

The role of whale falls: Insights from the Diamantina whale necropolis

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THE DEEPEST-RECORDED WHALE NECROPOLIS

A whale fall occurs when the carcass of a deceased whale sinks to the deep-ocean floor, forming a unique and transient ecosystem. The decomposition of the massive carcass typically progresses through three distinct stages: first, mobile scavengers, such as hagfish and sharks, rapidly consume the soft tissues; second, opportunistic organisms, including crustaceans and polychaete worms, colonize the exposed bones and surrounding organically enriched sediments to feed on the remaining organic matter; and finally, anaerobic sulfate-reducing microbes degrade lipids within the bones and produce sulfide, which is subsequently oxidized by chemoautotrophic microbes, supporting specialized fauna such as mussels, clams, and tube-worms. This process delivers a concentrated pulse of nutrients to the typically nutrient-poor deep sea, supporting a diverse community of life forms for decades and exemplifying a remarkable natural recycling system.¹

A recent study published in *Nature* by Peng et al. has documented extensive whale-fall ecosystems and fossils within the Diamantina Fracture Zone, with whale remains occurring at water depths of 4,616–7,001 m. The deepest active whale-fall community was recorded at approximately 6,789 m, making the Diamantina Zone the deepest-recorded whale necropolis to date (Figure 1). Across the 32 dives, 485 whale-fossil sites and active whale falls were documented, with 476 fossil cetaceans recorded. Of the recovered material, 43 fossils were subjected to palaeontological analysis. In the total surveyed area of 0.64 km², five active whale falls were observed, yielding a

density of 7.81 whale falls per square kilometer.² Strontium isotope dating indicates that whale-fall events in the Diamantina Zone have occurred since at least 5.26 million years ago.² This discovery reveals the potential of whale falls to shape biodiversity even in the most extreme marine environments. It also suggests that similar whale necropolises may be hidden in other deep-ocean basins globally, underscoring their critical recycling role in the marine carbon cycle.

ROLE OF WHALE FALLS IN THE MARINE CARBON CYCLE

The marine biological pump is a crucial process in the ocean's carbon cycle, driven by the sinking of organic carbon from the surface to the deep sea. It supports deep-sea ecosystems by supplying energy and nutrients to organisms in the dark, nutrient-limited depths.³ As a notable component of deep-sea carbon dynamics, whale falls act as evolutionary hotspots and biogeographic stepping stones for sulfide-dependent fauna in the deep sea. The sinking of a whale carcass delivers a concentrated pulse of labile organic carbon to food-limited benthic environments. For large baleen whales, a typical 40-tonne whale carcass contains approximately 2 tonnes of carbon, equivalent to the normal carbon flux received over 100–200 years on one hectare of an abyssal plain, while the carbon deposited directly beneath the carcass equals roughly 2,000 years of background flux.⁴ However, this carbon is not uniformly stored. The majority of the biomass consists of lipid-rich soft tissues (e.g., blubber, muscle, and organs), which are rapidly removed by

