Modeling the transition of death assemblages from surface to subsurface: predicting the effects of burial, mixing, and disintegration on time averaging

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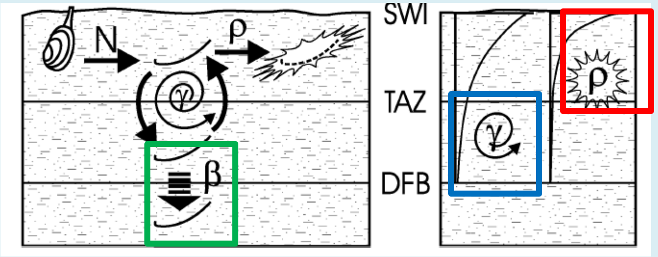


Olszewski 2004 Palaios

Taphonomic active zone (TAZ) (and strongly mixed)

Sequestration zone (SZ) saved from destruction but still within the reach of burrowers

Final burial zone (FBZ)

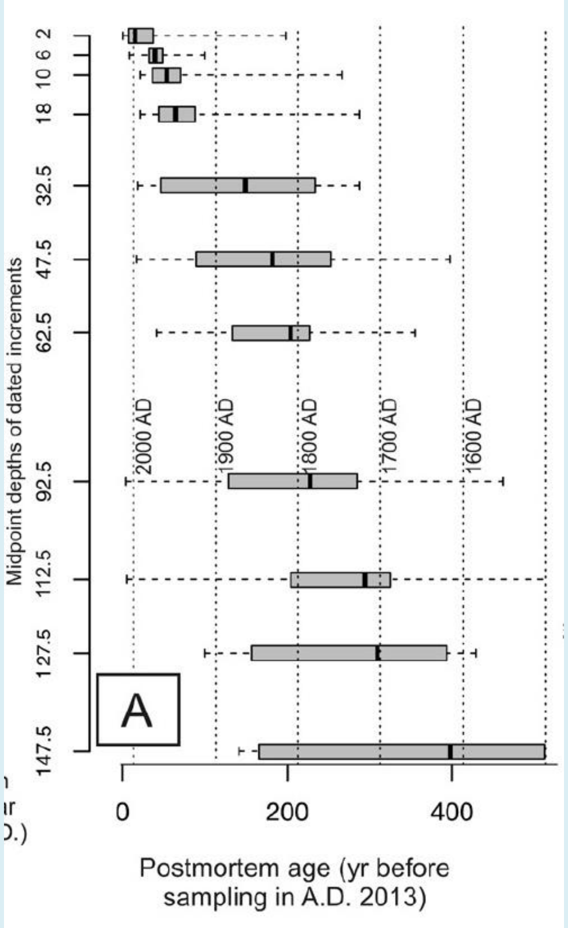
→ It is unclear whether the transition of death assemblages through the mixed layer and through the taphonomically active zone (TAZ) into historical layers produces stratigraphic trends in time averaging

→ it is (relatively) simple to predict spatial and temporal variability in time averaging when mixing (by bioturbation), shell disintegration and sedimentation vary in isolation

→ **but it is difficult to predict spatial and temporal variability in time averaging when mixing (by bioturbation), shell disintegration and sedimentation covary**

→ Former empirical studies suggested that time averaging shifts directionally downcore from skewed to more symmetrical distributions → Great Barrier Reef (Kosnik et al. 2007; 2009; 2013), Copano Bay (Olszewski and Kaufman 2015), Sydney Harbour (Dominguez et al. 2016), northern Adriatic Sea (Tomašových et al. 2017, 2018, 2019b), southern California (Tomašových et al. 2019a), as well as in terrestrial systems (Terry and Novak 2015)

→ this downcore trends is coupled with an increase **in age range/inter-quartile age range**



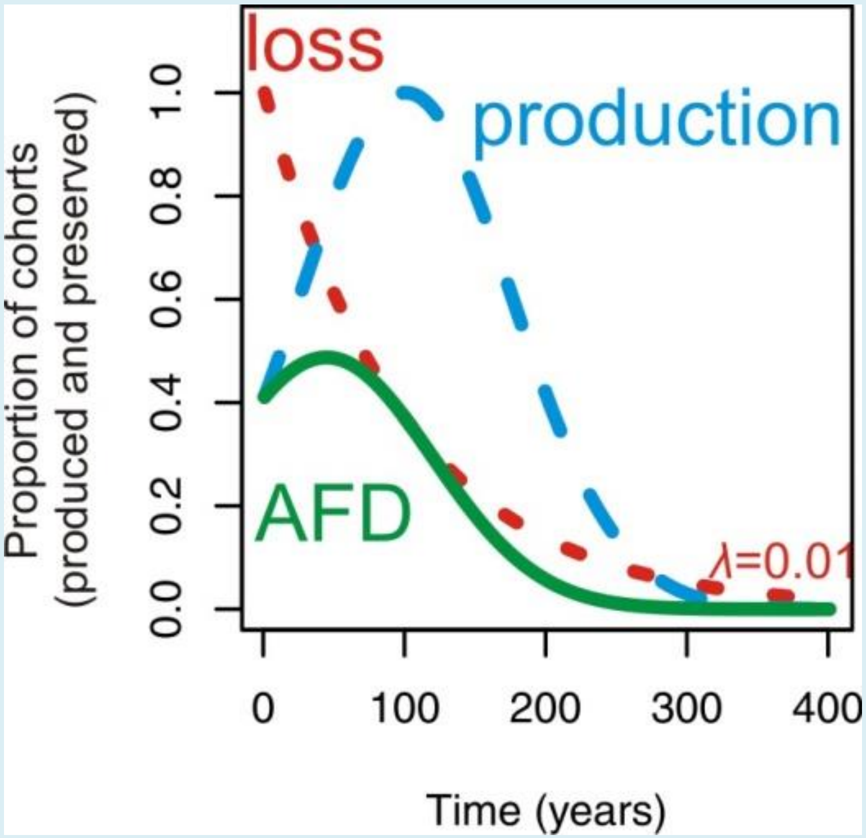
→ Modeling studies that showed the shift:

