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Evolutionary 'Game-Changer': Weird Armored Amphibian Lived in Ancient Triassic Seas

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To explore the physiological, geochemical, and evolutionary mechanisms governing this discovery, consult our peer-reviewed Encyclopedia entries on the Permian-Triassic Extinction Event, Homeostasis & Osmotic Regulation, Strontium Isotope Geochemistry, Fossiliferous Limestone, and Convergent Evolution.

For more than two centuries of vertebrate paleontology, one physiological boundary has appeared virtually absolute: amphibians do not live in the open ocean. Whereas reptiles, mammals, and birds repeatedly invaded marine ecosystems throughout the Phanerozoic, living frogs, salamanders, and caecilians are restricted to freshwater and terrestrial habitats by their permeable, scaleless skin. A landmark study published in *Nature Ecology & Evolution* by paleontologists Lipin Diao, Ryosuke Motani of the University of California, Davis, Da-yong Jiang of Peking University, and colleagues at the Geological Museum of Guizhou has overturned that consensus. The team describes *Gerrothorax maritimus*, a bizarre, heavily armored, flattened stem-amphibian from 237-million-year-old Late Triassic marine deposits in southwestern China that lived its entire life on the ocean floor.

1. The Amphibian Salt Barrier: Why Seawater Is Usually Lethal

To appreciate why an obligate marine amphibian represents an evolutionary game-changer, one must examine vertebrate osmotic homeostasis. Modern amphibians (Lissamphibia) rely heavily on cutaneous respiration -- exchanging dissolved oxygen and carbon dioxide directly across a thin, heavily vascularized epidermis coated in mucus. While effective in freshwater and humid terrestrial microhabitats, a water-permeable cell membrane and skin barrier become fatal liabilities in full-strength seawater.

Typical open-ocean water carries an osmotic concentration of roughly 1,000 milliosmoles per liter (mOsm/L; ~35 practical salinity units), whereas typical vertebrate blood plasma is maintained near 280 to 320 mOsm/L. Placed in seawater, an unarmored amphibian experiences a steep outward water potential gradient alongside a massive inward diffusive flux of sodium (Na⁺) and chloride (Cl⁻) ions, overwhelming cellular transmembrane pumps and inducing rapid systemic dehydration and organ failure. Among more than 8,700 living amphibian species, the only notable coastal exception is the Southeast Asian crab-eating frog (*Fejervarya cancrivora*), which tolerates brackish mangrove swamps for brief foraging bouts by accumulating high concentrations of urea and free amino acids in its blood plasma -- yet even *F. cancrivora* cannot survive permanently in offshore oceanic waters and must return to freshwater pools to breed.

2. Discovery in the Offshore Triassic Beds of Guizhou

The two nearly complete, articulated skeletons of *Gerrothorax maritimus* were

originally uncovered by local farmers and acquired by the Geological Museum of Guizhou from the Zhuganpo Member of the Falang Formation near Xingyi in Guizhou Province, southwestern China. Radiometrically constrained to approximately 237 million years ago during the early Carnian stage of the Late Triassic, these dark, laminated fossiliferous limestone and marl beds formed in a deep, quiet outer-platform basin of the eastern Tethys Ocean -- more than 30 kilometers (nearly 20 miles) from the nearest ancient mainland or island shoreline.

Measuring roughly 75 centimeters (30 inches) from snout to tail, *G. maritimus* belonged to the Plagiosauridae, an enigmatic family of stereospondyl temnospondyls famous for their extreme anatomical specialization. Its body was dorsoventrally compressed into a pancake-like profile, topped by a wide, parabolic skull bearing large, upward-directed eye sockets. Rather than dropping its lower jaw into the seafloor sediment to open its mouth, *G. maritimus* possessed a specialized craniocervical hinge (the Watson joint) that allowed it to swing its entire upper skull sharply upward, generating explosive gape-and-suction negative pressure to vacuum up passing benthic fishes and invertebrates -- a striking example of convergent evolution with modern angel sharks and wobbegongs.

| Taxon | | Age & Clade | | Habitat & Salinity Regime | | Dermal Armor & Osmoregulatory Adaptation |

| *Gerrothorax maritimus* | | Late Triassic (~237 Ma); Plagiosaurid Temnospondyl | | Offshore open marine (>30 km from shore; ~35 PSU seawater) | | Dense interlocking dorsal and ventral osteoderm armor; marine $^{87}\text{Sr}/^{86}\text{Sr}$ bone signature |

| *Gerrothorax pulcherrimus* | | Middle-Late Triassic (~240-205 Ma); Plagiosaurid Temnospondyl | | Continental lakes, rivers, and brackish deltas (Central Europe & Greenland) | | Tuberculate dermal ossicles; retained external gills for aquatic bottom-dwelling |

| *Aphaneramma rostratum* | | Early Triassic (~251-248 Ma); Trematosaurid Temnospondyl | | Nearshore coastal and estuarine waters (cosmopolitan littoral dispersal) | | Elongated gharial-like snout; transient euryhaline tolerance without heavy ventral armor |

| *Fejervarya cancrivora* | | Extant (Holocene); Dicroglossid Anuran (Lissamphibia) | | Intertidal mangrove swamps (brackish up to ~28 PSU; breeds in freshwater) | | Unarmored permeable skin; physiological hyperuremia (accumulates plasma urea to ~350 mM) |

3. Strontium Isotopes and the Dual Function of Heavy Dermal Armor

Because terrestrial carcasses occasionally wash out to sea during coastal floods, paleontologists have long debated whether earlier Early Triassic trematosaurid amphibians found in marine rocks were genuine ocean dwellers or riverine drifters. To settle the question definitively for *Gerrothorax maritimus*, Diao, Motani, and Jiang analyzed the strontium isotope ratio ($^{87}\text{Sr}/^{86}\text{Sr}$) preserved in the fossilized bioapatite of its dermal bones and teeth.

Because the ratio of radiogenic ^{87}Sr to stable ^{86}Sr in global seawater fluctuates over geological time at a tightly constrained value distinct from continental river runoff, bioapatite mineralizing inside a living animal records the exact water

chemistry of its food web. The $^{87}\text{Sr}/^{86}\text{Sr}$ values in both *G. maritimus* specimens matched coeval Carnian seawater and co-occurring obligate marine reptiles (such as the sauropterygians *Keichousaurus* and *Nothosaurus* and the ichthyosaur *Guizhouichthyosaurus*) from the same Guizhou beds. The isotopic signature proved that these amphibians did not wash out from a river; they grew, hunted, and ossified their skeletons entirely in saltwater.

How did a stem-amphibian conquer the osmotic barrier? The answer lies in its extraordinary armor. Unlike its European freshwater cousin *Gerrothorax pulcherrimus*, *G. maritimus* was encased in a dense, continuous carapace of thick bony plates (osteoderms) covering both its dorsal back and its ventral belly. Under natural selection during the intense marine trophic restructuring that followed the Permian-Triassic extinction event, this calcified dermal armor served three synergistic functions: it sealed off the skin surface to drastically reduce osmotic water loss and salt influx, provided dense skeletal ballast to keep the flat ambush predator pinned effortlessly to the seafloor without expending metabolic energy, and shielded the animal against predatory marine reptiles patrolling the Triassic water column.

References

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