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Annu. Rev. Earth Planet. Sci. 1994. 22:1–32

EARTH, SEA, AND SKY: Life and Times of a Journeyman Geologist

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It is the practice and privilege of age to hark back to days of yore, and I cannot resist—especially after being asked to do so by the Editor. Apparently this practice of inviting an earth scientist to write a prefatory chapter for the *Annual Review of Earth and Planetary Sciences* has been going on for over two decades. The list of authors has included several fellow scientists who have been my close friends such as Roger Revelle, Walter Munk, Sir Edward Bullard, and J. Tuzo Wilson. It is a privilege to be associated with them and I will try to roughly use their autobiographical style. I will follow the advice of the king in *Alice in Wonderland* who said, "Begin at the beginning, and go on 'till you come to the end: then stop."

My career as a government and academic geologist has been both fascinating and rewarding. I have often felt like a child let loose in a candy store. I have been able to sail on all the seven seas and with echo soundings pierce the blue mirror that reflects the sky and reveals the deep abyss. I have also been able to do research on all seven continents, including Antarctica on the Navy-Byrd Expedition of 1946–1947. My chosen profession has permitted me to fly over a million miles and into the stratosphere and to dive more than a mile deep in the oceans. My life has spanned an era of remarkable change; however, if I compare my college geology textbook of 1933 with one of today, I find that few really new chapters have been added. I take a modicum of pride in having been involved early-on in three of these: marine geology, astrogeology, and plate tectonics. I am pleased that a mountain in Antarctica, a tablemount in the mid-Pacific Mountains and an asteroid (#4666-Dietz) have been named in my honor. I recommend a scientific career as the best of all possible pursuits. Understanding the rainbow as a phenomenon of light

0084–6597/94/0515–0001$05.00

refraction rather than a heavenly miracle makes it no less interesting. Similarly, knowing the geologic history and structure of a mountain makes it no less awesome. My life has spanned a fascinating era of remarkable change—the telephone, the automobile, and the airplane were invented only shortly before my birth. Geology has evolved from an observational and field science into largely a laboratory science with instrumental capabilities that have improved data collection and data processing by orders of magnitude.

I have tried to pursue a policy of lifelong learning zeroed in on the earth sciences. I have been chided for never reading works of fiction but I have always considered novels a waste of time especially for the likes of me—those of us not bright enough to spread our efforts too thinly. My mentor Francis Shepard had it right when he was questioned regarding his obvious lack of student status in a discount line at the Scripps Institution of Oceanography lunch kiosk. Replied he, "Professors are students all their lives." No doubt this tunnel vision has stunted my intellectual maturity.

One way that I differ from nearly all research scientists is that I have never had a government grant—but this is not for lack of applying. It is also not for lack of need as I am not wealthy and never have I inherited so much as a red cent. Twice I almost received grants but these never finally materialized. On the first occasion in the late 1960s, I was funded for three dives with the *Reynolds Aluminaut*, a remarkable deep research vehicle with a hull less compressible than water. The principal purpose was to investigate a presumed south-setting bottom current that ran counter to the Gulf Stream in the Strait of Florida. This current, disbelieved by physical oceanographers, was indicated by the asymmetry of bottom current ripples on photographs. I arrived at the Miami dock in 1967 only to be told that my program had been cancelled. The *Aluminaut* had been preempted to search for an H-bomb that had fallen from an Air Force bomber into the sea off Spain's Mediterranean coast.

The second lost grant was from NASA and occurred in 1976. A year earlier I had been involved in astronaut tutoring and photographic target selection of volcanos and astroblemes for the Apollo-Soyuz handshake-in-space mission. My accepted post-mission proposal was to investigate some circular features in central Brazil which the astronauts had photographed. Unfortunately the funding was six months late in materializing. This exactly coincided with my retirement from government service and the beginning of my professorship at Arizona State University. This necessitated turning the grant over to a colleague, John McHone. He was able to reconfirm the astrobleme status of Serra da Cangalha and to locate another probable example in Brazil. So the number of grants I ever received remains at zero. Thus, perforce over the years I have had to be largely content with utilizing data sets in the public domain.

I have received some private support, however, for my research from the Barringer Crater Company, the nonoperating partner in Meteor Crater Enterprises of Arizona which operates Meteor Crater as a touristic facility. Over six decades, this company has supported much research in meteoritics under the successive leadership of D. Moreau Barringer Jr., Brandon Barringer, and J. Paul Barringer. In 1968 Paul and Dorothy Barringer supported and accompanied me (along with Robert Fudali of the Smithsonian, and William Cassidy of the University of Pittsburgh) in an investigation of the remarkable Richat dome in central Mauritania—a giant bull's-eye feature photographed by astronauts on the early Gemini missions. I had hoped that Richat would prove to be an astrobleme par excellence, but unfortunately we found it to be endogenic and presumably related to a buried intrusion. Dorothy and Paul also accompanied me in 1972 on a study by Indian canoe and Eskimo boat of the Nastapoka Arc, a giant hemi-circle marking the southeastern shoreline of Hudson Bay. Again our search for shock evidence suggesting an astrobleme was negative. This was really not surprising as ground zero lies far offshore and deeply buried beneath the Belcher Islands. I personally believe, however, that it does indeed mark an Archean impact event which will eventually be demonstrated. In 1978 the Barringers supported a month-long expedition by myself, my son Rex, John McHone, and Philippe Lambert into central Algeria where we investigated with good success several probable meteorite craters and ancient impact scars (see below).

I have been fully satisfied with my career as a research scientist in governmental and university settings. Even trivial discoveries in science are fun and scientific discoveries are a unique way of adding to knowledge. If I were a musician, a writer, or a theologian, I would never know for sure if I was a star performer, good, bad, or mediocre. Fortunately the star system does not generally apply to science; we are all journeymen doing the best we can with the tools we have. It is good to have lived long enough to see some findings and concepts believed; e.g. Sudbury Basin as an astrobleme, which achieved a consensus only in 1992 by my reckoning. Athletes tend to peak out in their twenties but scientists can do useful work, even beyond their usual biblical allotment of three score and ten. If Leonardo da Vinci suddenly came back to life, he probably would be unimpressed by the progress in the fine arts. Isaac Newton, however, would be utterly amazed by modern science and technology. And, as Mark Twain wrote in *Life on the Mississippi*, "There is something fascinating about science—one gets such a wholesale return of conjecture out of such a trifling investment of fact."

EARLY YEARS/UNIVERSITY OF ILLINOIS (1914–1936)

I was born in Westfield, New Jersey, in 1914, a bedroom city for white-collar workers who commuted to New York City. My forebears were entirely Anglo-Germanic having mostly arrived in the USA about 1850. They were average middle-class people with conservative values; my father was a civil engineer. Although I normally disapprove of large families, I make an exception here as I was the second youngest of seven children: six boys and one girl, Helen, the eldest. I would rate my schooling through high school as average. Helen was virtually a surrogate mother and, as the assistant librarian in our town's library, she introduced me to the world of books. Financially, times were rough especially during the Great Depression (1928–1936). My mother was a devout Christian Scientist, a nineteenth century cult which became an established church. By high school, I had largely rejected all religions and developed a serious interest in science, devouring library books by James Jeans, Arthur Eddington, and H.G. Wells. A school friend (Ralph Hall) and I became ardent amateur naturalists. We were rockhounds before this word was even invented, hitchhiking to such world class mineral localities as Franklin Furnace, New Jersey. The police offered to put us up in the jail. It was a friendly gesture but we opted instead for a farmer's barn. Visits to the American Museum of Natural History stimulated our interest and were enhanced by a retired Yale professor who was present every Saturday to answer our questions. He assured us that our specimens were as good as those in the Museum's J. Pierpont Morgan Collection, simply because we found them ourselves. My mother died while I was in high school and my father several years later. With no advice from anyone, I decided to go to college and study geology. I worked two summers in a resort hotel on the New Jersey shore for a paltry recompense of $12 per month plus room and board and rare tips. I was urged by a coworker there to split to Miami Beach, Florida and work for big money at the famous Roney Plaza Resort Hotel where he had connections. It was a tough choice but, instead, I hitchhiked west to the University of Illinois choosing that school mainly because the Chicago World's Fair (1933) was in progress. Another significant factor was the out-of-state tuition of only $65 per semester.

My liberal leanings probably derive from the slim pickings during my childhood when there was hardly enough food on the table for seven hungry children. There was a lot of sibling rivalry. My parents, however, remained staunch Republicans—even convervatives—throughout the Great Depression. Two summers of work on the New Jersey coast and one in Yellowstone in tourist hotels made me recognize the need for organized labor. Later, part-time work at the University of Illinois for 25 cents per hour under the National Youth Administration was critical to my survival as a student and made Franklin D. Roosevelt a hero figure to me.

