Talk 60.2 *Pywackia*

**SLIDE 1**: We have completed a restudy of *Pywackia* and concluded that it isa stem-group stenolaemate, or stony bryozoan, from the Late Cambrian. *Pywackia,* with tiny, elongate zooaria, is Earth’s oldest known bryozoan. The restudy is in press with the *Journal of Paleontology*.

**SLIDE 2**: Paul Taylor and others concluded in 2004 that bryozoans missed the Cambrian Radiation and appeared in the Ordovician. In 2007, they illustrated 481 m.y.-old, late Tremadocian forms as the oldest bryozoans from South China. In later papers, these bryozoans became the “oldest on Earth.” However, our 2010 Mexican report took the phylum record back 8 m.y. into the Late Cambrian and documented simple morphologies of early stony bryozoans. Interestingly, the oldest known bryozoans, euconodonts, and cephalopods—see the blue oval in the figure—have nearly coeval appearances for these three important groups of the Great Ordovician Radiation. Finally, the Mexican report concluded all biomineralized phyla and almost all classes appeared by the Late Cambrian.

**SLIDE 3**: On the left, it is evident the Chinese late Tremadocian bryozoans are derived. They include two orders with branched to small mound-like colonies and complex histologies with extrazooecial tissue and several types of large individuals. They cannot be “Earth’s oldest bryozoans.” They are much more elaborate than the unmineralized ctenostomes with a budding stolon and feeding zooids on the right. These simple forms are likely close morphologically to the oldest, stem bryozoans.

**SLIDE 4**: *Pywackia* was discovered in southern Mexico. The lower left figure shows central Mexico comprises the Oaxaquia terrane with a middle Proterozoic basement. On the right, Oaxaquia formed the South American margin of West Gondwana after the Rodinia breakup. Our two field areas north of Oaxaca City are in the red oval in the upper left. “SiX” is a slope succession of the Cambrian–Ordovician Tiñu Formation. *Pywackia* occurs in section “Tu,” a shelf succession of the Tiñu Formation.

**SLIDE 5**: The left figure shows the Tiñu Formation has a 13 m-thick, limestone-rich, Late Cambrian member. The limestones of this member on the right are wave-deposited tempestites. Back on the left, the red bar shows the small range in which *Pywackia* fragments were recovered by acid break-down of limestones.

**SLIDE 6**: The slab shows the distinctive phosphatic grainstones and mudstones that yielded *Pywackia*. Episodic high depositional energies and phosphatization on a low oxygen shelf were important in the taphonomy and preservation of *Pywackia*.

**Slide 7**: *Pywackia* was found in the lower 5 m of section, note the red rectangle. It only occurs with abundant phosphate sand, phosphatic cement druse, and hexaxons, chancellorids, gastropods, agnostoids, trilobites, and crinozoan columnals—all of which are phosphatized.

**SLIDE 8**: Exquisite fragments of *Pywackia* were found. They, as the originally calcareous fossils, are phosphatic, and include three parts of a small, tube-like fossil. The parts include a distal extremity, at the top left. “Medial stem” fragments form the middle of the diagram. And there is a saber-like to sharply rounded “basal extremity.”

Morphologic features, often badly obscured in wave-abraded specimens, show 11 synapomorphies or putative synapomorphies of *Pywackia* with stony bryozoans.

The eroded shallow to better preserved deeper pits on most fragments are zooecia of a colonial organism. A bilateral symmetry is indicated by interior, medial ridges, as in the specimen on the far left. Bilateral symmetry and associated mictostructures rule out a hydrozoan or a tabulate affinity.

Synapomorphies with stony bryozoans include coloniality and the bilateral symmetry of large zooids. Three more synapomorphies derive from polymorphism. Large, probable feeding individuals with rounded polygonal walls that cover most of the fragments are about the same size as stony bryozoan autozooecia. A hollow rod-like axial zooecium occurs in longitudinally broken fragments, see the upper right individual with “az” in red, and is easily seen when not filled and obscured by phosphate. Finally, the right-lower figure shows a tiny depression at autozooecial wall intersections; this third polymorph is a probable nanozooid. There is no size overlap or overlap in shape between the three zooid polymorphs.

Budding methods establish two more synapomorphies. The middle stem fragment with a red star shows autozooids budded as in stony bryozoans—the red star is on a broken, second generation autozooid. Now, the oval, transverse specimen in the upper right has 6 generation 1autozooecia, with red numeral 1s, formed by axial zooid budding. These generation 1 individuals then budded to form generation 2 autozooecia. Thus, *Pywackia* zooaria are 6- and 12-sided. A longitudinal fragment, upper right, shows the axial zooecium abuts a line of generation 1 autozooecia, and a generation 2 autozooecium is perched above the level of generation 1. Thus, what are the longitudinal ridges on the autozooecial midlines noted earlier?—they probably mark the wall separating the axial zooid from a daughter autozooecia, as in some later stony bryozoans.

