Arthur H. Lachenbruch

December 7, 1925–September 20, 2021
Elected to the NAS, 1975

A Biographical Memoir by Barbara Lachenbruch

In Arthur H. Lachenbruch's groundbreaking career as a geophysicist, he used observations of terrestrial heat flow and simple, yet powerful mathematical models to deduce temperatures, stresses, and failure patterns in materials at scales from ice-wedge polygons in permafrost to continental and oceanic plates. His research influenced engineering projects in the Arctic, geothermal energy development in the western United States, climate science, fracture mechanics, and our understanding of the mechanisms responsible for mid-oceanic ridges, transform faults—including the San Andreas fault—continental rifting, and basin formation.

Humble and unassuming, he often attributed his successes to the resources at his disposal and the people around him, especially his research team and family. He often said that his mentoring when he was a young field hand in Alaska and in the U.S. Army Airforce was instrumental to finding his strengths and his career. The U.S. Geological Survey (USGS), his employer of forty-four years (1943–1987), had a positive culture and provided him with the financial support and freedom to pursue the questions he thought were important. He was not shy of pursuing topical problems that would influence society directly. For example, he helped avert the colossal environmental disaster that would have occurred if the Trans-Alaska Pipeline of hot crude oil had been buried, as planned, in the frozen soils. His modeling convinced the federal government to require its redesign.

His diverse and significant impacts are even more remarkable given that he read very slowly and believed he had a learning disability; the high school counselor suggested he not go to college. Perhaps the slow reading contributed to his clear writing, his speaking that even laypeople could understand, and his ethic of developing thorough, informed positions. His positive outlook, deep thinking, mentoring, generosity of spirit, and interest in the environment had enormous effects on the people around him and the landscapes we live in.

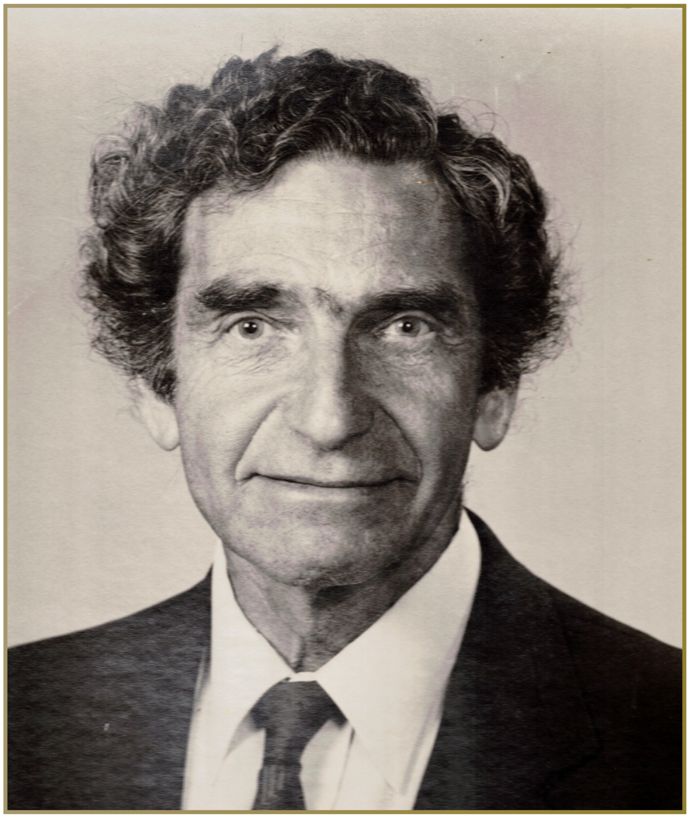

Figure 1 Art Lachenbruch, 1989. *Photo by James Kanne for the American Geophysical Union (AGU).*

Early Life and Mentors

Arthur "Art" Herold Lachenbruch was born New York City on December 7, 1925, and grew up in nearby New Rochelle until high school when he moved to Bethesda, Maryland. He was the youngest of four rambunctious and active boys. His parents were second-generation Jewish-German immigrants. His mother, Leah (née Herold), was a kind and independent woman from Shreveport, Louisiana, who had an advanced degree from Columbia University, was an ardent advocate for social legislation, and worked full-time as a social worker. Art's father, Milton Cleveland, enjoyed a good laugh but faced many challenges. He had to put his younger brothers through college before he could go himself, contracted polio that curtailed his athleticism, and lost his successful career in finance during the Great Depression. During much of Art's childhood, his father was out of town as a farm auditor for the federal government. The boys, therefore, grew up with much love, encouragement, and an ethic of hard work but with minimal supervision.

