among different specimens of the same microstructure (see scatter in Figure S1). Depending on the microstructural composition of the 3 primary shell layers, the overall shell might thus be entirely high-organic (score 1), entirely low-organic (score 3), hetero-organic (score 2), or hetero-organic but dominantly high-organic (score 1.5) or hetero-organic but dominantly low-organic (score 2.5). Observed values range from 1 (e.g., solemyids, trigonioids, pinnids) to 3 (e.g., many veneroids and myoids).

Scoring crystallite surface area: volume ratio (SAV).-- Reactive surface area is very difficult to determine analytically (*S4*), and should be a function of first-order crystallite shape (e.g., sphere, disc, lath, needle), crystallite size (surface area to mass ratios decrease with increasing size within any given shape category), roughness of crystallite surfaces, and the shapes and sizes of second- and third-order crystallites. This aspect of shell composition is the most difficult to estimate from information typically published for individual genera and in microstructure studies, and thus its quantification is most likely to be subject to future improvements. As a necessary simplification, the surface area to volume ratio (SAV) of a microstructure (volume is used as a proxy for mineral mass) is calculated solely from the typical size and shape of its first-order crystallites (Table S2). The relatively continuous spectrum of calculated SAV values (Figure S2) is subdivided into 3 non-overlapping categories of high SAV (granular homogeneous microstructure), moderate SAV (tablets of nacre and laths of foliated and cross-lamellar microstructures, prisms of composite or finely prismatic microstructure), and low SAV (columnar prisms of simple prismatic microstructure, both calcitic and aragonitic). This ordering of shapes is opposite to intuition because the roughly equant grains of homogeneous microstructure are very small ($\sim 1\text{-}5\mu\text{m}$ diameter), whereas the hexagonal prisms of simple prismatic microstructure tend to be very large (up to $80\mu\text{m}$ diameter and $200\mu\text{m}$ or more in length).

With the caveats below, a shell overall might be composed of microstructures that are entirely high SAV (score 1, i.e. entirely homogeneous), entirely moderate SAV (score 2; nacre, cross-lamellar, complex cross-lamellar, foliated, composite prismatic, fibrillar or finely prismatic, or some combination of these microstructures), or entirely low SAV (score 3; entirely simple prismatic, or prismatic of unspecified type). Shells containing both high and moderate SAV microstructures are scored 1.5, and those containing both moderate and low SAV microstructures are scored 2.5. If the second microstructure is limited to a very thin or patchy layer, it is given only a quarter-point (e.g., high-SAV with a trace of moderate-SAV would be 1.25, moderate with a trace of high would be 1.75, etc.). Genera having shells that incorporate microstructures drawn from both high- and low-SAV end-member microstructures (i.e., high-SAV homogeneous and low-SAV simple prismatic microstructures occur in same shell; 8% of all genera for which microstructure is known) are presently excluded from analyses (including the calculation of combined score, see below) rather than being assigned to one end-member or the other; they are not given an “average” score of 2 because this would signify moderate SAV. Observed values of SAV range from 1 (e.g., cuspidariids, thraciids, some nuculanids) to 2.5 (e.g., inoceramids and isognomonids with substantial simple prismatic layers); no genus is composed exclusively of simple prismatic microstructure (score 3).

Caveats for Surface Area:Volume Ratios.—One difficulty in extracting accurate SAV scores from the literature is that diagenetic recrystallization can apparently generate textures very similar to primary homogeneous microstructure (*S10*), and thus some reports of this microstructure, especially in extinct taxa, may be erroneous. In scoring taxa, early reports of homogeneous structure are thus ignored in favor of younger reports that find a different microstructure. In addition, not all homogeneous microstructure is composed of granules, which were the basis of calculated SAV for this analysis: on closer examination, specialists not commonly recharacterize apparently homogeneous shell layers as extremely fine-grained prismatic or cross-lamellar microstructure. Such errors are unlikely to affect the final scoring of

genera because the very small crystallite size, especially combined with the higher aspect ratios of these crystallite shapes, probably gives them as high a SAV as true granular homogeneous microstructure, but this presumption is difficult to test. An additional complication to extracting accurate SAV scores is that shell layers in some genera are described as prismatic without specifying whether this is simple prismatic (and thus low SAV) or composite or fine prismatic (moderate SAV). Thus, SAV scores here are preliminary estimates, and should be accorded less confidence than given to other aspects of shell composition.