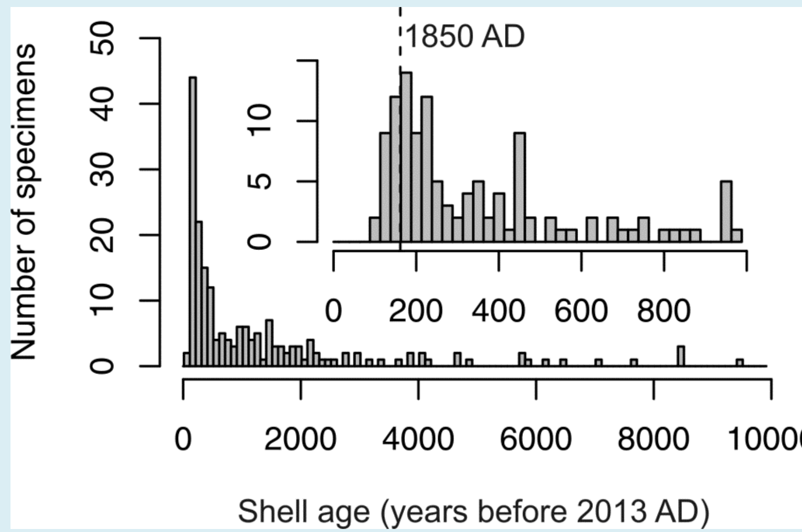
- Olszewski 2004 – sequestration model
- Tomašových et al. 2014 – sequestration model
- Terry and Novak 2015 – mixing model

→ unclear if this happens under some combination of parameters only, if this is some Anthropocene effect of reduced bioturbation, or both

→ Time averaging – or the structure of age-frequency distributions (e.g., 10-15 cm-deep Van Veen grabs or top-cores) – is also shaped by temporal changes in input (from production)

→ not the topic of this talk





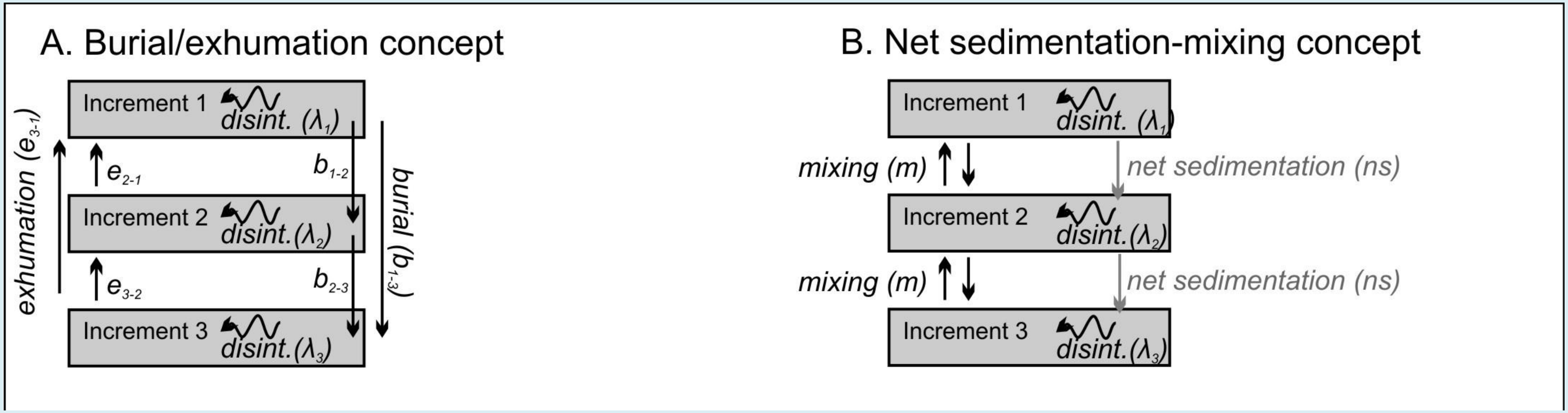
Tomasovych and Kidwell 2017 Proceedings RSB

GOALS

→ extend the framework used in the modeling of the transition of shells between the TAZ and SZ to more than two stratigraphic layers

→ use transition-rate matrices to model the effects of (1) mixing, (2) the depth of the mixed layer, (3) disintegration rate in the TAZ, (4) depth of the TAZ, and (5) sedimentation rate **on time averaging** (*in the absence of any temporal changes in these parameters)*.

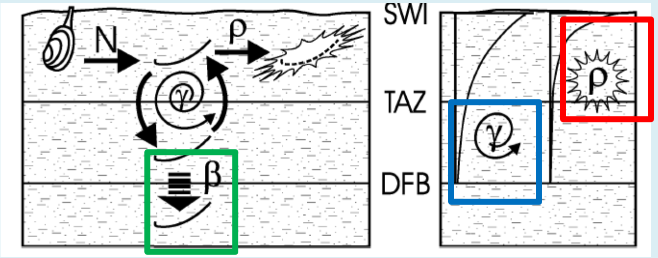
→ this approach can also inversely estimate these (sedimentation, mixing, disintegration) parameters from empirical data



Transition-rate matrices - individual shells are buried and exhumed between stratigraphic levels and disintegrate independently, i.e., some subset of particles (shells) can move into the next deeper increment, some can remain in place, some can move upward into a shallower increment, and others can be lost by disintegration
→ applies to increments affected by bioturbation

A → downward vectors of movement (burial *b* from all sources; movement into any deeper increment of the sedimentary column),
upward movement (exhumation *e*, which is movement up into any overlying increment), and disintegration (λ)

B → if downward and upward mixing are equal and non-local mixing is neglected, then the transitions reflecting burial and exhumation of shells can be converted to other two types of transitions - the net sedimentation rate and the between-increment mixing rate (with equal upward and downward component).