I heard many surprising tales, such as paddling a sinking homemade raft on the Long Island Sound, getting hauled to the hospital (where all the brothers were known by name) after roughhousing with an ice axe, and getting chased around the dining room table by his mother after knocking off the chandelier with a football. Art and his closest brother, Milton "Mickey" Cleveland Jr., made a hole in the wall between their bedrooms so they could talk at night. Mickey later became a petroleum geologist. Art's next oldest brother, David, was a trickster who later, as a journalist and editor, became a leading expert in the field of consumer electronics. Art's oldest brother, Simon, was a math prodigy who was featured on a national newsreel for saying all the states in alphabetical order in one breath. Although Simon later got a Ph.D. and taught math at several levels, he suffered from epilepsy that was difficult to control.

Perhaps his chaotic childhood household helps explain why Art ended up in the Arctic as a field hand in the summer of 1943. After he heard a USGS administrator speak at his high school, Art asked him for a summer job. The speaker would have seen a strapping 6'2" senior at a time when many potential field hands were in the military. He would not have known that Art's scholastic record was not very good and that Art bridled at the wartime marching exercises and other forms of conformity expected at his school. But he got the job, worked as a backpacker and cook supplying a field camp in southeast Alaska, and began his career. He loved the work. His notes detail that some days he covered twelve miles carrying a 115-pound pack. His co-workers joked that although he did a great job, he ate so much that he was a losing proposition.

After his first field season, at age eighteen, he volunteered for the U.S. Army Air Forces (1944–46), and he was placed into a corps of college grads who were working to improve the complex remote-control gun turrets of B-29 aircraft. He credited these corps mates with giving him a love of learning and turning him toward college. He appreciated many aspects of the service, including the camaraderie, the ample food, and a program letting him take college correspondence classes in geology, anthropology, astronomy, forestry, physics, logic, human physiology, and German.

After his discharge from the service in the spring of 1946, he had his second field season with the USGS in Alaska and then started college at Johns Hopkins University in Baltimore, Maryland, where he majored in geology and minored in math. He had to leave school a month early each spring to get to his job in Alaska, first as an assistant and then as a geologist on geological mapping and surveying projects. He spent field seasons with geologists H. Richard "Dick" Gault, Robert M. "Bob" Chapman, Ed Sable, George Gryc, Robert L. "Bob" Detterman, Charles "Chuck" Whittington, Marvin D. "Marv" Mangus, and D. Thomas "Tom" Dutro. He also struck a deep friendship with Hillard N. "Hill" Reiser, who became his close friend for sixty years, and eventually his next-door neighbor. I suspect that many of the traits I consider to be Art's core originated in these Alaska days—gratitude, love of arduous labor, awe of landscapes small and large, a zeal for addressing questions that had never been asked, and skills at leading people and sparking their interest in even the most mundane tasks.

In his final spring at Johns Hopkins, as he was dealing with finishing classes early and interview trips to the University of Chicago and Harvard University for grad school, he was set up on a blind date with Mary Edith Bennett, called Edie. She was a nurse who grew up in rural West Virginia in a Southern Baptist family. He fell asleep on their date, but Edie gave him another chance, and although he headed to the field two weeks later, they exchanged letters all summer. Several weeks after his return, in September 1950, they married. It was a Thursday, and so they celebrated on Thursdays for life.