I arrived at the University of Illinois in September 1933, already planning to major in geology. The room I rented was actually a windowless closet but the price was right—$5 per month. I had saved a little money from my summer job and my father sent me $400 over the first two years; but beyond that I would earn my own way over eight years: BS, MS, PhD at Illinois. This was not the best way to go but it was a matter of survival. These were maturing years and I am forever grateful to my alma mater. Thanks, Illinois—the truth is, I never left you. These were lean years but full of the exhilaration and challenge of youth. A defect in my college education was my being hell-bent for high grades. This was successful in that I earned a Phi Beta Kappa key. But this also stunted my learning as I purposely avoided the advanced levels of physics, chemistry, and math and, hence, I became more qualitative than quantitative, a skewing that I have regretted. One's best learning years are over by age twenty-five.

One way life has changed is the ease of travel for Americans in the modern world of jet aircraft. My lifelong desire to see the world has been amply fulfilled, the only major gap being mainland China. My father was regarded as well-traveled having been as far west as Chicago, built a logwood dye factory in Haiti, and worked on the Panama Canal. My mother's life was confined to the limits of Boston, Cleveland, and Washington, D.C.

I chose my country, my hometown, and my parents well. Nonetheless life is a crapshoot—snake eyes, boxcars; once in a while you make your point or even roll a lucky seven. Life is a rocky road, but along its highways and byways I never met a rock I did not like. And rocks are composed of crystals, the glittering flowers of the inorganic world. It is a theorem of geometry that when lost in a maze, if you place your hand on one wall and never take it off, you will find your way out. It works!—because I am a survivor. But even a geologist must recognize that the awesome story of the rocks must yield to the mysteries of life on Earth.

MARINE GEOLOGY WITH FRANCIS SHEPARD (1936–1941)

In my junior year at Illinois, I struck up a friendship with fellow student, K. O. Emery whom I now recognize as the only true genius I have ever known—but defined in Edison's terms, "90% perspiration and 10% inspiration." (I have just recently written the preface for his latest treatise with Elazar Uchupi, *Morphology of the Rocky Planets of the Solar System*).

Working for Professor Francis ("Fran") P. Shepard, Emery was making contoured bathymetric maps using raw sounding data collected by the U.S. Coast and Geodetic Survey. The main effort was to define the many submarine canyons off California, but eventually the entire continental borderland off southern California was mapped. I asked to join the effort and was accepted, an association that lasted for five years and was a defining event in my career. These were the early days of marine geology. The seafloor was *terra incognito* and the sea surface simply a mirror reflecting the sky.

I hold no brief for the "good old days" but perhaps it adds to the perspective of marine sciences, and certainly to humor, to recall something of the beginnings of marine geology in the United States by citing some of our early experiences. This subdiscipline of geology commenced almost simultaneously in the mid-1930s on the East Coast at the Woods Hole Oceanographic Institution with the research of Henry C. Stetson and the West Coast with the studies of Francis P. Shepard. Emery and I were the first of Shepard's sixty or so marine geology students, shuttling with him between Illinois and California. We originally met at the University of Illinois, where we arrived via modes of transportation that were the norm for those days of the Great Depression. I arrived by hitchhiking from the East Coast; Emery came by train, riding boxcars from San Diego.

In 1936 Shepard received a grant from the Penrose Bequest of the Geological Society of America for studying submarine canyons and the seafloor generally off the coast of California. The amount of $10,000 was a handsome grant for those days—in fact, the largest ever given by the GSA in prewar years. With the money he was able to charter the 96-foot schooner *E. W. Scripps* of the Scripps Institution of Oceanography for six one-month cruises, build the necessary scientific equipment, and employ us as his assistants at a salary of $30 per month. The low funding at least required us to develop some ingenuity in devising simple, inexpensive instrumentation. For example, we used the two-meter-tall Roger Revelle, later director of Scripps Institution of Oceanography, as a wave staff by having him stand at various distances from shore in the buffeting surf. As another example, we organized a rock preparation and sedimentation laboratory for which a budget of $50 per year was arranged. This was considered a reasonable proportion of the Scripps overall budget of $125,000 per year. The road to this now famous marine laboratory was marked by a forlorn sign reading *Fish Lab*.

Life aboard *E. W. Scripps* was somewhat different from shipboard duty today. The ship's crew consisted of only four persons—captain, engineer, deck hand, and cook; the scientific party was seven—the number of bunks available. We generally worked around the clock, six hours on and six off.

Members of the scientific party were expected to be sailors and to run the ship; technicians would operate oceanographic winches, assemble and use the water and bottom samplers, and do various shipboard analyses for water chemistry. Among our duties while steering the ship was to tabulate by hand the water depth every two minutes. We did this with great enthusiasm since we had installed aboard the latest Submarine Signal Co. fathometer which indicated the depth on a revolving red-flashing neon light. Graphic recorders had not yet been invented, so this instrument represented to us a remarkable advance over the sounding lead. And, in fact, we continued to use the hand-powered, wire-and-lead sounding winch installed on a rowboat for making hydrographic surveys of the inner heads of several submarine canyons. Rather remarkably, it was possible to demonstrate that canyon heads were repeatly filling with sediment and then emptying out. Prior to the cruises, we built dredges, grab samplers, sediment traps, and corers. The best corer that we constructed was a 600-pound open-barrel gravity model that increased the weight of such devices over earlier models by a factor of ten. We purchased junk lead at 3 cents per pound, used scrap 2.5-inch pipe, and built two corers for about $50 each. It was not until after the war that we heard about Kullenberg's invention in Sweden of the piston corer. Nevertheless, we commonly obtained cores 12 feet long, and in one instance, a diatomaceous ooze core in the Gulf of California which at 17 feet long was a new record.

In 1939, we joined Shepard and Roger Revelle for a three-month cruise of the Gulf of California. Our additional compensation for this cruise was one dollar, which made us nominal, hence insurable, employees of the Scripps Institution of Oceanography. Over a five year period, the Shepards took us in as part of their extended family traveling back and forth from Illinois for academic studies and Scripps for research. Shepard would eventually attain the status of the Father of Marine Geology.

Emery and I were as poor as church mice but I count these times as among the best days of my life. Shepard displayed contagious enthusiasm for seagoing research but great disdain for other than simple mechanical instruments and for armchair geologists. He was a skeptic and an iconoclast bent upon collecting his own new data. He preferred to "count the lion's teeth rather than consult Aristotle." His passion was submarine canyons which he wrongly believed until late in life were river-cut during great secular drops in sea level. Fran's intuitive grasp of physical laws lacked a certain spin control. In formal exchanges of views with Reginald Daly and Philip Kuenen (two great geologists of those days in my opinion) he invariably came out second best. As Boston Brahmin, Fran had considerable wealth but, while at the same time generous, was penurious to a fault. He kept a close tally on all expenses but never bothered to add them up. Looking back, these were halcyon years; and in memory of Fran Shepard, I recall some lines from Coleridge "Where Alph the sacred river ran/Through caverns measureless to man/Down to a sunless sea."

Students expect to be financially supported nowadays and to be assigned research topics. I chose my own theses subject—the phosphorite deposits Shepard, Emery, and I discovered on the continental borderland off southern California for my Master's degree, and deep sea clays for my PhD. I hitchhiked from Illinois to Washington, D.C. to obtain some *Challenger* Expedition worldwide, deep-sea samples from the Smithsonian to supplement those we had collected off California. One finding was a considerable uptake of potassium by illitization of clays. At my thesis defense one examiner wanted to disqualify it on the basis that I had been paid by the Illinois State Geological Survey while doing some minor aspects of this work. A guideline in those days was that a student should not receive any pay for research that pertained to his own thesis. Yes, times have changed, and for the better.

In 1939 I attended my first scientific meeting: the Geological Society of America's annual convention in Minneapolis. Such meetings were always convened between Christmas and New Year's so as to not conflict with the academic classes. I recall that I seemed to know all of the few hundred participants, at least by reputation, and to understand all of the papers. I naively thought I was a jack-of-all-trades and a master of four or five. The papers were generalized and totally lacking in sophisticated mathematics or "flute music." It has been downhill every since. Scientists know more and more about less and less. The age of the generalist seems to have passed.

Why is the Earth such a special planet? Of its many universal aspects the unique presence of water in the liquid state must rank first as this makes life possible. And so we have the oceans whose volume is often called Inner Space. In a similar vein I like to consider the ocean floor as the Third Surface. Earth uniquely has three volumes or "spheres"—hydrosphere, atmosphere, and lithosphere (liquid, gaseous, and solid states of matter). Geometrically, volumes intersect forming planes; thus there is the First Surface (land/air), the Second Surface (air/water), and the Third Surface (water/ocean floor). It is in the nature of things that energy exchanges take place primarily along surfaces; hence their importance in the scheme of things. The Greek philosophers of ancient time believed the universe consisted of four things or "elements"—earth, air, water (the three states of matter), plus fire. But if we consider life to be fire (reasonably so because we live by burning calories) and add a fourth sphere, the biosphere, then the list agrees with the Greek's classification. Earth, as perhaps Planet Ocean is, indeed, a remarkable abode—and is everyone's favorite planet.

