



Giant tube worms can thrive among deep-sea hydrothermal vents

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Life in the extreme

"Science constantly humbles us." **Barbara Sherwood Lollar** recounts the radical shifts in understanding of how and where life exists, even within her lifetime

OUR UNDERSTANDING of the complexity of life on Earth changed profoundly during the late 19th century. With many in the scientific community doubting that life could survive the colossal pressure, darkness, and cold of the deep ocean, the community was astounded when crews aboard the HMS *Challenger* (1872-1876) dredged up an array of deep-sea creatures from greater than 4 km beneath the ocean surface. Later, during the 1890s, scientists such as Sergei Winogradsky, Martinus Beijerinck and Wilhelm Pfeffer

showed that rather than relying on sunlight, bacteria could derive energy from inorganic chemical reactions, a process Pfeffer named chemosynthesis (as opposed to photosynthesis).

However, it wasn't until the late 20th century that we truly began to appreciate the extent to which chemosynthesis could sustain life. In a major breakthrough in 1977, geoscientists aboard the deep ocean research submersible *Alvin* discovered vast, complete communities not just existing, but thriving in total darkness on hydrothermal vents

deep within the Galápagos Rift of the Pacific Ocean. Communities of giant tube worms, clams, shrimp and other creatures, all ultimately sustained by chemosynthetic bacteria that oxidise hydrogen sulfide from the hydrothermal vents to produce energy and nourish an entire food chain.

As Barbara Sherwood Lollar, Professor in Earth Sciences at the University of Toronto, Canada, explains, that discovery completely transformed our understanding of biology by showing that, rather than photosynthesis, "life can use other strategies to survive, even in the deep dark environments of the ocean floor".

A deep and ancient biosphere

Since that astonishing encounter in the deep Pacific, Barbara's own work has dramatically extended

this concept to even more extreme environments by showing that chemosynthesis can sustain microbial life in ancient water-bearing fractures several kilometres deep within Earth's continents.

"Working with teams of microbiologist colleagues, we have identified microbial communities that are living in the ancient groundwaters of this planet – waters that are millions and even up to a billion years old. There we have found novel habitability strategies – for example, microbial organisms that take advantage of electron donors and electron acceptors created by radiation breaking down water molecules to produce hydrogen and reacting with surrounding minerals in the deep Earth to produce sulfate and other compounds microorganisms need to survive."

Barbara's pioneering demonstrations of how life can persist in extreme environments has profoundly influenced both our understanding of the evolution of life on Earth and the search for extraterrestrial life. Barbara and her team have identified isotopic signatures that can distinguish between abiotically and biologically generated methane and other hydrocarbons – signatures that are used by space missions searching for signs of past and current subsurface life across our Solar System.

"These non-photosynthetic-based biomes provide possible models for organisms on the early Earth before photosynthesis evolved, and possible habitability models for other planets and moons in the Solar System."



Societal impact

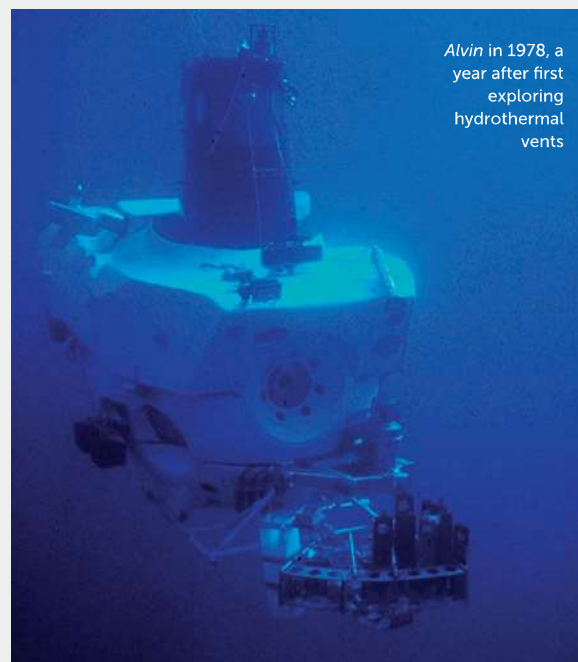
While Barbara's work has transformed our understanding of many distant realms, her group's fundamental discoveries, which are focused on the intersection between the water, carbon and microbial cycles, also have immediate societal impacts, with transformational applications to groundwater quality and remediation globally.

"We are harnessing those discoveries to identify and quantify the role of naturally occurring microbes that can help decontaminate the drinking water sources that are so critical to society right now. The new isotopic techniques that we have proposed to quantify the rates of this biological remediation are now in application throughout the world."

Like many, Barbara was not really exposed to Earth science during high school. Rather, it was a fortuitous elective class with the American palaeontologist and evolutionary biologist Professor Stephen Jay Gould that sparked her interest in the field: "I left that class having caught his passionate love of the interconnectivity between chemistry, biology and geology, which forms the foundation of the Earth sciences."

Today, Barbara feels more passionate than ever about the critical role for geoscientists in addressing some of society's most pressing global challenges.

"Science can be an incredibly powerful means of communication. It can support the fact-based solutions needed for making good decisions and creating policies to sustain the environment, as well



Alvin in 1978, a year after first exploring hydrothermal vents

“Science can support the fact-based solutions needed for making good decisions and creating policies to sustain the environment, as well as human society and communities”

as human society and communities. We need to double down on that outward facing impact of what we do – to ensure our discoveries are communicated and positively impact the lives of those around us, and those far across the globe. Science is a team sport, and we need everyone's contributions.” 

Professor Barbara Sherwood Lollar is a University Professor and the Dr. Norman Keevil Chair in Ore Deposits Geology at the University of Toronto, Canada, and the 2025 recipient of the Society's Wollaston Medal.

Interview by Amy Whitchurch, Executive Editor, *Geoscientist* magazine