Combined score. – This is the sum of scores for mineralogy, organic content, and surface area:volume ratio (SAV). Because each component can range from 1 to 3, the combined scores can hypothetically range from 3 to 9. The observed range of combined scores in the database is 4.25 (most reactive, thus lowest intrinsic preservation potential; e.g., trigonoids and some pholadomyoids composed of nacre and subordinate simple prismatic aragonite) to 8 (least reactive; deltopectinids, monotids, and some pectinids, gryphaeids and ostreids using mixes of foliated and finely prismatic calcite).

Extrapolating compositional information to related genera in the stratigraphic-range database. – The procedure was as follows:

1. If published data for shell composition are available (“documented”) for more than one genus in a family and those data are consistent, then those data are extrapolated to all other confamilial genera. 33% of all 256 bivalve families in the stratigraphic range database are in this category, accounting for 68% of 2983 genera in the updated version of Sepkoski’s compendium. If documented genera diverge in some aspects of composition but are identical in others, then the identical scores were extrapolated. If the divergent scores are quite similar (e.g., various genera in the family have a SAV scores of 1, 1.5, and 1.75, so that all of them are at the highly reactive end of the spectrum), then a median was applied to confamilial genera. If divergent scores differ strongly (e.g., some are entirely aragonite whereas others include some calcite, thus crossing a divide of major analytic interest), then no score was assigned to undocumented genera for that particular aspect of shell composition.
2. If shell composition is documented for only a single genus in the family, that information was assumed to apply to all other genera in the family. 30% of families are in this category, but account for only 17% of genera.
3. For genera in families where no compositions have been documented, information was extrapolated assuming conservatism at the Order level, but only for those aspects of composition that show no variation among other families in the Order (e.g., all documented genera of Arcoidea have shells that are entirely aragonite). 37% of families are in this category, but account for only 14% of all genera.
4. Shell composition cannot be inferred for 48 genera – these are from undocumented families within an order too compositionally diverse to generalize – but these represent less than 2% of genera in the stratigraphic range database. These are almost exclusively genera of uncertain family assignment within the Order Pterioidea.

Using this procedure, information on all three aspects of shell composition (and a combined score) can be generated for 88.5% of genera in the stratigraphic range database. An additional 10% of genera have information for 1 or 2 of aspects of composition.

II. Stratigraphic range database

The stratigraphic ranges of all bivalve genera having a fossil record were based on the bivalve section of the compendium of fossil marine genera compiled by JJ Sepkoski Jr (S28), as updated by Jablonski et al. (S29; July 2004 version of database). Genera were assigned to families using the Treatise of Invertebrate Paleontology (S30) and, for post-Treatise genera, the original author. Genera in some large families were further assigned to subfamilies following the Treatise or, in the case of pectinids, recent treatments such as Waller (S31-32) and others as summarized by H.H. Dijkstra (S33).

This database comprises 256 bivalve families and 2983 genera. Shell composition was assigned to genera following the procedure described above, retaining all single-interval (singleton) taxa. For age assignments, I followed Jablonski et al. (S29), who followed Sepkoski (S34), in using the midpoint of each stage or substage to calculate the time of first and last stratigraphic occurrence for each taxon, based on geologic ages provided by the same standard geologic timescales (S35, S36).

For plots of secular trends (Figure 1 in main text), raw numbers and proportions of genera in different compositional categories were determined for ~20 m.y.-duration bins of Phanerozoic time (x-axis in Figure 1), adjusting bin lengths as needed (usually less than 2 m.y.) so that no bins spanned the boundaries between geologic periods. Because recoveries from mass extinctions require <20 m.y., the overall diversity curve for the Class Bivalvia (dashed line in Figure 1a) is relatively smooth. The impact of mass extinction on the fates of clades is instead reflected in the sharp changes in proportions of shell compositions at those times, especially across the Permo-Triassic and Cretaceous-Tertiary boundaries.