The cosmological paradigms from Copernicus to Newton were a blow to Man's pride. We live on an average planet circling an average star in an average universe: the principle of mediocrity applies. Planet Earth, however, is habitable because of two key criteria—temperature and size, sometimes called the Goldilock's paradox because, as in the children's tale, things are "just right." These insure the *sine qua non* for life, the presence of liquid surface water creating the oceans unique among the terrestrial planets and their satellites. The oceans are, of course, where life began. We must rank in order of increasingly stressful environments, the oceans, fresh water, and the land. Rigor is hard on the individual but is good for the species. Hence animals that now rule the sea are the mammals, all of which spent considerable time evolving on land. And even modern Man would not be here today were it not for the rigors of the Ice Age.

MILITARY SERVICE IN WORLD WAR II (1941–1945)

Yogi Berra once advised, "When you come to a fork in the road take it!" Beginning my junior year in 1935 at the University of Illinois I unknowingly did just that. All students were required to take two years of basic military training but accepting advanced training and earning a commission was optional. I had definitely decided not to go on but, as I passed through registration, the $16 per month stipend for advanced Reserve Officers' Training Corps was a windfall I could not forego. The thought that I would ever be called to active duty never crossed my mind. But, as is often said, the rest is history. Eventually, the U. of I. ROTC program would provide more officers for WWII than even West Point.

When I received my PhD in June 1941, I quickly realized I was not any smarter than the day before. There was no obvious employment for a marine geologist as this discipline had not been invented yet; nor had such things as post-doctoral fellowships. I painfully recalled a research paper in the early twenties in which Chester Wentworth questioned the need for more than a couple of new PhDs in the USA each year. I wistfully recognized that my co-graduating colleague Emery would have first choice of any position as his qualifications were truly outstanding: For example, while still an undergraduate, he was the coauthor with Shepard of the Geological Society of America Special Paper #31 concerning submarine canyons off California. Emery, a human dynamo and later a member of the National Academy of Sciences, sent out 137 job applications. I opted to hang back and accept one of his discards but he received not a single job offer. Accordingly, I returned to the Scripps Institution of Oceanography in La Jolla and applied for work with the Navy-sponsored newly organized University of California Division of War Research on Point

Loma in San Diego—the dogs of war already had been unleashed in Europe. They refused to hire me as I was a reserve First Lieutenant in the U.S. Army Reserve. And, indeed, on August 7, 1941 the traditional President's "Greeting" arrived. I was called to active duty as a ground officer in the U.S. Army Air Corps (probably because I already had a private flying license) with the 91st Observation Squadron in Fort Lewis, Washington. Enroute I climbed Mount Adams in Washington, my first and last high mountain although I was destined to eventually sail over and map many others from the deck of a rolling ship. Everyone of my vintage knows where they were and what they were doing on Pearl Harbor day and when President Kennedy was shot. On Dec. 7, 1941, I was the squadron adjutant at Pine Camp, New York, making up a duty roster when the news broke. Rumors ran rampant and we were led to believe German aircraft might even attack our snowbound airfield.

To play a more active role even before Pearl Harbor, I applied for flight training immediately after being called up, but failed the rigorous physical exam because, it was claimed, I had a slight muscular eye imbalance. Believing this to be nonsense, a month later I drove 200 miles overnight with no headlights in a driving rain to retake the exam. It was the day before my 27th birthday—when I would have been too old, disqualified because of age. This was the first time in my life when I would have been too old for anything rather than too young. I passed. In 1942 I went through the seven-month flying training (Kelly, Randolph, and Ellington fields) and graduated in Class 42-1. The class consisted mostly of cadets but included seven student officers of which I was one. Six of this group were ordered to B-26 (later regarded as a flying coffin) training and on to Europe from whence, I understand, few ever returned. Presumably because of my academic background, I was posted to an air navigator's school in Hondo, Texas, where I served as an instructor for about 18 months.

By emphasizing my geologic training, I was eventually able to be transferred to a photo mapping squadron. My wish, however, for duty either in Europe or the Pacific, was not accommodated. My principal overseas mission was commanding a four plane flight of B-25s (Billy Mitchells) modified for photo mapping in South America. Our major mission was to map a boundary dispute region in the Amazon claimed by both Equador and Chile. This required flying over the high Andes to the headwaters of the Amazon from which we could never return if we ever lost even ten percent of our engine power. Fortunately this never happened although our operational casualties were high elsewhere. We also mapped extensively in Chile where our official task was to provide the data for air navigation maps. In reality we were sent in as soon as Chile broke diplomatic relations with Germany, so I suppose our primary purpose was to establish an

American presence. We worked closely with the Chilean Air Force and in appreciation I was made an honorary pilot in that Air Force. Our squadron eventually did mapping in all South American countries except Bolivia and Argentina which never did break relations with Germany. My total flying time was nearly 3000 hours which was twice the normal life expectancy in terms of flying hours for a WWII pilot. As the war wound down, I was being retrained for the assault on Japan but the A-bomb ended that program. After World War II, I remained in the reserves for 15 more years and am now a retired Lt. Colonel. Not being a West Point graduate, I did not envision a bright future in the military service. It was my plan to establish a private photo mapping company but that was not to be.

NAVY CIVILIAN SCIENTIST (1946–1963)

After the War, in the early fall of 1945, I received a letter from Eugene LaFond, one of my prewar colleagues at Scripps who had served with the University of California Division of War Research and was then organizing an oceanographic research section at the new Navy Electronics Laboratory (NEL) in San Diego. He asked me to organize a seafloor studies group. It was a time for decision. The bait of being the oceanographer with Admiral Byrd on his Navy-sponsored fourth and last expedition to Antarctica (Operation Highjump) was too tempting to turn it down. I joined the Naval Electronics Laboratory as a civilian scientist. My tenure there for 17 years would be interrupted by a one-year (1953) Fulbright Fellowship in Japan and four years (1954–1958) with the Office of Naval Research in London, England.

These were productive years with much work at sea and numerous scientific publications. Science was simpler in those days so it was possible to make contributions outside of my specialty in marine geology; for example, on the origin of natural slicks on the ocean and the worldwide distribution of the deep sound scattering layers as zooplankton migrations. My best coup was the hiring of the brilliant H. W. (Bill) Menard—a new PhD from Harvard. We collaborated for several years on problems of the Pacific Ocean floor which was then little known. We published, for example, the first contoured bathymetric map of the Gulf of Alaska based on USC&GS sounding lines and also a paper on the discovery of the Mendocino Fracture Zone, the first such fracture zone to be described. We wrongly interpreted the nature of this prototype fracture which only became apparent some years later in terms of plate tectonics. Menard later joined Scripps Institution of Oceanography and under the Carter administration was appointed Director of the U.S. Geological Survey. With the coming of the Reagan years, Menard was fired from this position by James Watt with whom he had philosophical differences—as did practically all scientists. Watt, a Mormon, thought there was no need to conserve natural resources because the second coming of Christ was imminent. This was not a joke: It is recorded in the Congressional Record which reports official testimony. Watt, however, had thc right to expunge such remarks, but he chose not to do so. Bill Menard returned to Scripps where he died an untimely death at the peak of his career in 1985.

In 1952 I co-led the joint Navy-Scripps Mid-Pacific Expedition, a two-ship operation with the major goal of seismic refraction profiling by Russel Raitt to determine the thickness of coral reef limestones atop Bikini Atoll—the recent site of atom bomb tests. A principal effort of mine, however, was to dredge the edges of some drowned ancient islands (tablemounts or guyots) to determine if these features were Precambrian, as Harry Hess supposed, or much younger. We were successful in obtaining an excellent fauna of both micro- and macro-fossils including, for example, rudists. Thc rcsults, published by E. L. Hamilton, revealed a Cretaceous age for these guyots; hence, it was inferred that Pacific seamounts generally were not an ancient graveyard of geomorphology like mountains on the moon but were geologically young. This was one of several surprises in marine geology that conditioned some of us in the mid-1950s to become mobilists, eventually accepting continental drift. Later a Scripps expedition doing a more extensive survey of these Mid-Pacific Mountains honored me by giving one of the guyots my name. Work as a Navy scientist was not without its frustrations. There were great geographic and geologic discoveries to be made about the virtually unknown Pacific floor. But all our work required military justification and an "admiral's page"—something the "brass" could understand if they ever actually bothered to read it. In the early years at NEL our research had somehow to apply to submarine warfare and underwater sound. My small group of five persons churned out a considerable number of papers in the open scientific literature which gained media attention and so was a source of embarrassment. We were criticized for not being invisible. In the late 1950s, the so-called Mansfield amendment became law; it was intended to quash all basic research within Navy laboratories. About the same time oceanography suddenly became a high profile science and an OK study to pursue. Many acousticians changed their position description to oceanographer creating considerable confusion.

On leave from the Naval Electronics Laboratory, I spent my entire year of 1953 in Japan at the University of Tokyo and the Japanese Hydrographic Office as a Fulbright Fellow. Japan was still recovering from the ravages of World War II. I acquired great respect for the Japanese culture—the people's intelligence, skill, and diligence. Their modern economic power is no surprise to me. I have even considered writing a book about why this is so, which would emphasize their genetics, the analog nature of the writing, etc. I arrived with an underwater camera and scuba gear—the first such diving equipment in Japan. It created quite a sensation all around that sea-oriented country. I was able, for example, to obtain some good footage of the tai fish, sacred to the Nicherin Buddhist sect.