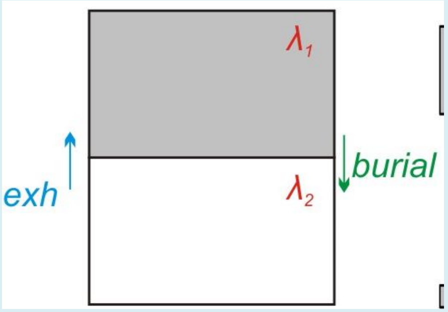


Olszewski 2004

1. Disintegration
2. Exhumation
3. Burial

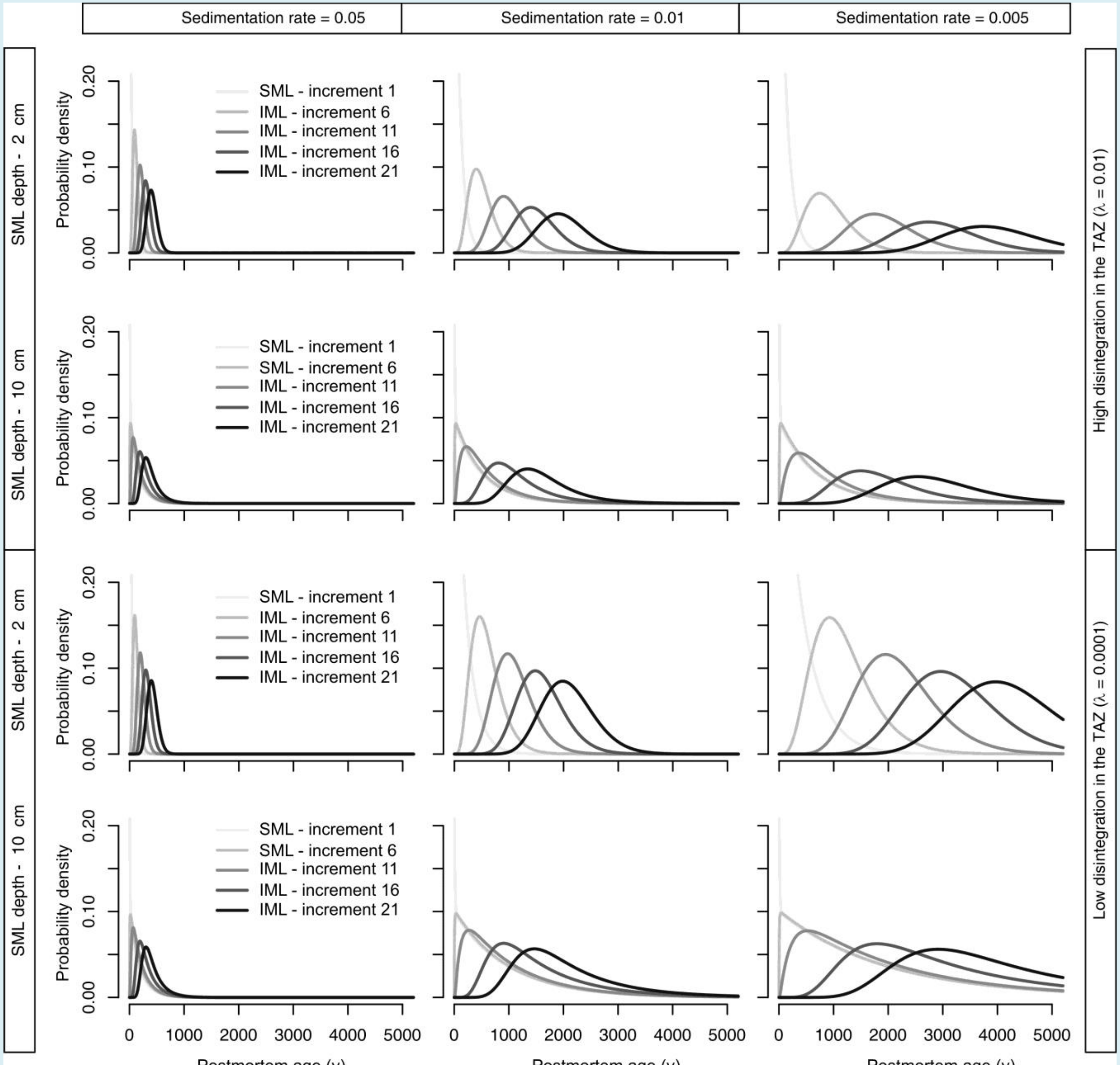
→ Two-phase exponential models with two phases of shell disintegration (in the TAZ and in the zone below) is equivalent to transition-rate matrix with three parameters

→ example of transition-rate matrix with 2 stratigraphic layers



	Layer 1	Layer 2	Disint.
Layer 1	-(∑qij)	b12	λ_1
Layer 2	e_{21}	-(∑qij)	λ_2
Disint.	0	0	0