ANALYTIC RESULTS

I. Singleton Analysis

High-reactivity shells are defined as having a mineralogy score of 1 (composed exclusively of aragonite), organic content score of 1 (composed exclusively of high-organic microstructures), or a surface area:volume ratio (SAV) score <2. To calculate proportions, N was the number of genera for which that category of shell composition data were available (Table 1). Total N in the Phanerozoic database is 2983 genera, with 554 genera in the Paleozoic subset, 2471 in the post-Paleozoic subset, and 42 taxa common to both subsets. The completeness of data ranges from 95% of genera at the high end (singleton G-test for mineralogy in the Phanerozoic, total N of 671+ 2175 = 2846) to 68% (Paleozoic SAV test, N = 378; Table 1).

In most two-way comparisons of %-singletons, observed differences are opposite to the taphonomic expectation that singleton taxa would preferentially have shells composed of aragonite, high-organic or high SAV microstructures (far right column in Table 1). G-tests indicate that only ~half of all differences are significant, especially after Sequential Bonferroni Correction to compensate for the large number of tests (S37), and of these significant results only

2 are consistent with taphonomic expectation (lying above the diagonal in Figure S3). These are the tests for organic content in the post-Paleozoic (post-Pz) portion of the database and in the entire Phanerozoic (Phan) database, which the post-Paleozoic data dominate. A third point above the line – the test for a mineralogy effect among Paleozoic genera – is marginally significant ($p = 0.054$ after correction). Differences between singletons and non-singletons are also significant for SAV and mineralogy, but in a direction opposite to taphonomic expectation. All differences, both significant and insignificant, are relatively small (usually <10 percentage points separate the proportions being compared; envelope defined by dashed lines in Figure S3).

It could be argued that, as a group, singletons might not include a significantly higher proportion of highly reactive shells than non-singleton taxa (the finding above) because the majority of highly reactive genera (singletons) have already been lost from the fossil record, and thus cannot be counted. A more telling test is thus whether, among genera having highly reactive shells, singletons are more common than they are among genera with less reactive shells. Among the 9 pairwise tests of this (Table S3), only 4 indicate significant differences after Bonferroni correction and, of these, 3 are opposite to taphonomic expectation (Figure S4). Overall, ignoring significance, 6 of 9 tests find differences opposite to taphonomic expectation.

The results are thus robust: the most common (and the most frequently significant) differences are opposite to those expected if singleton status were largely the product of preservational bias. In both sets of tests for relationships between shell composition and singletonhood (Figures S3 and S4), the only taphonomically consistent relationship with statistical significance is with organic content, but this is as likely to be a reflection of evolutionary dynamics, owing primarily to the relatively large number of singleton trigonoid and inocermitid genera in the Mesozoic (both families underwent major diversifications and have long histories of systematic analysis and biostratigraphic application).

II. Median Duration Analysis

Highly reactive shells are defined as in the singleton analysis above. Combined scores are considered to be highly reactive if <5 and less reactive if ≥ 5 based on the observed range of values (combined scores are normally distributed; mean combined score is 5.9 for the Phanerozoic database, 5.5 for the Paleozoic subset of genera, and 6.0 for the post-Paleozoic subset).

Frequency distributions of genus stratigraphic ranges are strongly right-skewed (Figure S5), requiring non-parametric tests for significant differences in duration as a function of shell composition. Results of median tests are summarized in Table S4, including p-values before and after a Sequential Bonferroni correction to compensate for the large number of tests. Tests (four) where one or both median durations in the comparison were based on fewer than 100 genera were eliminated from the analysis, given the strongly skewed distribution from which genera were drawn.

III. Mineralogy and organic content considered together

Genera within Paleozoic and post-Paleozoic subsets of the database were grouped into four categories of different intrinsic preservation potential, based on a combination of shell mineralogy and organic-content. Ranked from low to high expected preservation potential, the categories were:

- a. shells composed entirely of aragonite and of high-organic microstructures (nacre and simple prismatic aragonite);
- b. shells composed entirely of aragonite but including some quantity of low-organic microstructures (shell may be entirely low-organic aragonite, e.g. some combination of composite prismatic, crossed-lamellar, complex crossed-lamellar, and homogeneous);
- c. shells contain some quantity of calcite but are composed entirely of high-organic microstructures (e.g., shells combine nacre and simple prismatic calcite); and
- d. shells contain some quantity of calcite (shell may be entirely calcite) and include some quantity of low-organic microstructures (may be entirely low-organic, e.g. some combination of foliated and finely prismatic or fibrillar calcite microstructures).