My principal effort was to study the marine geology of the northwest Pacific seafloor using soundings collected by the Imperial Navy during World War II. These had been organized by the Japanese Hydrographic Office into a bathymetric chart which I revised and reorganized for my own interpretation. One aspect was the description of a majestic range of drowned ancient islands (guyots) striking northwest from near Midway Island to the Kamchatka trench. I named these the Emperor Seamounts after ancient Japanese emperors (e.g. Jimmu, alleged founder of the royal lineage in 600 B.C.), and empresses (e.g. Suiko). My idea for this nomenclature came from the Presidential Range in New Hampshire and Vermont. Much objection was voiced against this nomenclature but it seems now to be accepted.

Another study concerned the undersea eruption of Myojin Reef volcano in the fall of 1952. By happenstance I searched the underwater sounds recorded on the Navy's newly installed SOFAR stations (two off California and one off Hawaii) for sounds coming from the erupting Barcena volcano off Mexico. Instead I found explosions arriving from Myojin. A research ship had mysteriously disappeared with all 31 hands including my intended Fulbright fellowship host, R. Tayama. A single plank was later found embedded with bits of fresh scoria. I was able to show from the SOFAR records that the vessel was blown up by a great explosion at 12: 33 hours on September 23, 1953. At the time, it was the most distant undersea sound transmission ever recorded.

A high point of this Fulbright fellowship was a visit to the royal palace's marine laboratory where nudibranchs (shell-less gastropods), the emperor's hobby, were studied. A 90-minute audience with Emperor Hirohito followed. I explained my underwater film of kelp beds off California which he had seen. I also spoke about the tragic disappearance of a research ship *Kaiyo Maru* 5. Then I discussed the marine geology of the northwest Pacific Ocean and the majestic chain of seamounts stretching from Midway to Kamchatka, the Emperor Seamounts. The Emperor seemed uninterested, so upon leaving I asked my escort what the Emperor had said—as my Japanese was limited. My escort replied, "Emperor he say, 'Ah so des ka?' (Is that so?) one hundred and thirty-seven times." I assess Hirohito as a very shy, average Japanese, and a bird in a gilded cage. It seemed evident to me that he probably had little to do with the glossy books on marine invertebrates printed with his nominal authorship, except to collect the nudibranchs at his seashore summer palace. During World War II, the Japanese people were told that the emperor was brighter than the sun and staring at his highness directly would be blinding. Such naive beliefs could only be foisted upon a populace before the advent of television. All heroic figures have been reduced to common people under the glare of this new medium.

From 1954–1958 I once again took leave from the NEL in San Diego to join the Office of Naval Research, London, a small group attached to the American Embassy. A principal task was to help rehabilitate war-ravaged research institutes in the United Kingdom and western Europe, administer contracts, and re-establish firm ties to the USA. Part of my work was also overt intelligence—learning about new technologies and scientific discoveries. A whole generation of scientists, especially in Germany, had been lost to World War II. The work was enjoyable and worthwhile but a critical turn occurred in 1955 when I met Jacaques Piccard at a deep-sea diving symposium in London. I offered to promote support for the further development and testing of his bathyscaph *Trieste*—essentially a deep-diving "blimp" with a gasoline-filled float for buoyancy and a high-pressure-resistant sphere for the pilot and one observer. The rationale was to get the Navy involved in oceanographic research using deep research vehicles (DRVs). The Navy, for example, spent enormous sums on aircraft, thus successfully invading the atmosphere, but zero on invading the hydrosphere (their principal realm) below the shallow depths penetrated by submarines. Military submarines of that time were surface vessels that could dive only to the upper several hundred feet of the ocean. As machines of war they were not useful as research vehicles.

After a protracted effort the Navy agreed to sponsor a series of dives off Italy in 1957. Twenty six dives were made off Naples to depths of a mile or more. Because a bathyscaph is uniquely capable of ultra-deep diving, I envisioned a plan I called Project Nekton to descend to the seven-mile bottom of the Marianas Trench, the world's deepest spot and a mile deeper than Mt. Everest is high. With the purchase of the *Trieste* by the Navy and its transfer to the NEL in San Diego, this dream became a potential reality and soon full sponsorship emerged. A new float and a stronger sphere was manufactured in Germany. By the fall of 1959 the *Trieste* was stationed in Guam ready for test dives preparatory to the ultimate plunge. By January 1960, it was finally ready to dive. The Navy, of course, wanted this to be a uniformed military event, and as the saying goes, "He who rules the waves, waives the rules." Although still a member of the team, my role had been reduced to being a consultant. As the zero day approached, push gave way to shove and an attempt was made to coopt Piccard's role as pilot. This was saved only when Piccard invoked a clause in his Office of Naval Research contract that I had originally negotiated stating that Piccard had the option of being the pilot on "any special dives." A flurry of messages flashed back between Guam and Washington. The Office of Naval Research stood firm supporting Piccard and left the copilot choice to the Bureau of Ships. So Piccard piloted the dive to the nadir of the Earth, on January 20, 1960 with Lt. Don Walsh as copilot. As I was the most qualified scientist, Piccard requested my participation in a second dive. But major structural damage made further descents impossible. Irked with his treatment, Piccard asked me to coauthor the definitive documentary account. Our book *Seven Miles Down: Story of the Bathyscaph Trieste* was published by G. P. Putnam & Sons in 1961.

For the first two years after my return from London to the San Diego naval laboratory (by then renamed Navy Undersea Center), my major involvement remained with the bathyscaph *Trieste*, but after the ultimate dive the Navy created a deep submergence group within the submarine service on Point Loma, San Diego, allowing me to return to more scientific pursuits in the field of marine geology. Deep submergence was alive and well—a multi-million dollar program. With this program winding down I vowed to try to work alone: 1. eschewing team projects, 2. avoiding classified work which could not be published in open scientific journals, 3. avoiding contributing to the grey or internal Navy reports, and 4. selecting research on the leading edge of science. Although it was not in my position description to engage in scientific generalities, I chose to write about the marine geologic evidence for continental drift. A flurry of papers resulted concerning the origin and nature of continental slopes, the continental rise prism as nascent eugeoclines, and a mechanism for continental drift which I called seafloor spreading—a name I considered awkward but it has stuck.

In late 1960, I initially wrote a brief speculative paper entitled *Continent and Ocean Basin Evolution by Spreading of the Sea Floor* which eventually appeared in *Nature* in June 1961. It provided a reasonable mechanism for continental drift by implanting new ocean crust at mid-oceanic rift zones. It was a pot boiler that boiled over attracting much attention, as continental drift was a hot subject. I also read this paper at the 1961 Pacific Science Congress in Hawaii where J. Tuzo Wilson was present. I recall that he immediately found the concept appealing which surprised me as he had recently written about the impossibility of continental drift. I believe it converted him to mobilism and he then became a major contributor to the plate tectonic revolution. Unbeknownst to me, Harry Hess, independently and earlier (1960 preprint published in 1962), had suggested almost the same idea. Bill Menard received a copy of the preprint in May 1961 and contacted me since he had earlier reviewed my manuscript already in press. I agreed that Harry Hess should be accorded priority and did so in a 1962 publication (*AGU Monogr*. 6: 11–12). A full and accurate account of these seminal days for plate tectonics is found in Menard's excellent 1986 book, *The Ocean of Truth*. Looking back, Hess and I were agents of the inevitable: It was an idea whose time had come. The data base had been largely generated by Maurice Ewing and the Lamont Geological Observatory. Ewing remained a fixist until the bitter end at the 1967 American Geophysical Union meeting in Washington. I believe I was sitting next to him when he finally accepted the reality of drifting continents. Acceptance of my paper by *Nature* probably involved a bit of luck, as soon they would turn down L. W. Morley's correct explanation of the ocean's magnetic reversal stripes leaving it for Vine and Matthews to rediscover, and thereby provide an important verification of seafloor spreading.

The merit of seafloor spreading to me was in its explanatary power. It provided a reasonable mechanism for continental drift. It also offered an explanation for continental slopes as rift scars (Atlantic-type) or accretionary prisms (Pacific-type). Seafloor spreading further offered a new understanding for ensimatic eugeoclines and ensialic miogeoclines. It explained the mystery of the thin pelagic ocean floor sedimentary cover and the apparent youth of tablemounts—the ocean floor was not a repository of ancient geomorphology like the moon. Most significantly, rifting mid-ocean ridges provided the logical couplet for trench underthrusting about which I was fully convinced. I was also earlier impressed by S. W. Carey's mobilism and appearance of new ocean floor but rejected his expanding Earth model. He also showed that the cratonic fits across the Atlantic were cartographically-precise hard data and not on a par with Italy looking like a boot. Plate tectonics has subsequently revolutionized our understanding of terrestrial and planetary tectonics.