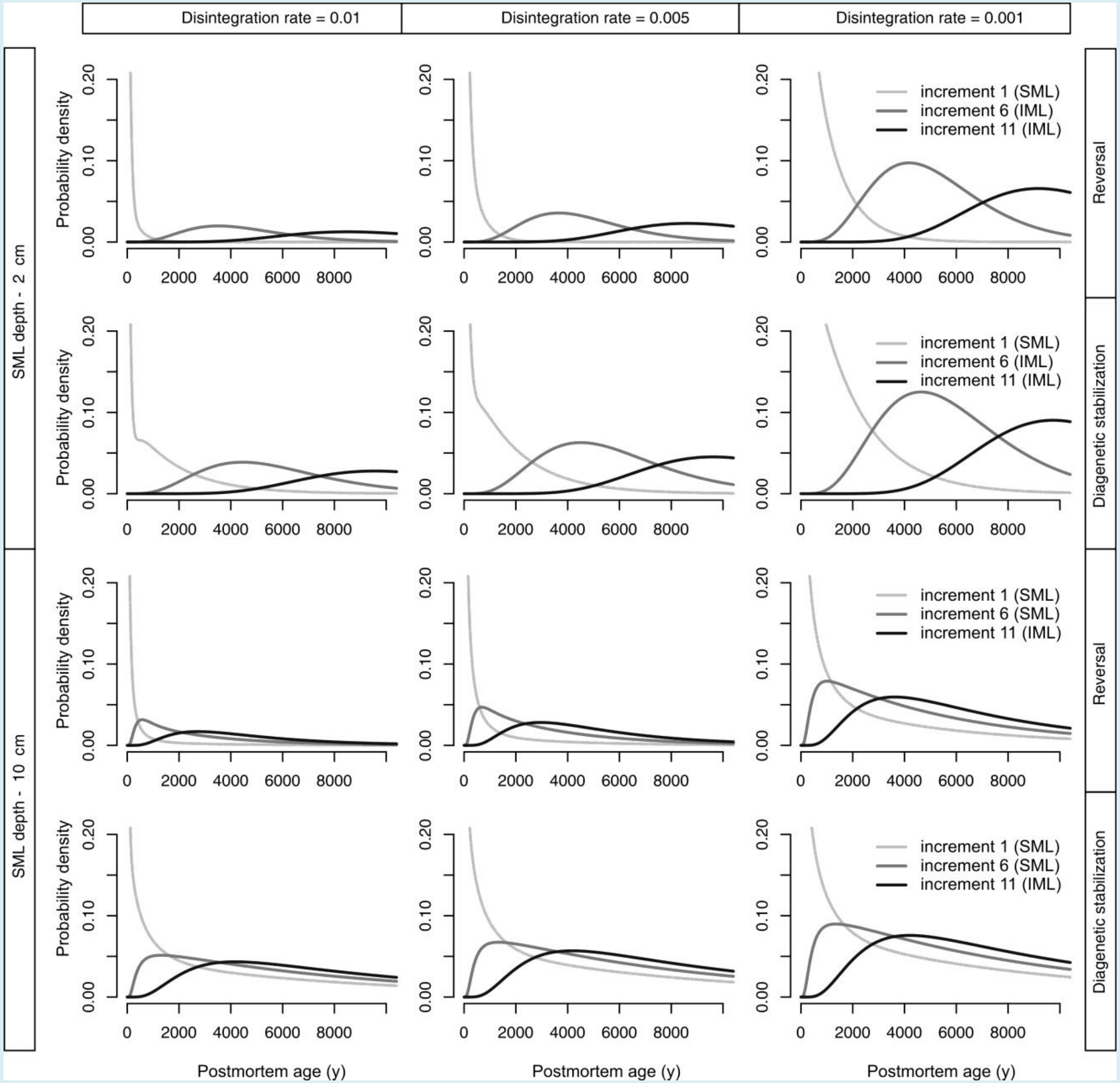
MODEL RESULTS



→ Downcore shift in the shape of shell AFDs as a function of three net sedimentation rates, two disintegration rates, and two depths of the surface mixed layer

→ all combinations produce a downcore shift from right-skewed to more symmetric distributions, with an increase in inter-quartile age range and a decline in skewness and kurtosis.

MODEL RESULTS



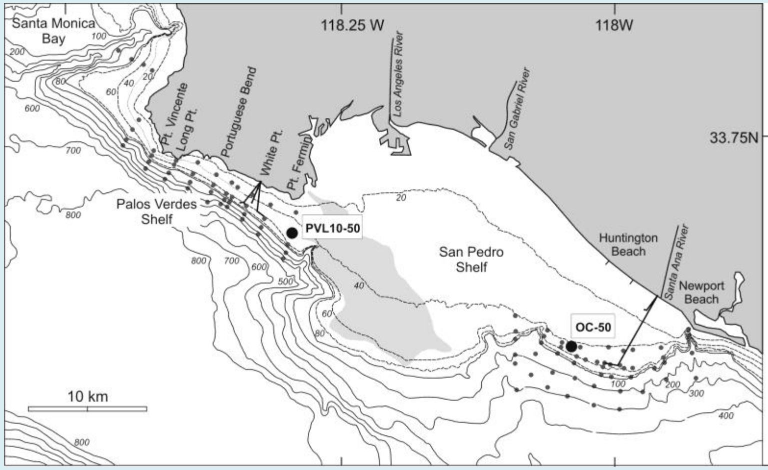
→ Downcore shift in the shape of shell AFDs within layers as a function of scenarios with and without diagenetic stabilization