The newlyweds headed to Cambridge, Massachusetts, where Art began a Ph.D. in geophysics at Harvard with Albert Francis Birch. But they spent little time in Cambridge. After a year of classes, Art spent the summer of 1951 in Dillingham, Alaska, working with geologist Ernie Muller. After a second year of classes, he spent almost two years (1952–early 1954) at the Naval Arctic Research Laboratory near Barrow (now Utqiagvik), the northernmost point of Alaska, working alongside M. C. "Max" Brewer. Max became a colleague and good friend. Edie accompanied him on these adventures, working at Native healthcare facilities or as Art's field hand. They returned to Massachusetts in time to have their first child, Roger, in 1954. In 1955, Art took a permanent position at the USGS in Menlo Park, California, and they had their second child, Charles. In 1956, I was born. But Art still had not written a dissertation, although he had published a series of analytical models on the thermal effects of buildings, boreholes, roadways, and the ocean on permafrost. A colleague suggested he ask if he could, essentially, collate his publications and call that a dissertation. That was deemed acceptable, and in 1958, Art earned a Ph.D.

Arctic Ice and Permafrost, 1953 to 1963

The Alaskan Arctic is a landscape of strange features—oriented lakes, sloughing slopes, mounds, polygonal chunks of ground surrounded by troughs—begging the observer to solve the riddles of how these features formed. Therefore, after completing the research that became his dissertation, Art turned to the mechanics of thermal contraction cracks and ice-wedge polygons in permafrost, a topic he had thought about since he was twenty years old (Figure 2). Although these polygons are not always visible from the surface, they form honeycombs over thousands of square miles of the Arctic. Each polygon is a chunk of land (up to 100 feet in diameter) delineated by intersecting wedge-shaped plates of ice (up to twenty feet deep). Using data on polygon dimensions, crack depth, temperature profiles, and the material properties of ice and permafrost, he developed a model of thermal stress that explained the observed landscape patterns. The best model was a non-linear viscous thermoelastic model, and it indicated the importance of the rate of temperature change. This research also informed people of the specific challenges of construction in permafrost zones and provided a basis for modeling tensile fracture systems such as basalt columns and mud cracks. The work was touted as one of the first applications of modern fracture mechanics to earth science.

In 1957, Art's research was interrupted by a call to join an interdisciplinary group to gather baseline data and judge the potential ecosystem impacts of excavating a harbor on the northwest shore of Alaska. The endeavor, called Project Chariot, was run by the U.S. Atomic Energy Commission as part of the Plowshare Project, designed to investigate peacetime uses for nuclear explosives. The harbor was not wanted by the Inupiats of the region, and after much controversy and contention, it was not excavated. As Art wrote to the author of a popular press book on Project Chariot, "Much more important than [the project's defeat] was the demonstration that a thorough objective survey of the relevant environmental sciences was a necessary first step to informed debate on environmental impact of large projects."[1] The collection of forty-two essays[2] that the Project Chariot scientists produced was, in effect, the first environmental impact report, unique in the scientific literature, and the model leading to the National Environmental Policy Act of 1969 (NEPA). Art met many scientists in these years, including botanist Max Britton and polar geologist Jerry Brown, and was exposed to scientific thinking from diverse disciplines that informed his thinking throughout his career.

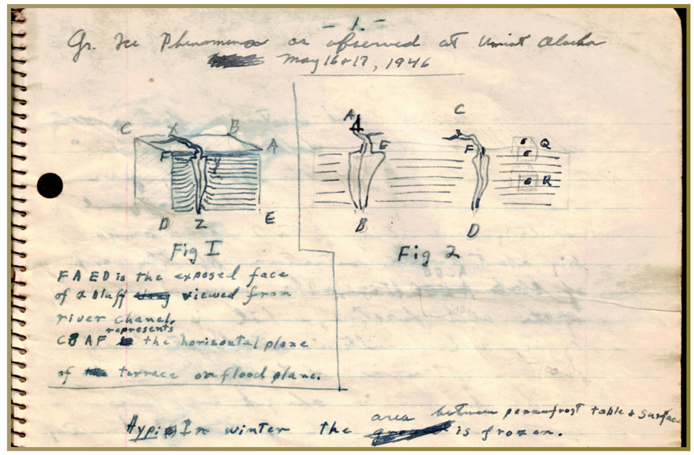

Figure 2 Diagrams from Art's field notebook in May 1946 (the start of his second summer as a field hand in Alaska) depicting the foundations of his mathematical model to explain the formation and propagation of ice wedges and polygonal patterned ground in the Arctic. He was twenty years old and would begin college in the fall.