Nearly three decades ago we learned how our world works by plate tectonics and uniquely so. Alone among Solar System members, Earth has a carapace of eight major lithospheric plates and many lesser ones which drift and rotate a few centimeters per year interacting along their boundary by subducting, shearing, or spreading apart. Mountains, volcanoes, and earthquakes and even the continents and ocean basins are the result. Hypsographic bimodality is unique to Earth and is the hallmark of a highly evolved planet where basalt is extruded as a partial melt of mantle peridotite and is then remelted to create the sialic rocks of the granitoid continental plateaus. A convecting body like the sun is understandable and so is a solid rock in space that has gravitationally collapsed into a sphere like the Moon. But a planet with surficial plates drifting only as fast as one's fingernails grow is nonintuitive. This must be why we were so slow in understanding our own planet. Continental drift is simply part of a larger scenario: the drift of lithospheric plates in which the cratons are imbedded. Certainly plate tectonics ranks as a paradigm if not *the* paradigm of geology. It has proven to be a concept of broad explanatory power and prediction.

USC&GS AND NOAA (1963–1977)

In 1963 at the behest of Harris B. Stewart, one of Shepard's early students, I joined the U.S. Coast and Geodetic Survey in Washington, D.C., an ancient, honorable and traditional governmental establishment primarily involved in geodesy and constructing coastal navigation charts within the Department of Commerce. These were the heyday years of oceanography which unfortunately were short-lived. Other than making charts this organization had little scientific interest in oceanography. Sounding data were rarely contoured into bathymetric maps and there were almost no scientific interpretations of the ocean floor.

The Kennedy and Johnson years supported science, unlike the subsequent administrations. We organized an Indian Ocean expedition to take part in the International Decade of the Indian Ocean. An excellent survey was made of the *Swatch of No Ground*, a picturesque name for a remarkable submarine canyon off the Ganges delta down which a substantial percentage of the world's sediments are dumped to create a complex system of deep-sea channels in the Bay of Bengal. I had originally spotted these channels from the Swedish Albatross Expedition results where they had been wrongly interpreted as graben rifts.

With a new oceanographic research ship, the *Oceanographer*, we then mounted an around-the-world cruise with myself as chief scientist for the leg from Perth to Sydney, Australia. It was a voyage of exploration in the heroic tradition such as started by the British ship *Challenger* (1872–1876) and carried on after World War II by the Swedish *Albatross* and the Danish *Galathea*. This was the last of such voyages. NOAA had two ships capable of extended deep-sea voyages. They were used to some extent in running trans-Atlantic geophysical traverses between the east coast of the United States and the congruent bulge of Africa. My suggestion was that they should be used for studying plate boundaries especially along the mid-ocean ridges (even before the "black smokers" were discovered), but such cruises never materialized.

Another expedition on the newly launched *Discoverer* explored the South Atlantic. As a historical curiosity we resurveyed the location of the first deep-sea sounding made by James Ross in 1843 enroute to Antarctica.

Ross's depth measurement was too deep—presumably he did not recognize when his cannonbell sounding weight first touched bottom. Also, the sounding, still recorded on modern charts, had drifted in position and been mis-transcribed—a 5 had become a 3. I was reminded of an oceanographic study I made of the Bering Sea in 1949. I searched for two anomalous holes in this broad shelf sea on the standard charts only to find them nonexistent. Upon completing the search, I realized that some early cartographer had recorded two longitudes, 174°W and 175°W, as depths in fathoms.

Around the bulge of Africa I charted in detail two great submarine canyons, both of which create deep-sea channel systems: the *Trou sans Fond* ("Bottomless Hole") off the Ivory Coast and Cayar off Mauritania. Both canyons tap the shoreline and are of considerable economic importance. The *Trou sans Fond* makes the port of Abijan (second only in importance to Dakar along western Africa) possible. The wave refraction pattern associated with the Cayar canyon permit piroques to launch through a low surf to a rich fishing ground.

Our survey of the small Bijagos excrescence off Portuguese Guinea proved especially interesting since, like the large Bahama platform, it creates a continental drift overlap when the Atlantic Ocean is closed. Since seafloor spreading is usually a symmetrical process, it would appear that a Jurassic hot spot beneath the Bahamas caused asymmetrical spreading in the initial phases of the opening of the Atlantic Ocean. Thus these congruent excrescences are now of grossly unequal area. This is a matter resolved by hot spots which measure absolute drift while drifting plates measure relative motion.

Unfortunately, changes were in store for the USC&GS which did not bode well for decp-sca marine geologic research. Through a series of reorganizations USC&GS became the Environmental Sciences Administration (ESSA) and then the National Oceanographic and Atmospheric Administration (NOAA). The oceanographic effort was spun off to laboratories at Miami and Seattle where they languished. The "O" in NOAA became very small while the "A" became very large. Efforts in geology and geophysics were cut down to nearly zero. Disenchanted with prospects, I looked forward to retirement from federal service and joining academia.

Mention must be made here of extensive collaboration with John C. Holden, a fine scientist with unique graphic and cartooning ability. We wrote about a dozen or so papers together in the mid-1960s to the early 1970s. I wrote the words and he composed the graphics ("music"). Holden was unfortunately lost to NOAA by a reduction in force in 1973. Holden was an "almost PhD" from the University of California, Berkeley. He even completed an accepted thesis on the microfauna from a drill core on

Midway Island. He finally gave up after failing the (ridiculous, in my opinion) language requirement for German—after failing the test, as I recall, twelve times. Holden, his talent lost to science, remains today a sociable, but now virtually incommunicado, hermit somewhere in the outback of Washington state. Before moving even further into the boondocks (and beyond telephone range) Holden was known to many geologists as the self-appointed President of the tongue-in-cheek *Stop Continental Drift Society*, complete with newsletter.

ARIZONA STATE UNIVERSITY (1976–present)

Although I thoroughly enjoyed my governmental career, there were many drawbacks and constraints. One never has free reign, the level of stimulus is low, and there are too many mundane assignments. As in the military, one gets paid just as much for marching as for fighting. The rules of Civil Service employment are not conducive to high quality selection of scientists. In 1992, I was one of the three alumni given a Special Achievement Award by the College of Liberal Arts and Sciences of the University of Illinois. It was of more than passing interest to me to observe that all three of us were from scientific academia—apparently the place where worthwhile contributions can be most readily made.

Throughout my federal career, tempting opportunities arose to join academia. I turned these down until 1975 when I had completed my 30 years of duty which provided immediate retirement benefits. On leave with generous rights to re-employment, I accepted temporary assignments at the University of Illinois, Washington University in St. Louis, Washington State University, and Arizona State University. After a brief return to NOAA, I accepted an appointment with Arizona State University in 1977. In 1985 I became active emeritus. I never gave any thought to retiring to the quiet life. Being a professor in a research-oriented university strikes me as the best of all possible worlds even as an emeritus without compensation. I find that people my age are too old for me. Working with college students helps one to remain young, at least in mind. The university has been sufficiently generous in providing me office space to continue pursuing my research interests. An end to age discrimination is one of the new rights that has enhanced the quality of life. A principal interest for coming to ASU was the presence of a strong planetary group and its Center for Meteorite Studies which houses one of the world's largest collections of meteorites. This association has been stimulating. One interesting example has been the recognition with John McHone of the 20-km-across El Gygytgyn crater in Siberia, not as a volcanic caldera, but as the world's largest Neogene meteorite impact crater.

As one ages there is a normal tendency to indulge in criticism and I am no exception. An example is the geologic concept made especially popular by Kenneth Hsu that the Mediterranean Sea dried up to the point of complete desiccation in the late Miocene. It is apparently now a consensus model. It seems to be both intuitively and scientifically unlikely that this could happen. In my view the proper explanation for the undersea salt deposits is by precipitation from a saturation brine basin creating "precipitites" rather than evaporites. Remarkable ideas require extraordinary proof and must be challenged. More importantly, on the fringe of science I have locked horns with the resurgent creationist movement and especially to the claim of "scientific" creationism. The integrity of science must be defended from the onslaught of pseudoscience. I find it particularly galling for religion to attempt to trade on the prestige of science. As one of the sponsors for the National Center for Science Education, I have been active in the creation versus evolution controversy. In the mid-1980s, Arizona was the scene of a strong effort to introduce creationism into the science curriculum of public schools. So far only a few scientists have played a role in preventing this from happening.

A project that brought considerable satisfaction to me (along with Troy Pewe and Mitchell Woodhouse) was getting Arizona petrified wood (*Araucariaxylon arizonicum*) designated as the official state fossil in 1988. This spectacular rainbow-hued Triassic silicified wood displays exquisite beauty and is a significant link in the evolution of vascular plants. Now, more than a score of states have state fossils. The effort was not easy as it took four years of background work. The then Governor of Arizona, Evan Mecham, a Mormon creationist, vetoed the bill for reasons that seemed to be dissembling. In reality, I assume that a 225 million-year-old fossil interfered with his belief in a 6,000-year-old Earth. His veto has also been termed a retaliation against state senator Doug Todd, sponsor of the state fossil bill, who was apparently critical of Mecham. Mecham also attempted to get equal time for creationism in the public schools. Fortunately, Mecham was involuntarily removed from office and a new governor signed the resubmitted Arizona fossil bill in 1988.