Median durations were calculated including singletons (Table S5). Observed p-values are significant for differences between lowest and highest ranked post-Paleozoic taxa but the values are opposite to taphonomic expectation (taxa with lowest preservation potential have longer median duration). The differences in median duration between lowest and highest ranked Paleozoic taxa, and between Paleozoic and post-Paleozoic low-ranked taxa (entirely high-organic aragonite) are consistent with taphonomic expectation but only marginally significant before Sequential Bonferroni correction and insignificant after correction. Because the percentage of singletons in groups varies in a way that magnifies the slopes of the two trends (see main text), excluding singletons from the analysis would only further reduce the significance of the differences in all comparisons, aside from the additional effect of reducing N's, which are already relatively low.

DISCUSSION

These results for bivalves are opposite to the consequences that are usually assumed to cascade from taxa having intrinsically low per capita preservation potential. The reasoning that low-potential groups will be rich in or consist exclusively of singletons (an idea going back at least to Raup 1938) may hold for non-mineralizing groups, where specimens are either beautifully preserved (rare lagerstätten) or not preserved at all. However, this same reasoning does not necessarily apply when considering preservational effects among mineralizing groups, which dominate the known fossil record: fossil shells can be preserved under a range of circumstances, albeit sometimes in poor condition, and in fact their condition can range from poor to excellent even within a single bed. Taxa having the intrinsically highest preservation potential (generally expected to be those secreting low-Mg calcitic, low-organic, and/or low SAV microstructures) should tend to have relatively high morphologic acuity per preserved specimen, a high proportion of specimens preserved per locality, and a high proportion of fossiliferous localities within their stratigraphic and geographic ranges, all of which should lead to well-refined taxonomies (including over-splitting), more densely constrained range data, and thus the recognition of many (truthfully) short-ranging genera. The known record of low-potential shelled taxa should be less well-resolved both taxonomically and stratigraphically, leading to (artefactually) fewer singletons and longer median ranges.

Thus, based on the analyses here, the usual algorithm for modelling the effects of intrinsic preservation potential on evolutionary patterns might need inversion, at least when considering shell composition. Namely, among shelled taxa, having high proportions of singletons and shorter median durations is linked to having an intrinsically *high* preservation potential, not a low potential. Importantly, among shelled taxa, % singletons should probably not be used as a negative correlate of preservation (i.e., high when the quality of the record is low), but instead as neutral or perhaps positive index to the quality of large-scale evolutionary information.

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Table S1. Published data (S6, S39-40) on weight-percent organic matrix in bivalve shell microstructures. All values are means of multiple determinations.

Source	Microstructure, <i>Genus</i>	Mineralogy	Weight-%
S39	[Simple] prismatic, <i>Solemya</i>	Aragonite	4.8
S40	Simple prismatic, <i>Pinctada</i>	Calcite	4.8 (range 4.4-5.3)
S6	[Simple] prismatic, <i>Atrina</i>	Calcite	1.78
S6	[Fine] prismatic, <i>Mytilus</i>	Calcite	1.12
S40	Sheet nacre, <i>Pinctada</i>	Aragonite	2.3 (range 1.6-3.1)
S40	Sheet nacre, <i>Modiolus</i>	Aragonite	0.9 (range 0.72-1.05)
S6	Nacre, <i>Atrina</i>	Aragonite	1.30
S6	Nacre, <i>Unio</i>	Aragonite	0.69
S40	Composite prismatic, <i>Mercenaria</i>	Aragonite	0.34 (range 0.32-.039)
S6	[Composite] prismatic, <i>Mercenaria</i>	Aragonite	0.29
S40	Foliated, <i>Pecten</i>	Calcite	0.4 (range 0.29-0.42)
S6	Foliated, <i>Hinnites</i>	Calcite	0.08
S40	Homogeneous, <i>Arctica</i>	Aragonite	0.4 (range 0.14-0.55)
S6	Homogeneous, <i>Arctica</i>	Aragonite	0.05
S40	Crossed-lamellar, <i>Glycymeris</i>	Aragonite	0.3 (range 0.23-0.32)
S40	Crossed-lamellar, <i>Tridacna</i>	Aragonite	0.17 (range 0.13-0.19)
S40	Complex crossed-lamellar, <i>Tridacna</i>	Aragonite	0.06 (range 0-0.098)
S6	Crossed-lamellar, <i>Tridacna</i>	Aragonite	0.05