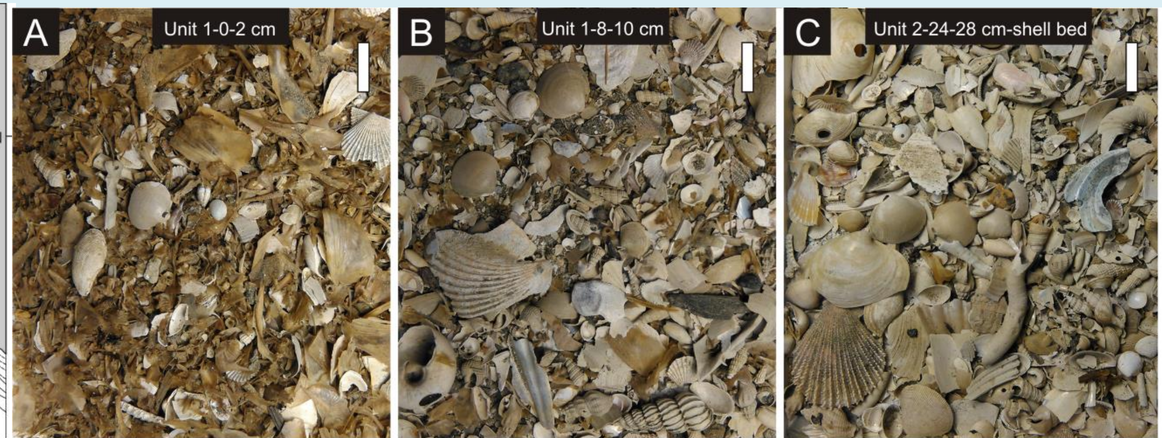
→ when λ_1 is high in the TAZ, SML assemblages become L-shaped under diagenetic stabilization below the TAZ (as those shells are exhumed back to the TAZ), but time averaging will still increase downcore.

RESULTS

→ The subsurface AFDs become flatter and less skewed as deeper increments within the incompletely-mixed layer (IML) still receive younger cohorts from shallower increments, producing the left tail and increasing their age range.

→ The increase in time averaging develops even (1) when disintegration rate in the TAZ is zero and thus does not decline downcore, (2) when mixing rate declines downcore within the mixed layer, (3) when shells in the sequestration zone (SZ) are diagenetically-stabilized, and (4) without recourse to temporal changes in the rate of sediment accumulation or in the rate of bioturbation.





Parvilucina

Nuculana

- → 266 dead specimens of *Parvilucina* and 583 dead specimens of *Nuculana*
- → Collected at two sites at 50 m on the southern California shelf with boxcore and vibrocores in 2012
- → Age data collected from the the uppermost 51 and 85 cm, collected at 4 cm resolution
- → Coarser, 20 cm-thick units used here

Paleoceanography and Paleoclimatology

RESEARCH ARTICLE
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Key Points:
- Age offsets cannot be predicted from estimates of sedimentation rate and the thickness of the surface mixed

Millennial-Scale Age Offsets Within Fossil Assemblages: Result of Bioturbation Below the Taphonomic Active Zone and Out-of-Phase Production

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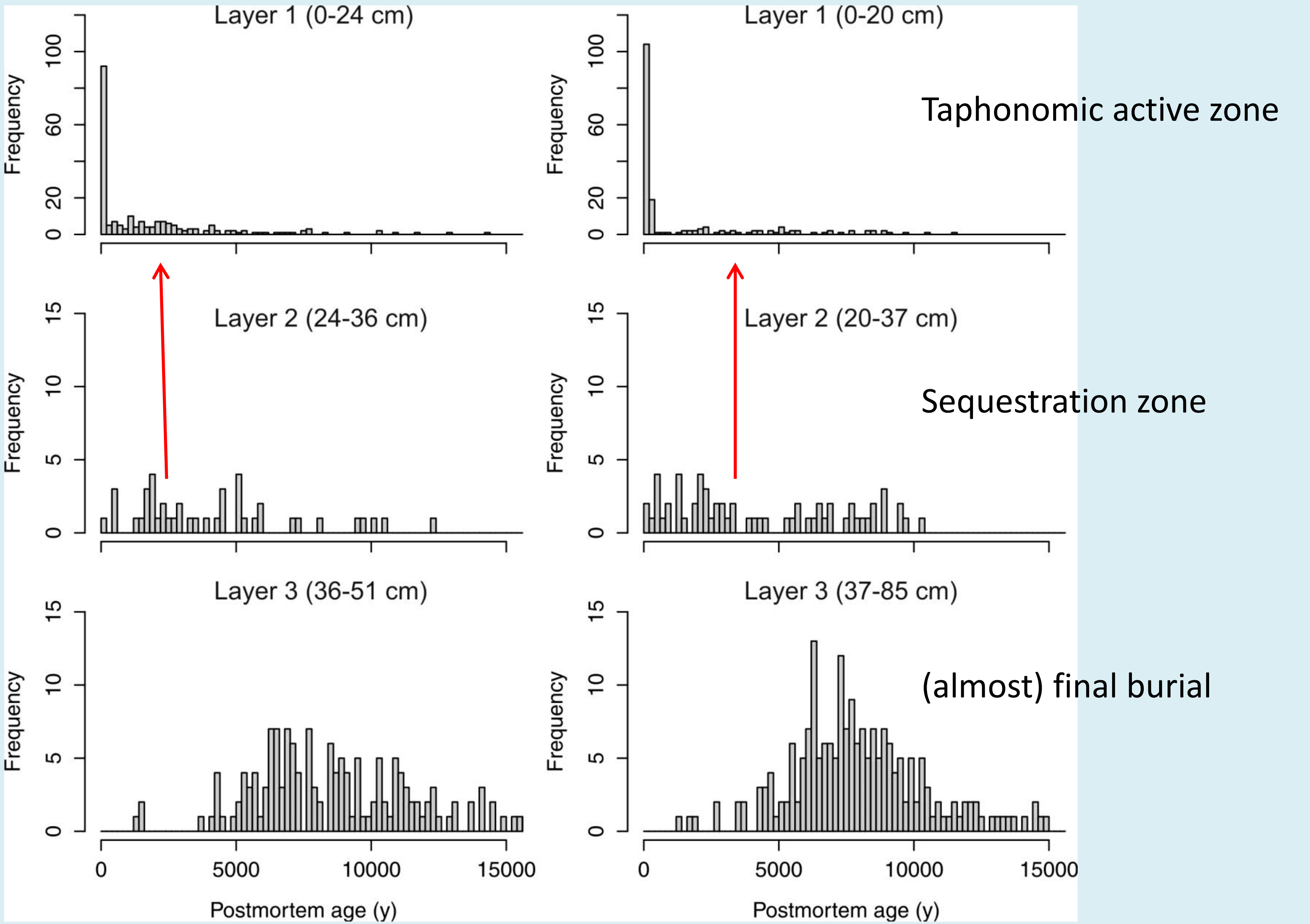