MOON, METEORITE CRATERS, AND ASTROBLEMES (1945–present)

I will treat this aspect of my scientific life separately as astrogeology has been a continuing interest largely as a hobby until I retired from federal employment to join Arizona State University in 1977. My interest in astronomy and especially in the Moon commenced in high school with the dream of one day being an astronomer, a desire entirely self-generated and of course never fulfilled. At the University of Illinois I took the only two courses available. As a graduate student I proposed writing my PhD thesis about the surface features of the Moon, but it was turned down as not a subject suitable for scientific contemplation. The idea was chided as totally bizarre and besides "there was no one to check my field work." I was told that speculation does not become a young student and it would be better to do some real geology like mapping a quadrangle in Vermont. However, during my WWII years as a pilot in the Army Air Corps I wrote a paper entitled "Meteoritic Origin of the Moon's Surface Features." Delays were inevitable, especially because R. T. Chamberlin, editor of the *Journal of Geology*, had recently written a paper on the tectonic origin of the lunar geomorphology; but eventually in 1946 he did publish my paper. It was the first such paper in a geological journal to suggest neither a volcanic nor a tectonic origin since that of G. K. Gilbert in 1895. Although volcanic and endogenic explanations remained the consensus view until about 1970, the cosmic bombardment interpretation for lunar craters is now unquestioned. I also recognized the dark maria as giant impact basins but erred in the belief that their basaltic infill was created at the time of impact and not much later.

Flying long navigation training missions caused me to reflect about the Earth below in a generalized way. It is a form of remote sensing not unlike contemplating the Moon. One day in 1943, it occurred to me that the disrupted nest of lower Paleozoic strata in the Kentland quarry in Indiana might not be cryptovolcanic as commonly supposed but an astroidal impact scar. Could not the orientation of shatter cones exposed there resolve this uncertainty? To test this idea I later stopped over at the Air Force Base in Rantoul, Illinois, and hitchhiked to Kentland. There, indeed, was a preferred orientation such that, when the vertically-dipping strata were rotated to an assumed original horizontal position (a counterclockwise rotation in this case), the cones pointed upward suggesting by Hartman's Law that the fracturing impulse came from above and hence was cosmic rather than volcanic. A year later, when I was based in Nashville, I searched the Flynn Creek and Wells Creek Basin cryptoexplosion structures in Tennessee with a mine detector for a possible remnant meteoritic debris. This was a direct but naive effort resulting only in my finding some nails and horseshoes. I already was inclined to believe that the eight cryptovolcanic structures described by Walter Bucher in 1935 as abortive volcanic explosion features were most likely impact structures.

With the launching of *Sputnik* in 1958 there was a sudden surge of interest in space. I was invited along by Gerard Kuiper, along with Eugene Shoemaker and two other geologists, for four nights of moon observation with the McDonald Observatory telescope in west Texas. Once there, I suggested we spend one day examining thc Sicrra Madera, a deranged mountainous structure, as a possible terrestrial analog of a lunar crater. Claude Albritton, although he had never visited the site, suggested it to be a candidate astrobleme based upon its damped wave structural style as mapped by Philip King. We found it to be nicely shatter-coned, which already for me was a definitive criterion for astroblemes. Years earlier I had studied them at the Steinheim Basin, Wells Creek Basin, Flynn Creek, and Kentland. Two publications resulted. This started me on a worldwide search for shatter-coned structurcs. About 70 are now known out of about 140 putative impact structures worldwide. Two U. S. Geological Survey geologists subsequently were assigned to map Sierra Madera. They were initially avowed skeptics of its impact origin but came away convinced of its astrobleme status.

In a *Scientific American* article in 1960 entitled "Astroblemes," I coined this term from Greek roots meaning "star" and a "wound by a thrown object." The term has been widely accepted and I still regard it as appropriate for the Earth but not for the Moon or Venus where impact structurcs retain their pristine form. Certainly, most ancient terrestrial impact sites are not crater-form and many like Sierra Madera are actually mountains. It is useful to have a prototype or a type-locality. Accordingly, I have suggested Meteor Crater as the prototype meteorite crater and the twin and simultaneous created, but remarkably different structurally, Steinheim and Ries basins of Miocene age in Germany as jointly the prototype astrobleme. The German sites are actually transitional between a crater-form and an eroded scar but together they provided the criteria needed for identifying ancient impact scars. I first visited these sites twice in the mid-1950s. The second visit was with Preston Cloud who at the time could not accept my interpretation but later would become an ardent supporter. Then in 1978, as an Alexander von Humboldt awardee at Tübingen, I had a chance to examine these astroblemes in some detail.

While searching for the terrestrial equivalent of the lunar crater Copernicus on Earth, I was drawn to a giant bull's-eye in South Africa, the Vredefort Ring, a central Archean granite body 40 km across surrounded by a thick upturned collar of Precambrian sediments. It seemed a prime suspect as an astrobleme created by recoil uplift following a hypervolocity asteroidal impact. I wrote letters to South African geologists seeking to know if this structure was shatter-coned. Answers were at first negative but eventually Robert Hargraves replied "Yes!" and sent definitive photographs to prove it. With that information in hand I committed a cardinal sin: writing a paper before visiting the site entitled "Vredefort Ring Structure: Meteorite Impact Scar" espousing an impact scenario. This model has stood the test of time pretty much intact although the local geologists immediately rejected it. A few years later (1964) I was able to visit the Vredefort Ring and test my ideas. My hour-long invited talk was immediately followed by an even longer critique offered by Louis Nicolaysen who totally rejected my interpretation. It was an interesting exchange of views and a good example, I believe, of South African geologists being ultra-conservative and bound by traditional views.

Following my Vredefort paper I turned my interest to searching for a terrestrial analog of a lunar mare—a "wet" impact with a central melt sheet or triggered volcanism. The large (35 × 60 km) kidney-shaped Sudbury Igneous Complex (S.I.C.) in Canada seemed a potential tectonized or squashed example. Of course, as an astrobleme one needs to scrap the classical model of an intrusive lopolith and consider the S.I.C. as an open pool of chilled magma crusted over with a fall back suevite (impact microbreccia) rather than a volcanic tuff. In the spring of 1962, to investigate my hunch I took leave from my position at the Navy Electronics Laboratory to visit Sudbury. A brief field study convinced me of the reasonable reality of my model based largely on geological relationships. It was not until the end of my visit that I discovered definitive shatter coning, as this fracturing is degraded in Precambrian rocks, unlike its development in limestone terranes. The resulting paper entitled "Sudbury Structure as an Astrobleme" eventually appeared in 1964. Publication had been delayed by a "pocket veto" by the reviewer—who finally returned the manuscript only long after being prodded to do so. Even then the only comment was "nonsense." Fortunately the editor of the *Journal of Geology* decided to override this negative appraisal. In 1972, I amplified my model to argue that the Sudbury nickel ores found in the sublayer were cosmogenic. The view has yet to be accepted although geologic relationships, especially the emplacement timing, support this view. In 1992, I participated in a NASA symposium at Sudbury on large terrestrial impacts with Sudbury being the type example. It was good to hear one's ideas become mainstream.

My inborn yen to see the world has been amply fulfilled by sailing the seven seas (North and South Atlantic, North and South Pacific, Indian, Arctic and Antarctic Oceans) as an oceanographer. I have spent a total of about four years at sea. This has also permitted me to visit and do geological research on all seven continents. Several of my visits to impact sites were made possible only enroute to join or leave various oceanographic expeditions. Thus, I was able to study the Serra da Cangalha and Araguainha astroblemes in Brazil enroute to work in the South Atlantic. Similarly, out of Dakar I organized an expedition into the Richat Dome in central Mauritania. This most wondrous giant dome, a giant bull's-eye from space, proved not to be meteoritic. A French report of coesite (a silica polymorph created by shock) proved to be barite and a central breccia is not an impact breccia. The centers of impact structures are upturned, disrupted, and eviscerated but Richat Dome has horizontal beds in the central eye. Oceanographic travels also permitted a study of both the Lonar Crater in India and the Vredefort Ring in South Africa enroute to work on the Indian Ocean. And I studied Gosses Bluff astrobleme in Australia enroute to leading a research cruise out of Perth and across the Great Bight of Australia.

Much of 1978 was spent at the University of Tübingen in Germany as a Humboldt Prize awardee. It was a fruitful and broadening experience offering especially a chance to study the Steinheim Basin and Ries Basin astroblemes in some detail. Remarkably, although the product of a twin impact event about 15 Ma, they are wholly different in structural style and shock effects. More importantly, I organized a month-long expedition with John McHone, Philippe Lambert, and my son Rex to reconnoiter possible impact sites in Algeria. It was exceedingly frustrating to set up this fieldwork but once in Algiers, almost on speculation, we had full cooperation and a joint program with Algerian geologists. It was a good example of comraderie achieved among scientists at the working level once the political difficulties are ignored even though these are never solved. We visited many sites deep in the Sahara; Talemzane and Amguid geomorphically appear to be meteorite craters, while Tin Bider and Ouarkzis are probable astroblemes.