Table S2. Calculations for crystallite surface area:volume ratios (SAV), based on published data (S6, S8, S40) on crystallite dimensions (lengths and diameters). Mineralogy A = aragonite, C = calcite.

Source	Microstructure & mineralogy, <i>genus</i>	Idealized crystallite shape	Axis of rotation μm	2nd axis μm	3rd axis μm	Surface area μm^2	Volume μm^3	Surface Area / Volume
S6	Homogeneous A, <i>Arctica</i>	sphere	1	1	1	6.28	0.52	12
S8	Homogeneous A, <i>Arctica</i>	sphere	1.5	1.5	1.5	14.13	1.77	8
S8	Homogeneous A, <i>Arctica</i>	sphere	3	3	3	56.52	14.13	4
S40	Composite prismatic A	cylinder	10	2	2	69.08	31.4	2.2
S8	Fine prismatic C, <i>Mytilus</i>	cylinder	20	1	1	64.37	15.7	4.1
S8	Fine prismatic C, <i>Mytilus</i>	cylinder	20	3	3	202.53	141.3	1.4
S8	Fine prismatic C, <i>Mytilus</i>	cylinder	50	1	1	158.57	39.25	4.0
S8	Fine prismatic C, <i>Mytilus</i>	cylinder	50	3	3	485.13	353.25	1.4
S40	Small-tablet nacre A	cylinder	0.4	2	2	8.792	1.26	7
S6	Nacre A, <i>Unio</i>	cylinder	1	5	5	54.95	19.62	2.8
S6	Nacre A, <i>Unio</i>	cylinder	1	7	7	98.91	38.46	2.6
S6	Nacre A, <i>Atrina</i>	cylinder	1	10	10	188.4	78.5	2.4
S8	Normal-tablet nacre A	cylinder	2	10	10	219.8	157	1.4
S8	Normal-tablet nacre A	cylinder	3	10	10	251.2	235.5	1.07
S40	Slender lath in foliated C	prism	20	2	0.2	25.2	8	3.2
S40	Stubby lath in foliated C	prism	20	4	0.5	33	40	0.8
S8	Lath in crossed-lamellar A	prism	20	5	0.5	36	50	0.7
S40	Slender column in simple prismatic C	cylinder	200	9	9	5779.17	12717	0.45
S40	Stubby column in simple prismatic C	cylinder	200	80	80	60288	1004800	0.06

Table S3. Results of G-tests of the proportions of singletons among genera having highly reactive shell types versus all other shell types. Min = mineralogy, Org = organic content, SAV = surface area:volume ratio. Phan = Phanerozoic, Pz = Paleozoic, post-Pz = post-Paleozoic. Boldface = difference is significant at $p < 0.05$.

Aspect tested	Time bin	Total N	Highly reactive genera		All other genera		p-value observed	Difference consistent with taphonomic expectation?
			Singleton N	% singletons	Singleton N	% singletons		
Min	Phan	2846	407	20.5	264	30.7	<0.001	No, opposite
Org	Phan	2792	172	26.6	387	18.0	<0.001	Yes
SAV	Phan	2662	38	15.4	568	23.5	<0.005	No, opposite
Min	Pz	479	147	49.7	72	38.5	<0.025	Yes (but n.s. after Bonferroni)
Org	Pz	432	96	43.4	96	45.5	>0.5	No, opposite
SAV	Pz	379	3	42.9	165	44.4	>0.9	No, opposite
Min	Post-Pz	2367	261	15.4	193	28.7	<0.001	No, opposite
Org	Post-Pz	2360	76	22.5	378	18.7	>0.1	yes
SAV	Post-Pz	2283	35	14.6	403	19.7	>0.05	No, opposite

Table S4. Results of median tests for differences in the median duration of genera having highly reactive shell compositions and those having other shell compositions. Significant differences are boldface. Comb = combined score; all other abbreviations as in Table S3.