→ Age-frequency distributions in three stratigraphic units at PVL10-50 and OC-50

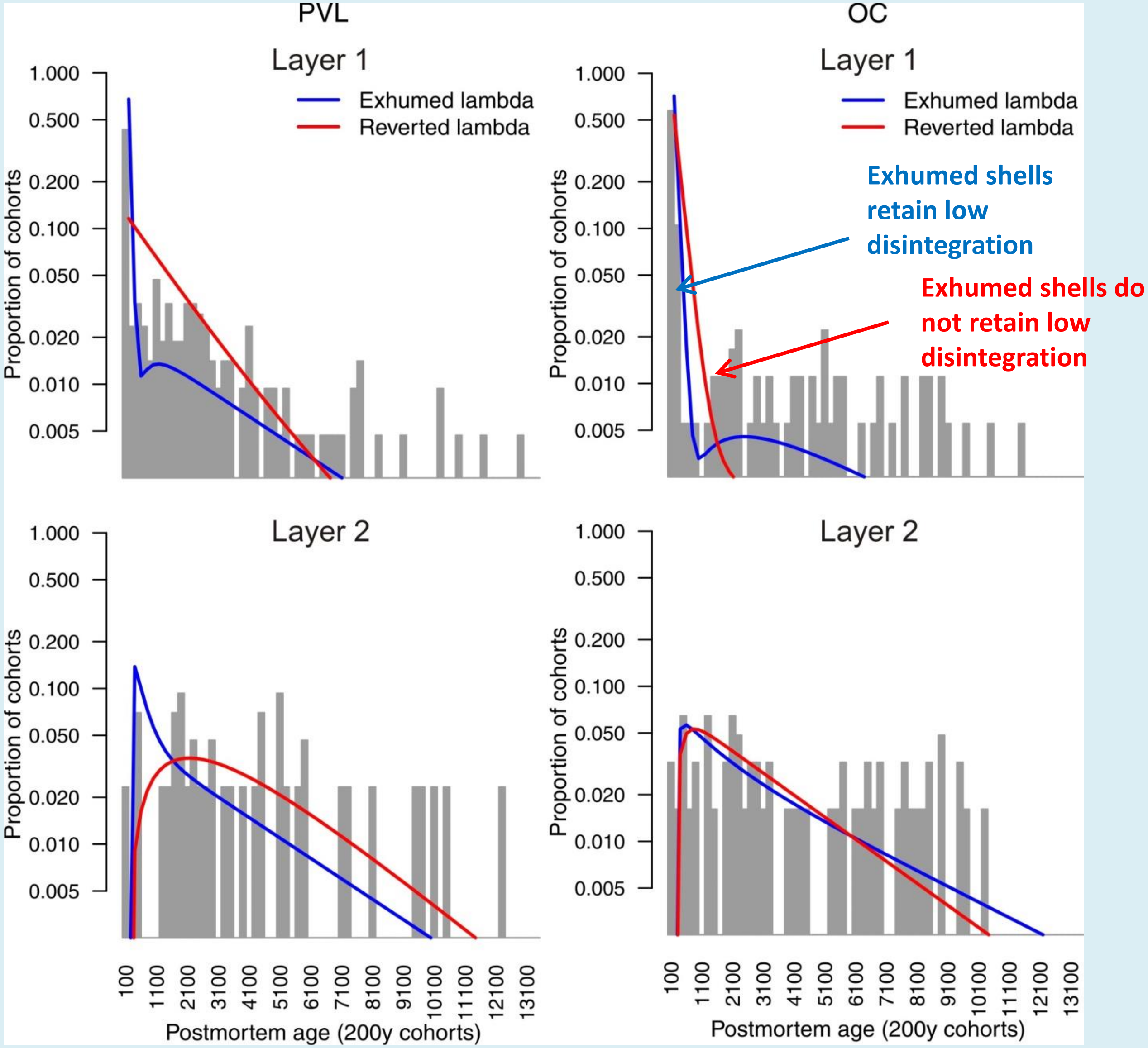
→ Downcore shift from L-shaped to normal-shaped distributions

→ **Visually, the fat tail of the surface AFD is sourced from the underlying shell bed**

RESULTS

→ using transition rate matrixes to fit empirical data and estimate parameters of burial, exhumation and disintegration

→ exhumed lambda – diagenetic stabilization scenario is better than scenario without stabilization