Mention must be made here of the original significant chance encounter with John McHone (then a recent MS from Old Dominion University and later a PhD from the University of Illinois) at NOAA in Miami. I had arranged a trip to study Laguna Guatavita in Colombia, a sacred high Andean crater lake famous as the supposed site of the El Dorado golden trove. My initial companion canceled out at the last moment, so on the spur of the moment I invited McHone. This lake remains a site for treasure hunters as the pre-Columbian Indians were said to have littered the bottom with sacrificial gold icons. We assessed this feature as not meteoritic but, in all probability, the collapsed summit of a salt dome following ground water solution. Incidentally, we discovered that the lake had been secretly and successfully drained about 1905. Apparently no significant treasure was discovered—or at least none to speak of. Collaboration with McHone has now extended over two decades with other successful studies in South America, Europe, Africa, Canada, the United States, and from space imagery.

One of our more exotic exploits was gaining entry in June 1991 into politically-closed Cuba under the guise of attending a marine science meeting. Our real purpose was to check out the circular and domal Isle of

Pines (location of a maximum security prison) as the possible ground-zero site for the Cretaceous/Tertiary cosmic impact believed to have caused the great extinction of life including the last dinosaurs. Our interest had been aroused by the report of such things as cone beds. These, however, turned out to be cannon-barrel-shaped concretions and not shock-created shatter cones. There is a saying that one cannot prove a negative but we actually did. We found no evidence of shock in any rocks from the region. Co-operation by Cuban geologists proved once again that comraderie among scientists transcends political differences. Subsequently, the correct ground zero was located in Yucatan, the site of the buried Chicxulub crater.

As with poets, the Moon was a source of wonder to me early in life. In the early 1940s when I first studied selenography, no one in their wildest dreams even thought that twenty-five years later Man would walk on our satellite. Especially startling to me was the pre-*Apollo Ranger* 7 missile impact on the Moon which transmitted live video images of the crater Alphonsus back to Earth as it crashed. With the drift of the continents over the aeons, Mother Earth has slowly changed her expression while the Man-in-the-Moon has looked down with a fixed stare since the terminal bombardment. Plate tectonics has been the game plan for Earth but cosmic impacts have been the wild cards. Their significant role, even in perturbing evolution, ranks as a new geological paradigm.

SOME RECOGNITIONS AND HONORS

What drives people to do what they do? In my case, wealth, power, and fame have been unimportant. I have regarded gathering material goods as an encumbrance and preferred the simple life or, as Picasso once advised "Be a poor man with money in your pocket." As a journeyman scientist my stimulus has been delving into the nature of Nature. Along this pathway, it has been satisfying to be overly recognized by my peers and colleagues with various honors. I will list some of them here for the record, and perhaps this will also provide some credentials for the subsequent venting of my sure-to-be unpopular recipe for curing Man's basic problems: Phi Beta Kappa, University of Illinois, 1937; World War II, multi-engine pilot, five medals; Brevet Captain, Illinois State National Guard; Honorary Pilot, Chilean Air Force; Lt. Col., U.S. Air Force Reserve (Ret.); Antarctica Service Medal, Navy-Byrd Expedition 1946–47; U.S. Navy Civilian Service Award (1960) for bathyscaph *Trieste* ultra-deep diving program; Walter Bucher Medal of American Geophysical Union for geo-tectonics, 1971; Gold Medal of U.S. Department of Commerce for Exceptional Service, 1972; Alexander von Humboldt Prize (West German) 1978; Francis P. Shepard Medal of Society of Economic Paleontologists and

Mineralogists for Marine Geology, 1979; Barringer Medal for terrestrial meteorite crater research, 1985; Founder of Plate Tectonics Award, Texas A & M University, 1987; Doctor of Science (*honoris causa*), Arizona State University, 1988; Penrose Medal, Geological Society of America, 1988; Distinguished Achievement Award, Arizona State University, 1990; Distinguished Alumni Award, University of Illinois, 1992; Honorary Fellow Geological Society of London, Geological Society of Brazil, and Canadian Society of Petroleum Geologists; Fellow, Geological Society of America, Meteoritical Society, American Geophysical Union, Mineralogical Society of America.

PERSONAL PHILOSOPHY AND GRATUITOUS ADVICE

I will end this account of my life and times with my worldview—my philosophy of life. This, of course, has been molded by my lifetime of experience and my scientific (and hopefully objective) outlook. I define myself as a naturalistic materialist, a no-nonsense scientist. The natural to me is sufficiently awesome with its three "infinities": the infinitely large celestial universe, the infinitely small world of the atom and quantum mechanics, and the infinitely complex realm of life. I reject the supernatural realm of miracles and faith. I accept the material—the reality of matter, but I reject mind and spirit. The mind is what the brain does. I am certainly a skeptic but I do not qualify as an agnostic—this, in my book, is a gutless atheist. Nor am I an atheist as this term carries a lot of negative connotations; I regard the terms nontheist or ethical culturist, as better. Besides an overt admission of atheism would disqualify one from holding public office in many states. I am a secular humanist, a term of derision coined by the TV evangelists, but it describes me well. Humankind must accept the here-and-now and the natural scheme of things in the real world by resolutely solving our own problems through reason and evidence. And since I have recently written a book entitled *Creation/Evolution Satiricon: Creationism Bashed (Did the Devil Make Darwin Do It?)* with illustrator John Holden, perhaps this qualifies me also as a secular humorist. I believe my views are typical of most scientists with a philosophical bent, although most prefer to remain silent as being outspoken is not the way to win friends and influence people.

All of the "infinites" mentioned above have philosophical import. This applies also to the "finite"—the nominal or meter-sized world. The cosmological paradigms from Copernicus to Newton have revealed that the Earth is not special (the principle of mediocrity). Subatomic quantum mechanics with its uncertainty principle has torpedoed determinism. But evolution as the paradigm of life most profoundly affects one's worldview.

I hold no brief for the "good old days" as the human condition has improved each year of my lifetime. Science and technology are responsible as the prime movers advancing our improved circumstances. Scientists and engineers, not wars and generals, have fashioned our present society. For example, I believe the world would be much the way it is even if Hitler had won World War II. Nevertheless, I remain pessimistic about the future. I envision that our civilization is even now descending on a downward spiral as man forsakes his proper stewardship of the Earth and our environment. Remarkably, solutions to the world basic problems, although stark, are simple. They can be defined by the acronym ZEES—Zero population growth, Evolution, Eugenics, and Secularization. Unfortunately, these are currently all politically incorrect concepts. I also hold no brief for the wisdom of the ages, or of the aged. People of my age are too old (in their rigidity of mind) for me. I have lectured as a naturalist on about a score of deluxe cruises all over the world. These mostly retired people seem not to respond to any intellectual stimulation above the level of playing bingo.

In 1981, during the early days of the resurgent creation/evolution controversy, the Council of the National Academy of Science stated in a resolution, "Religion and science are separate and mutually exclusive realms of human thought whose presentation in the same context leads to misunderstanding of both scientific theory and religious belief." This official statement, apparently a peace offering in response to creationism parading as science, is off the mark. Science and religions are not separate and mutually exclusive realms of thought. They are overlapping and irreconcilable modes of thought with science being uniquely the way of knowing. The tenets of religion can and should be subject to exacting scrutiny and testing. Miracles, the power of prayer, life after death, heaven versus hell, and the god concept should not be placed off-limits for investigation. Religion should not remain exempt from criticism and science should not avoid confrontation. After a millenium, men of the cloth still have not resolved, "How many angels can dance on the head of a pin?" Perhaps the answer is: All of them. Let the theologians refute each other!

In the past century an attempt was made to measure the weight of the soul by weighing a dying person just before and after death—a crude but reasonable first approach. The answer, as I recall, was three ounces. Modern scientists and theologians both laugh at the result as they believe, for different reasons, that the answer is zero. To scientists the soul is nonexistent; to the theologian the soul exists but is weightless—although even light has mass, and one photon is measurable nowadays, so a soul cannot even wear a halo. This question is not trivial because it bears upon when a zygote becomes a person and this is central to the pro-life/pro-choice debate. As President Clinton remarked at a press conference in early 1993, "theologians disagree about when the soul enters the fertilized cell and personhood is achieved." For workable public policy purposes, we should accept "never," as the burden of proof logically falls on those who propose.

The greatest immediate threat to this world are the religious fundamentalists, especially the Muslims and the Christians. There are countless zealots who stand ready to terrorize the world and "do what God would have done, if only He had facts of the case." Witness the 1993 Branch Davidian holocaust in Waco, Texas, or the bombing of the World Trade Center in New York. Over the millennia, religious conflicts have been and continue to be the major cause of war. We even have a word for it—holy terror. While the religious right remains the principal problem, the mainstream churches as well need to shift away from the supernatural and become centers of ethical culture. Our ethics in turn must be based on the realities of the human condition and these are Darwinian. We must not appeal to some Santa-Claus-in-the-Sky. This would be like throwing a drowning man both ends of a piece of rope.