Aspect tested	Time bin	Includes single-tons?	Highly reactive genera		All other genera		p-value observed	Sequential Bonferroni p-value	Difference consistent with taphonomic expectation?
			N	Median duration m.y.	N	Median duration m.y.			
Min	Phan	Yes	1986	16.6	848	11.5	<0.0001	<0.0001	opposite
Min	Phan	No	1580	25.3	586	22.4	0.2314	n.s.	opposite
Org	Phan	Yes	559	14.5	2233	16	0.2985	n.s.	yes
Org	Phan	No	387	31	1759	23.5	0.0061	0.1037	opposite
SAV	Phan	Yes	243	16.6	2200	15.6	0.356	n.s.	opposite
SAV	Phan	No	208	24.9	1675	24.3	0.8384	n.s.	opposite
Comb	Phan	Yes	326	14.6	2109	16	0.3577	n.s.	yes
Comb	Phan	No	238	28	1644	24.1	0.212	n.s.	opposite
Min	Pz	Yes	291	2	187	7.9	0.0074	0.1184	yes
Min	Pz	No	147	23.5	113	31	0.3835	n.s.	yes
Org	Pz	Yes	221	7.5	211	5.4	0.556	n.s.	opposite
Org	Pz	No	125	39	115	29	0.366	n.s.	opposite
Min	Post-Pz	Yes	1695	18.5	661	12.1	<0.0001	<0.0001	opposite
Min	Post-Pz	No	1432	25.6	480	22.2	0.0671	0.9394	opposite
Org	Post-Pz	Yes	338	17.3	2021	16.6	0.573	n.s.	opposite
Org	Post-Pz	No	319	27.5	1644	23.1	0.0082	0.1230	opposite
SAV	Post-Pz	Yes	238	16.6	1875	16.6	0.633	n.s.	no
SAV	Post-Pz	No	204	24.4	1500	23.3	0.7517	n.s.	opposite
Comb	Post-Pz	Yes	230	18.4	1884	16.6	0.356	n.s.	opposite
Comb	Post-Pz	No	185	28	1522	23.2	0.137	n.s.	opposite
<i>Tests excluded due to small sample size:</i>									
SAV	Pz	Yes	7	19.5	325	4.5	0.69		opposite
SAV	Pz	No	4	87.8	175	35.5	0.2958		opposite
Comb	Pz	Yes	98	3	225	5.5	0.477		yes
Comb	Pz	No	53	2.8	122	37.5	0.657		yes

Table S5. Results of median tests for differences in the median duration of genera having maximum and minimum intrinsic preservation potential. Numbers in parens are N for category. A = entirely aragonite; C = includes some quantity of calcite; hi-org = entirely high-organic microstructures; other org = includes other microstructures. Significant results in boldface.

	Median Duration (m.y.)				Observed p-value	Sequential Bonferroni p-value	Consistent with taphonomic expectation?
	A + hi-org	A + other org	C + hi-org	C + other org			
Paleozoic	4.4 (58)	2 (157)	7.5 (116)	16.5 (49)	0.066	n.s.	Yes
Post-Paleozoic	17.9 (219)	18.45 (1407)	16.5 (114)	12.1 (543)	0.004	0.012	Opposite
Observed p	0.04			0.46			
Bonferroni p	n.s.			n.s.			
Consistent?	Yes			no			

Figure Captions

Figure S1. Despite variability in measurements, microstructures sort into two groupings: high-organic types with $\sim >0.5$ and as much as 5 weight-% organic, and low-organic types having <0.5 and as little as 0.05 weight-% organics. Plotted from data in Table S1.

Figure S2. First-order crystallites in bivalve microstructures exhibit a continuous spectrum of surface area: volume (SAV) ratios spanning almost 3 orders of magnitude. Homogeneous microstructure and simple prismatic microstructure define end-member high and low SAV categories respectively, and all other microstructures are categorized as moderate SAV. Plotted from data in Table S2.