From 1963 to 1973, Art's team made the first comprehensive heat-flow measurements in the western Arctic Ocean, a region whose evolution was little known. Over that decade, the lab, which sat on a drifting ice island, was able to get measurements at 356 sites. But Art's attention was redirected by what would become NEPA's first major application, the Trans-Alaska Pipeline. In 1969, after Alaskan colleagues told him that a consortium intended to bury a hot oil pipe in the permafrost, he contacted the director of the USGS in alarm. In January 1970, he published a USGS circular[3] that predicted in the first year such a pipeline would produce a canal of melted slurry twenty-five feet deep beneath the pipe, causing a profound environmental and engineering disaster. By the end of March, the circular went into a second printing because there had already been 3,600 reprint requests "from all sorts of groups—from oil companies, schools, individuals, and wilderness groups to name a few."[4] The circular persuaded the development-minded Department of the Interior and Pres. Richard Nixon to prohibit pipeline construction until costly design changes were made. From 1969 to roughly 1975, Art was up late most evenings reviewing the tomes of long, convoluted output from the pipeline design team. He was later told that these products were sent to him because an undercover industrial psychologist had determined that he liked analytical solutions. He did not enjoy this slog. During this period, both his parents died, my brothers finished high school, and Art could not get to his research. One of the casualties was the analysis of the ice island data, which was finally published in a comprehensive form by a USGS colleague, Carolyn Ruppel, fifty years after data collection started.[5] Art was ninety-three.

Decades after moving out of permafrost studies, he realized that the temperature profiles from deep boreholes that had been drilled for petroleum exploration decades before could provide evidence of climate change. His 1986 publication in *Science* showed that temperatures at depth were lower than expected given the surface temperatures.[6] The profiles were consistent with surface heating since the industrial revolution and provided the first evidence of terrestrial heating from climate change.

Geothermal Studies, 1963 to 1994

In the late 1950s and early 1960s, studies of continental and oceanic heat flow were increasingly providing insights into fundamental geologic and tectonic processes. In 1963, the chief of the USGS Geophysics Branch encouraged Art to apply his permafrost heat-flow techniques to the scale of geologic provinces and gave him the resources to do so. Art recruited a talented team of people who would work together for a quarter of a century. John Sass would become his close scientific collaborator, J. P. "Jack" Kennelly and W. E. "Walt" Wendt would create innovative instrumentation to make new measurements possible, and T. H. "Tom" Moses would adapt the oil industry's technology and culture to the needs of their scientific heat-flow studies. Beyond the postdocs, visiting scientists, and grad students, the other team members included B. Vaughn Marshall, Gordon Greene, R. J. "Bob" Munroe, E. P. "Gene" Smith, S. P. "Pete" Galanis, F. V. "Fred" Grubb, and the beloved administrator, Nancy Sandoval.

Over the years, they characterized the thermal regimes throughout the western United States. Among the uses of this work was the identification of locations and magnitudes of geothermal energy resources. They also developed a ground-breaking model for the depth distribution of radiogenic heat-producing elements in the crust. Armed with that model, they could then use heat flow to estimate the friction that came from moving plates, after first subtracting the heat from magma chambers, from conduction from deeper layers and generated by the radioactive decay. They applied these techniques to faulting and confirmed the absence of a frictional heat flow anomaly along the San Andreas Fault. Then, they were able to deduce that this absence signified a weak fault, which was consistent with horizontal detachment and decoupling at the base of the brittle seismogenic layer.

Art and his team then turned to the extension of continental crust. After finding that crustal extension could not be adequately explained solely by the thermal conduction data, Art made more realistic models that were one-dimensional, steady-state, and incorporated magmatic underplating and intrusion from the upper layer of the mantle. This work helped explain the geomorphology of regions of young and contemporary plate extension, such as the U.S. Basin and Range Province, and regions of developing sedimentary basins, such as the Salton Trough.