In bizarre contrast to conventional geology, the creationist young-Earth scenario compresses all world class geologic events into Noah's Flood year about 2400 B.C. by Archbishop Ussher's calendar, some 1600 years after Earth's creation. Accordingly, in 375 days all Phaneorozoic strata were laid down by the raging Deluge, then Ararat was erupted, and this was followed by the docking of the ark. Whew! Elsewhere in the world, the ocean basins were catastrophically opening up, mountains were folded, volcanoes erupted, continents drifted apart at 45 miles per hour, and in the final days the Grand Canyon was cut. It was a good year for geology! The Ice Ages then waxed and waned in the century or so following the Flood. Creationists like to emphasize that some classical geologists believed in the reality of Flood deposits or diluvium. True, but this interpretation only applied to the regolithic Pleistocene till plains of Great Britain. Modern creationists accept the modern geological interpretation of their deposition by continental glaciation. Instead, however, they lay claim to the entire lithified Phanerozoic sedimentary sequence, with a composite thickness of at least 150 km, down to the Basement complex as Noachian. This would be high humor except that many Americans accept this nonsense—and this is sad.

So what should scientists do other than be amused? In view of the evident fragility of the human condition, I submit that we should enter the campaign against creationism for the human mind which must be won one issue at a time. Although holdouts remain, science has defeated flatearthism and the geocentric Solar System. Can we not also return the Noah's ark story to being an ancient legend in the heroic tradition and convince the public that Earth is more than 6,000 to 10,000 years old, a remarkable uncertainly for so recent an event? The geologists' age ($4.54 \pm 1\%$ Ga) is nearly one million times longer, hardly a trivial disagreement. These issues, on a par with the flat Earth, are the Achilles' heel of the creationist movement which pits pseudoscience against the real thing. Somewhere out in this great land of ours there must be geologists ready to stand tall and defend our science. As the Bible tells us: "When I was a child, I spake as a child; I understood as a child, I thought as a child: but when I became a man, I put away childish things" (Cor. 12: 11). Young-Earth and Flood creationism are glaring nonsense and nonscience. We must sink the ark and the young Earth as well. Inaction is also taking action.

The larger question is: Can the findings and realities of science change our cultural ethic as it already has our technology? Most futurists agree that our civilization is on a downward spiral owing to the population explosion. The ultimate solutions such as zero population growth, eugenics, and secularization are so stark that even their mere mention is a media taboo. Because such ideas are not politically correct, no advocate could ever win political power—the ultimate *Catch* 22. Even these could never occur anyway until an ethic based on Darwinian evolution is accepted. It is the most important of all paradigms and is the mirror we must use to see ourselves. We must play the hand we were dealt even if evolution has a dark side. As top primate, Man is super ape, not a fallen angel; the world belongs not to Man but we belong to the world; and the good of the species takes precedence over the rights of the individual. Evolution is a random walk through time with no ultimate goal in mind. Opportunism is the password and, if a new structure works, build on it through natural selection. We do not live in the greatest of all possible worlds but only the real world. The Greek gods had it better. Truth may be stranger than fiction but it is not as popular. In the long run, the reality of evolution must prevail over make-believe and feel-good creationism.

Not far from my home in Tempe, Arizona is Biosphere II, a giant glasshouse enclosure which is a one-trillionth scale model of the Earth (Biosphere I). It is a fascinating environmental research project concerned with Man's survival on Earth and perhaps eventually on Mars. But, in a sense, there have been many earlier "experiments" where in all cases society has crashed. A good example is Easter Island where the early Polynesian settlers died out apparently soon after they cut down the last tree. Already heavily damaged by a plague of people, the Earth is a fragile oasis in space. I have enjoyed a minor association with the Biosphere II project.

Environmental problems now head the list of human concerns with the

Malthusian specter of mass starvation standing offstage. In my worldwide travels I have been increasingly impressed that most countries are already "basket cases," which certainly applies to much of Africa, India, Indonesia, and South America. It has been a decade since a Caribbean cruise ship has dared to visit Haiti. The rampant population explosion is, of course, the world's major problem; it is aided and abetted by religion, but any direct mention by the media is taboo. The recently held Rio de Janeiro conference on the environment could not even be convened until all parties agreed that demographics would not be on the agenda. The threat of nuclear war has ebbed but our social order remains archaic relative to the advances of science and technology.

Eugenics was a popular idea at the turn of the century; today most persons do not even know the meaning of the word. Among those that do there is usually a knee-jerk reaction concerning Adolf Hitler and racism; the word has been redefined with entirely negative connotations. We all take pride in being distinctly different from anyone else but when it comes to larger groups, like races, we must accept them all as clones. I believe that any individual's persona is dominantly controlled by genes rather than environment. This view must remain intuitive until information is collected but science must not be prohibited from collecting this data base. The human gene pool must be protected and improved. This does not mean homogenized but instead diversified. Bringing a child into this world should become not a right but a special privilege. Would it not be wonderful to raise a child who is free of all the 4,000 plus genetic diseases, as bright as a Nobel Laureate, capable of winning a decathalon, and as handsome as, say Harry Belafonte?

Recently media mogol Ted Turner funded a competition for a book offering a workable plan for a sustainable peaceful world. Ten thousand manuscripts were submitted, but not one passed muster. This is understandable as no one is willing to bite the bullet because the obvious solutions are stark. Scientists must lead the way first in getting rid of backward religions and cults (the world of make-believe) and replacing them with an ethical culture (reality based on Darwinian evolution). Experimental societies are needed free of gurus and books of revelation to show the way. Such a plan could never be implemented within the USA because of its limited executive power. The most socially advanced society I have ever visited is the city-state of Singapore, a model to be emulated, including its severe restrictions on free-wheeling democracy.

A United Nations study group on demographics reported that the present population growth curve produces a one hundred-fold increase in the world population to 697 billion by the year 2150. This is clearly an extrapolation to the impossible and foretells of catastrophic perturbations by such events as pestilence, starvation, ethnic cleansings, or nuclear wars. Even today 99.9 percent of our overall population would starve were it not for artificial selection by plant physiologists of the Green Revolution, but such scientific fixes cannot cope with exponential peopling. We must thank Charles Darwin for discovering the malleability of species, the Franciscan monk Gregor Mendel for studying peas rather than piety, and God for not meddling while evolution produces its wondrous works. There is no limit to what science can do if left unfattened.

Again, let me emphasize that the solution to the apparent degradation of the human condition is ZEES. This is Zero population growth, accepting Evolution as the ruling paradigm of life, Eugenics, and Secularization. Spaceship Earth is hurtling through space and no one, or any collective conscience, is at the helm. Time is of the essence and it is already late. Planets with biospheres where conditions are just right (The Goldilocks's paradox) for higher life are exceedingly rare in the cosmos. Planet Earth may even be unique. Nature is amoral and does not care. Regarding secularization, let me emphasize that I am not opposed to churches per se, as they serve many useful social needs. But churches should eschew infallibility, faith, magic, the supernatural, liturgy, dogmas, vestments (especially funny hats), books of revelation, special diets, heaven and hell, life after death, mind-stomping chants, miracles, and petitionary prayers to an old-man-in-the-sky—and that is just for starters. But there is still a role for ethical culture and humanism.

A Japanese billionaire recently assembled a book on the meaning of life by polling famous people for their opinions. The answers were facetious, mystic, religious, irrelevant, or psychobabble: Life has no meaning; intelligent life is an accident of evolution; living well and ethically is the best revenge. No one got it right. The true Darwinian "purpose" (nonteleological) of all life is to reproduce—and in excess numbers, fueling natural selection. It is one of the dark sides of evolution that the drive to reproduce is greater than the will to live. So what about the eternal questions: Where did we come from? Why are we here? And *quo vadis*? Darwinian evolution, the greatest of all paradigms, explains it all (even though the real world is not the best of all possible worlds) and leaves God unemployed. Since the first spark of life (biopoeisis) four aeons ago by mutations and natural selection, man has evolved by ascent with modification. We are here at this point in time because one has to be somewhere. As for *quo vadis*, sentient man is no longer subject to natural selection. We can control our future but probably do not have the collective will to do so. Exit *Homo sapiens*?

CONCLUDING REMARKS

Now in my so-called Golden Years, I am thankful that one's mind ages better than one's body. My hero in this respect is Frank Lloyd Wright (Wrong?) who did his best work in his cantakerous late years. I must confess that I am a bit seduced by the words of the late William Saroyan who, when he was told his days were numbered, said "I expect that I know we all have to go sometime but I sort of hope that they might make an exception in my case."

My eventual wish is to be struck by a meteorite and then fossilized. This would be a privilege. I would be the first human to meet such a heroic demise although this apparently happened to an Ordovician cephalopod in Sweden. Hopefully the meteorite might even be a fragment of the Phoceaid family asteroid #4666, so kindly named Asteroid Dietz by its discoverers Caroline and Eugene Shoemaker. As a memorial it is certainly better than any headstone. They assure me that the number 666 is fortuitous but I sometimes wonder. In May 1993, it was a profound experience for me to be able to see an image of this cosmic cannonball acquired by a telescope in Colorado by my astronomer nephew Richard Dietz. It is commonly supposed that old scientists like old soldiers, should just fade away. I, for one, refuse to do so. Although my mountain climbing days are past, I have yet to meet a rock I did not like. I remain anxious to contribute and especially to defend the integrity of the scientific method as the only road even to proximal, small-truth. As the circle of light expands, the perimeter of darkness grows ever larger.