Figure S3. Results of G-tests of proportions of singleton taxa and non-singleton taxa having highly reactive shells (see text for definitions). Points falling above the diagonal match the taphonomic expectation that singleton taxa have a higher frequency of highly reactive shells than do non-singleton taxa. Significance is based on results of a Sequential Bonferroni Correction using a threshold p of 0.05. Plotted from data in Table 1 in main text.

Figure S4. Results of G-tests of proportions of highly reactive genera (y-axis) and all other genera (x-axis) that are singleton taxa. Points falling above the diagonal match the taphonomic expectation that aragonitic, high-organic, or high SAV shells contain higher proportions of singleton taxa. Significance is based a threshold p of 0.05. Plotted from data in Table S3.

Figure S5. Stratigraphic durations of genera are strongly right-skewed with or without singletons included in the frequency distribution.

Figure S1.

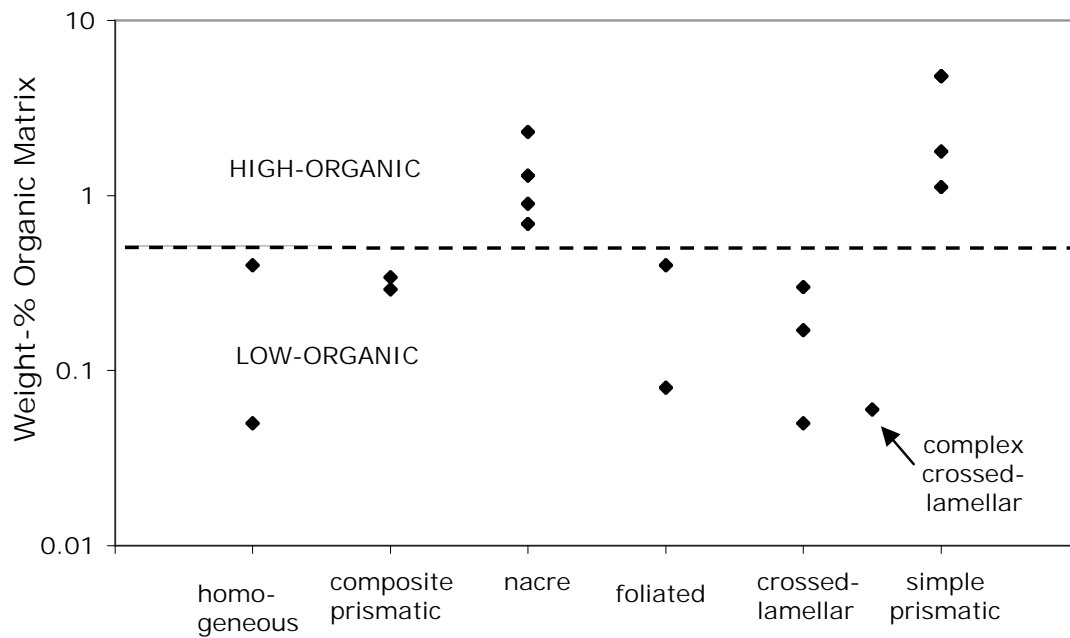


Figure S2.