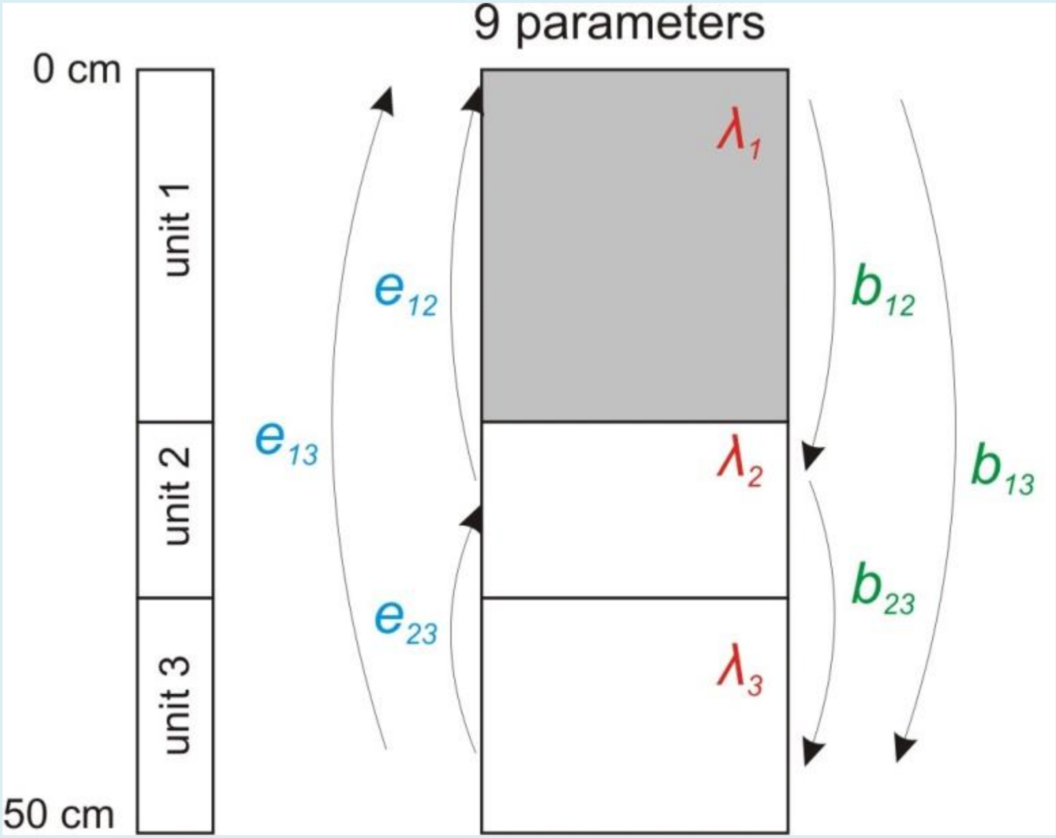


Disintegration in Layer 1 = 65 yr
Disintegration of exhumed shells ~2,200 yr
Disintegration in Layer 2 > 10,000 yr
Burial = 1880 yr, **Exhumation = 600 yr**

Disintegration in Layer 1 = 107 yr
Disintegration of exhumed shells ~2,500 yr
Disintegration in Layer 2 > 10,000 yr
Burial = 5600 yr, **Exhumation = 2100 yr**

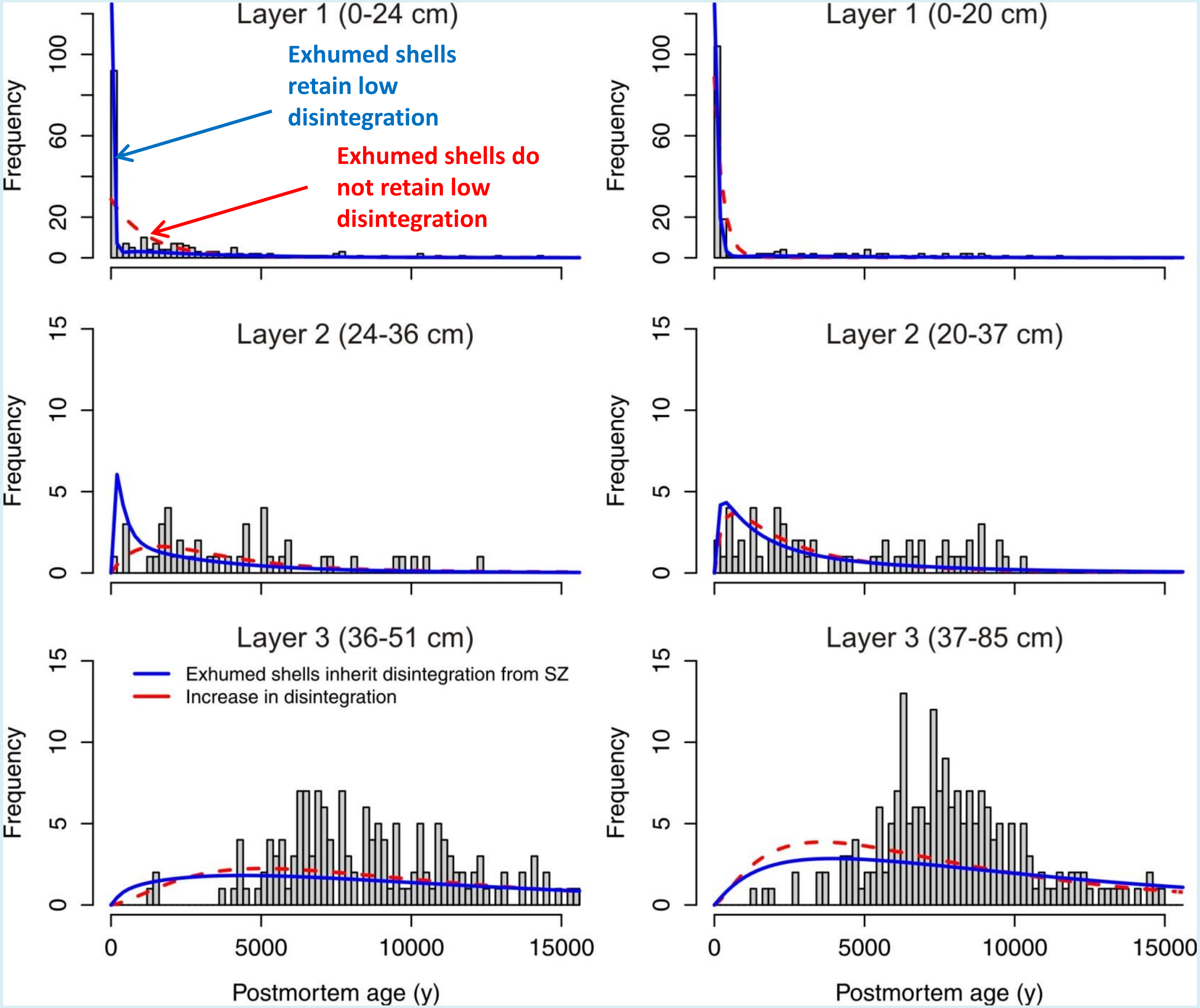
Stratified data – 3 layers – 9 parameters (3 disintegration, 3 burial and 3 exhumation rates)