With less wave abrasion and higher autozooecial walls, the bulky specimen on the middle left shows that autozooecia had at least two levels of cross partitions, or diaphragms, labeled d1 and d2.

The basal extremity on the lower left has a succession of diaphragms marked “d” and low transverse ridges, or hemiphragms, marked “h.” This specimen shows how very deep unabraded *Pywackia* autozooecia were. Diaphragms, deep autozooecia, and hemiphragms mean *Pywackia* has10 synapomorphies with stony Bryozoa.

**Slide9**: Based on this evidence we proposed *Pywackia* as Earth’s oldest known stony bryozoan and suggested it formed part of a low feeding tier.

**Slide 10**: Paul Taylor et al. largely discounted all of this in a 2013 paper, but, oddly, accepted without discussion such bryozoan-like features as hemiphragms, diaphragms, nanozooecia, and the size of autozooecia apertures. They proposed *Pywackia* was the axial rod of an originally phosphatic pennatulacean octocoral.

The Tayor et al. paper has a high mountain to climb. Pennatulaceans have frond-like or stubby colonies. Their hard parts are primarily limited to a high-magnesium calcite axial rod with a longitudinal, wood-fiber histology and circular to quadrate cross section. Many papers regard Ediacaran fronds as pennatulaceans—this is incorrect as these vendozoans lack a mineralized axis, have a fractal structure, and grow from the base, not, top of the frond.

As pennatulaceans are unknown before the middle Mesozoic,Taylor et al. extended the group’s range 410 m.y. into the Cambrian—our range extension of bryozoans is 8 m.y. Taylor et al. presumed that Cambrian pennatulaceans like *Pywackia* should be phosphatic—this was based on a 1980’s paradigm that very early Cambrian biomineralization was largely phosphatic, a belief first shown to be false by Landing et al. in 1989 and 1992, who documented largely calcareous and aragonitic original compositions of small shelly fossils that were phosphatized in Asian successions.

**Slide 12**: Taylor et al. compared *Pywackia* to the larger axial rod of *Lituaria,* a Recent pennatulacean with mineralized autozooecial walls. Except for coloniality, none of the stony bryozoan synapomorphies listed above occur in *Lituaria*—as no diaphragms, hemiphragms, or autozooid budding. The taxa have twig-like zooaria, but those in *Pywackia* are 6- or 12-sided, those in *Lituaria* 4-sided*.* More importantly, the budding individual or central chord remains open in *Lituaria*, but was apparently closed by the mineralized ridges on the *Pywackia* autozooecial midlines.

**Slide 13**: *Pywackia,* if a pennatulacean, should have a wood grain histology. No!—*Pywackia* has a granular fabric and a local, granular-prismatic histology. Granular and granular prismatic fabrics are an 11th synapomorphy of *Pywackia* with bryozoans. Indeed, these fabrics are unknown in any originally phosphatic sclerite of any taxonomic group. Thus, *Pywackia* zooaria cannot be considered to be originally phosphatic, were originally likely calcite, and cannot be histologically related to the Pennatulacea.

**Slide 14**: Taylor et al. claimed the irregular form and distribution of *Pywackia* autozooecia and lack of branching were non-bryozoan. Regular autozooid spacing in bryozoans reduces inter-individual competition. But no one seems to have explained how the regular spacing is achieved. We propose that advanced bryozoans use “spacers,” as extrazooecial tissue and large polymorphs, some of which are represented by styles, to maintain regular autozooid spacing.

*Pywackia* lacked “spacers.” Its autozooecia are comparable to the generally 5- to 7-sided, rounded polygons formed by packing of initially soft cellular units into a 14-hedron. 14-hedrons basically look like the Beijing Water Cube on end. With budding from an axial zooid, the initially soft, unmineralized autozooids would find their closest packing in a 14-hedron. Without spacers, the daughter zooids remain in close-packed association and this precludes branching. In short, *Pywackia* “looks topologically normal” for a “stripped-down” stony bryozoan.

**Slide 16**: In conclusion, a *Pywackia* restudy shows that stem-group stony Bryozoa appeared by the Late Cambrian. 8 m.y. later, derived, typical Paleozoic-aspect stony Bryozoa occur in the late Tremadocian. Earth’s oldest stony Bryozoa may have appeared early in the Cambrian.To imagine this ancestor, take a ctenostome-like form, close-pack newly biomineralized autozooecia around a newly mineralized stolon, and the result resembles *Pywackia*.

Thank you.