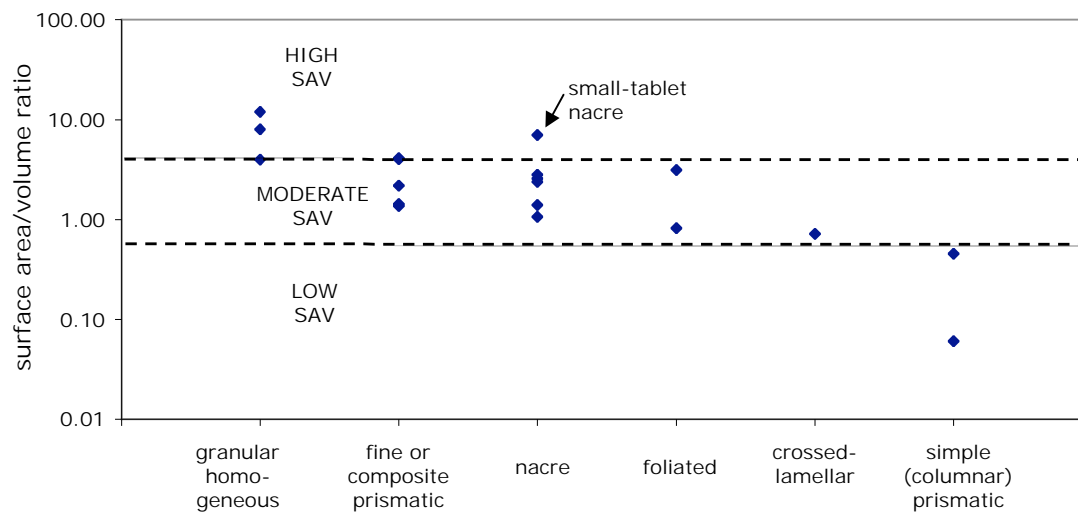


Figure S3.

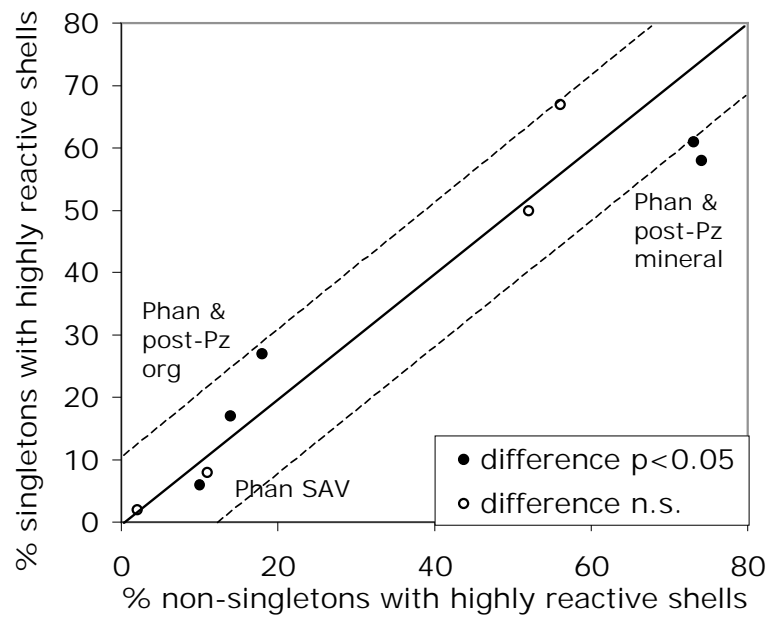


Figure S4.

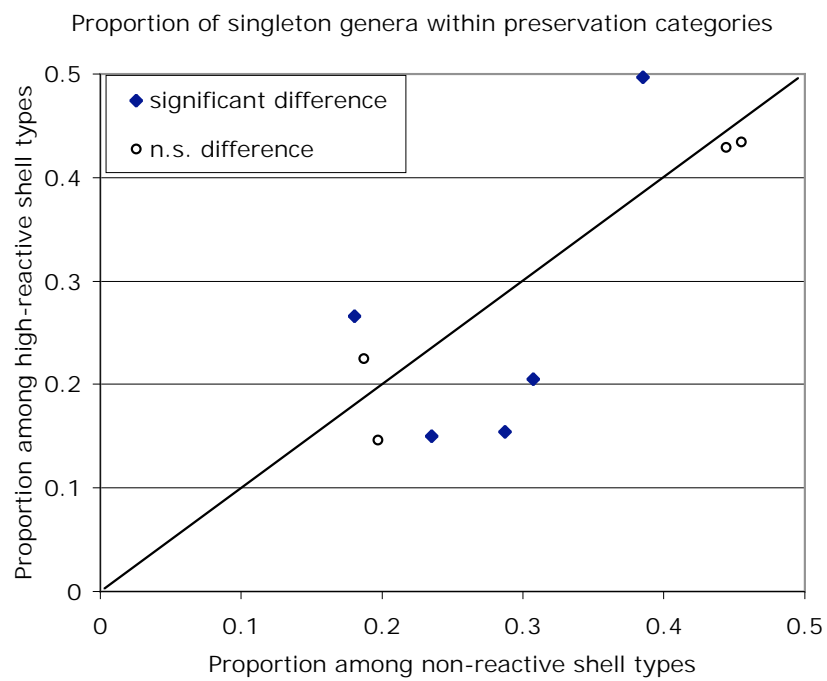


Figure S5.