	Layer 1	Layer 2	Layer 3	Disint.
Layer 1	$-(\sum q_{ij})$	b_{12}	b_{13}	λ_1
Layer 2	e_{21}	$-(\sum q_{ij})$	b_{23}	λ_2
Layer 3	e_{31}	e_{32}	$-(\sum q_{ij})$	λ_3
Lost shells	0	0	0	0



RESULTS

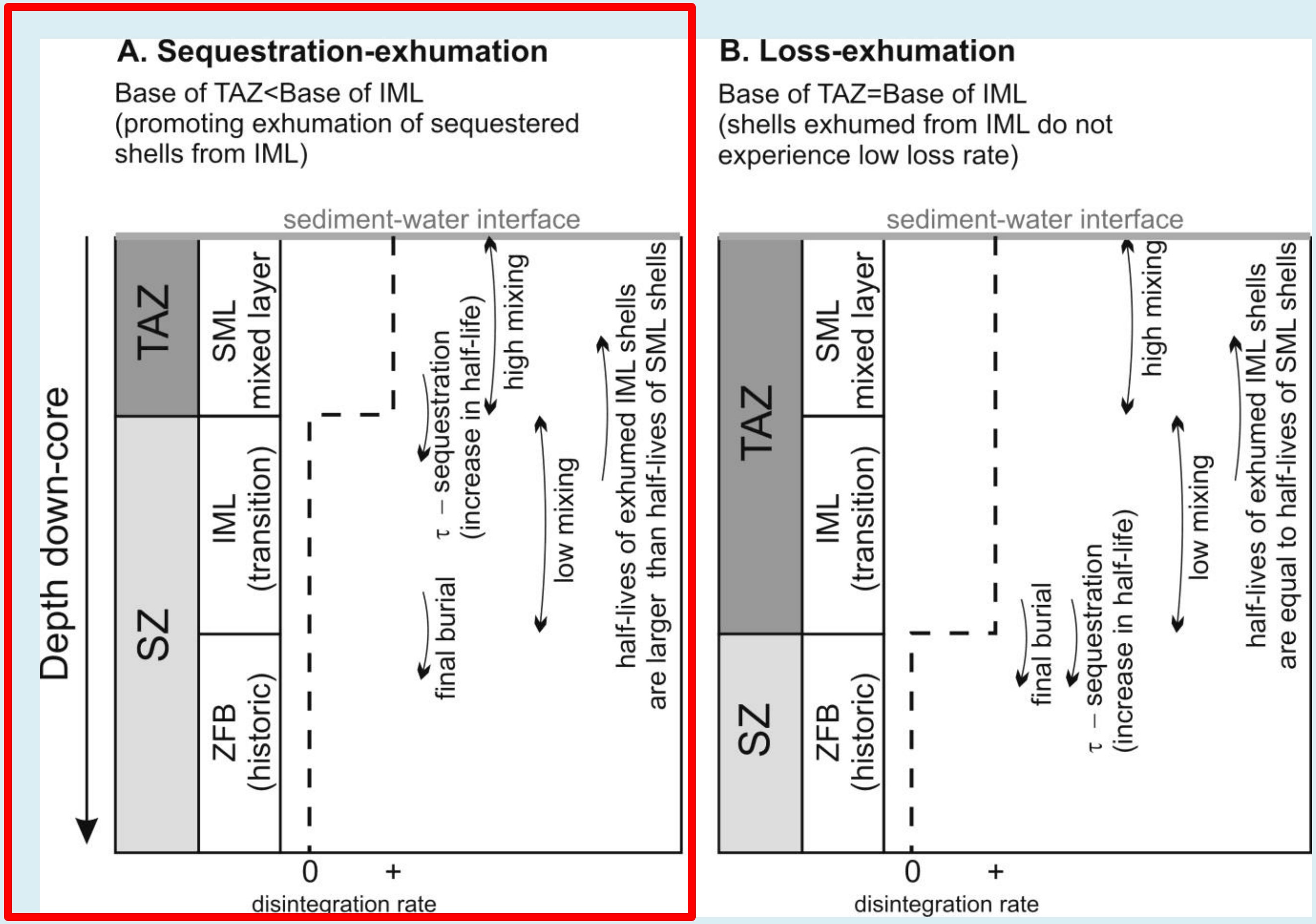
→ Support for models where the exhumed shells have two-order-of magnitude lower disintegration rate than non-exhumed shells in the TAZ



CONCLUSIONS

→ Transition-rate matrix models naturally extend from two-phase exponential models to models with depth-specific dynamic of disintegration, burial and mixing

→ bioturbation depth exceeds the depth of the taphonomic active zone and the tail of old shells is due to exhumation → significant implications for shell preservation



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