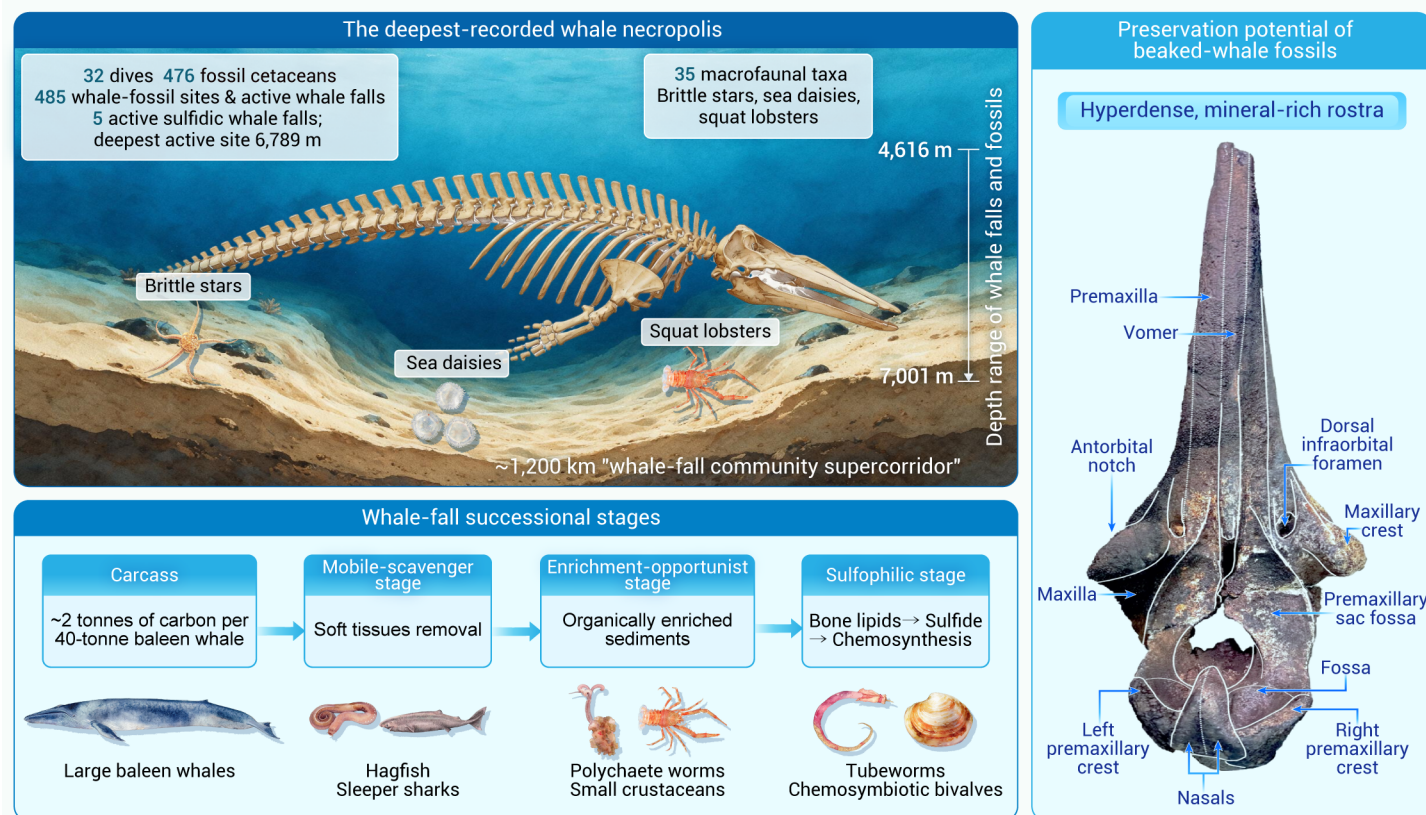


Figure 1. Whale fall and necropolis in Diamantina Zone.

mobile scavengers such as hagfish and sleeper sharks during the initial mobile-scavenger stage.⁴

The more persistent carbon reservoir lies in the bones. Whale bones contain approximately 10% lipids and 25% protein by weight, with lipid content in some bones reaching up to 80%; a large whale skeleton may hold 2,000–3,000 kg of lipids. Anaerobic microbes decompose these lipids via sulfate reduction, releasing sulfides that sustain chemosynthesis-based communities. Once sequestered in the deep sea, this carbon can be stored for centuries to millennia, with longer-term preservation possible under favorable burial conditions and low oxygen levels.

It is important to note that these quantitative estimates of carbon primarily derive from large baleen whales and serve as an upper bound or a general benchmark rather than a direct estimate. In contrast, the dominant beaked whales in the Diamantina region are much smaller, with reduced lipid reserves and lower per-carcass carbon contributions. In the total survey area of 0.64 square kilometers, five active whale falls were observed, yielding a density of 7.81 whale falls per square kilometer. Aligned along a northwest–southeast axis for 1,200 km, these falls may represent a previously unrecognized “whale-fall community super corridor”. Their significance lies not only in individual carbon inputs but also in their high spatial density across over 1,200 km and persistent occurrence over millions of years, highlighting their role as a sustained, though modest, carbon subsidy in deep-sea ecosystems.

POTENTIAL OF CETACEAN SPECIES TO FORM WHALE NECROPOLISES

The Diamantina Fracture Zone is located in the southeast Indian Ocean and hosts a diverse community of cetacean species, including both baleen whales and toothed whales. Historical stranding records from Australian regions indicate that humpback whales and sperm whales are among the most frequently recorded species, with several dozen individuals reported per year, suggesting abundant populations of these two species in the area. Furthermore, other cetaceans such as the southern right whale, fin whale, Antarctic minke whale, and common bottlenose dolphin are also frequently recorded as stranded, indicating a prosperous and diverse cetacean fauna. In contrast, very few strandings of beaked whales—the star species of the Diamantina whale necropolis—have been reported in Australian regions (<https://biocache.ala.org.au/occurrence/search>). This discrepancy raises a key question: do only a few specific species have the potential to be well-preserved after death and ultimately form necropolises?

According to the study of Peng et al., we now know that a large number of beaked whales (at least including Andrews' beaked whale and the strap-toothed beaked whale) historically inhabited the area, which aligns with current scientific knowledge. These species are seldom seen publicly because their carcasses are more likely to sink to the seafloor after death; consequently, their abundance, distribution, and ecology remain poorly understood. The discovery of the Diamantina whale necropolis provides a valuable resource for improving our understanding of beaked whale ecology.

Sperm whales, pygmy sperm whales, and beaked whales are among the deepest-diving cetaceans, foraging in mesopelagic and bathypelagic waters, although their typical foraging depths and maximum diving capabilities vary substantially among taxa. Although all these species are reported to live in the Diamantina Fracture Zone, the predominance of beaked whale fossils in the necropolis suggests that not all whale bones are preserved, even under suitable mineralization conditions.^{2,5} If differences in mortality and carcass delivery among cetacean taxa were limited, the predominance of beaked-

whale fossils could suggest preferential preservation over geological timescales. However, this remains a hypothesis that requires further testing, because alternative explanations, including historically higher local abundance of beaked whales or foraging behaviors that concentrate mortality in the Diamantina Zone, cannot be excluded. Under the broadly shared taphonomic conditions of the Diamantina Zone, the exceptionally high density of beaked-whale rostrum may represent an important lineage-specific factor contributing to their preferential preservation over geological timescales. Thus, the Diamantina necropolis may represent not only an ecological archive of cetacean occurrence but also a taphonomic filter, such that the composition and abundance of its fossil record reflect differential preservation potential as well as historical cetacean occurrence.

LESSON FROM DIAMANTINA WHALE NECROPOLIS

The recent discovery of the Diamantina whale necropolis has fundamentally reshaped our understanding of the scale and ecological significance of whale falls. It identifies whale falls as a critical and previously underestimated component of the marine biological carbon pump, particularly in deep-sea trench zones. Whale falls function not only as localized curiosities, but also as evolutionary hotspots, biogeographic stepping stones, and sites of carbon storage. Evidence from the Diamantina necropolis confirms that even in the most extreme marine environments, whale falls exert profound influences on biodiversity formation and carbon storage, which implies comparable unobserved biogeochemical processes may take place across deep-ocean basins worldwide.

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AUTHOR CONTRIBUTIONS

P.Z. designed the study and wrote the draft manuscript. All authors edited and approved the final manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.