Art also worked on oceanic plates, developing one of the first complete models of viscous flow at oceanic spreading centers. Through an elegant mechanical model, he showed why more slowly spreading oceanic ridges, such as the Mid-Atlantic Ridge, have an axial valley, and faster spreading ridges, like the East Pacific Rise, have an axial high. The model also explained why large oceanic plates are more common than small ones and suggested that oceanic transform faults are weak, just as they are on continents.

Awards and Honors

Art's first professional award was the 1963 Kirk Bryan Award for Geomorphology from the Geological Society of America for his work on ice wedge polygons. In 1972, he received a Meritorious Service Award from the USGS for his pipeline-related work. He was elected to the National Academy of Sciences in 1975 in recognition of his contributions to both permafrost science and crustal-scale geology. That was followed by a Distinguished Service Award from the Department of the Interior (1978) and election as fellow to the American Association for the Advancement of Science, the Geological Society of America, the Arctic Institute of North America, and the Royal Astronomical Society (all in 1980). In 1986, he received the Walter Bucher Medal from the American Geophysical Union in recognition of his original contributions to the basic knowledge of the crust and lithosphere.

Family Life and Wonder

Art and Edie enjoyed life together tremendously. While at Harvard, Art would make Edie's sandwich for her lunch. When she pulled it out a few hours later, there would be a bite missing—Art had had to test it to make sure it was good—and there were often love notes between the slices of bread. And although they came from different cultures, they soon moved west together and developed their own traditions.

He also treasured his family. With Edie's help, he was able to have a successful scientific career without neglecting personal ties. Soon after he started his permanent job, his parents moved nearby, and with grace, Edie became the hub for his side of the family. In 1963, Art and Edie got a chance to rethink their work and lifestyle after the family moved to New Hampshire, where Art taught graduate geophysics at Dartmouth College for a quarter. Although he decided to return to the USGS in Menlo Park, the family moved seven miles to Los Altos Hills for a more rural setting. As kids, we were able to explore the chaparral, help with the park-like gardens and wildlands, learn the wild plants and animals, have dogs, cats, chickens, and sheep, and take runs with Art and then jump in the pool.

Despite his work obligations, Art seemed able to prioritize family. He attended many of our school events, visited his parents several times a week for decades, and took in his brother Mickey's family for several months after Mickey's untimely death from malaria on a petroleum exploration trip in Africa. Like everyone else, I always wanted his time. When he put to me bed at night, I could get him to stay longer if I asked about his research. I still remember his demonstration of the crustal movements responsible for the Salton Trough: he put a different finger on his top and bottom lip, pulled them in opposite directions, then broke into a smile.

In 1970, he saw that our town's rural nature was becoming threatened by development, so he joined the Planning Commission and stayed on it for almost two decades. He helped develop and implement one of the earliest slope-density ordinances in the country, which adjusts the permitted lot size according to the steepness of the terrain. He also helped the town find ways to limit a lot's impermeable surface area, the height of structures relative to the topography, and the allowable quantity of cut-and-fill. Now almost fully developed, Los Altos Hills is one of the most prestigious suburbs in the United States.

In 1980, when all the kids had moved out, Art and Edie took inspiration from their long-time friend George A. Thompson (the chair of Geophysics at Stanford) and bought eighty logged-over acres in the redwoods. Over the next thirty years, they spent weekends there helping to reestablish the forest and waterways. They enjoyed the rural community and volunteered in a nearby interpretative nature center.

Art, Edie, and their dog moved to Oregon in 2011 to be near Roger, me, and my two children. They often sat touching hands as they read the newspaper and sipped their coffee. Art was deeply saddened by Edie's death in 2016 and their son Charlie's death in 2018, but he continued to see what was positive around him. He spoke frequently of his good fortune for the people he got to live and work with and for his chance to participate in this world. Until his very last, he saw the best sides of people and derived awe from small bits of nature and fracture patterns everywhere.

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