

## Chapter 1

## HOW MANY EYES HAVE SEEN THIS?

Within the hour I will be observing the deep universe again, this time from the mountains east of Phoenix. For over 50 years I have been traveling to remote dark sky sites with a succession of larger and larger telescopes to experience astronomical sights few people would believe visible. The sun sinks below a mountain ridge to the west leaving a brilliant red glow along the horizon that grades upward through gold into translucent green and sky-wide swaths of increasingly deep blue. The vibrant colors of this pageant indicate exceptional transparency and the prospect of an Arizona night sky for the ages. The brighter stars appear as twilight fades, so I rush to finish assembly of the biggest telescope that one person can transport and set up without assistance. A familiar excitement builds...and builds, for this is my heaven. However, little do I know that tonight's observing will induce an emotionally overwhelming experience that will launch me on a remarkable pilgrimage through the narrow confines of the Grand Canyon, across part of the Mojave Desert, up the long axis of Death Valley, and onto the crest of the Sierra Nevada mountains in California.

It has taken about 90 minutes to unload the trailer, roll out the rocker box holding the 25" mirror, assemble the ten-foot-high truss, align the delicate optics, and configure the onboard computers (Fig 1.1).



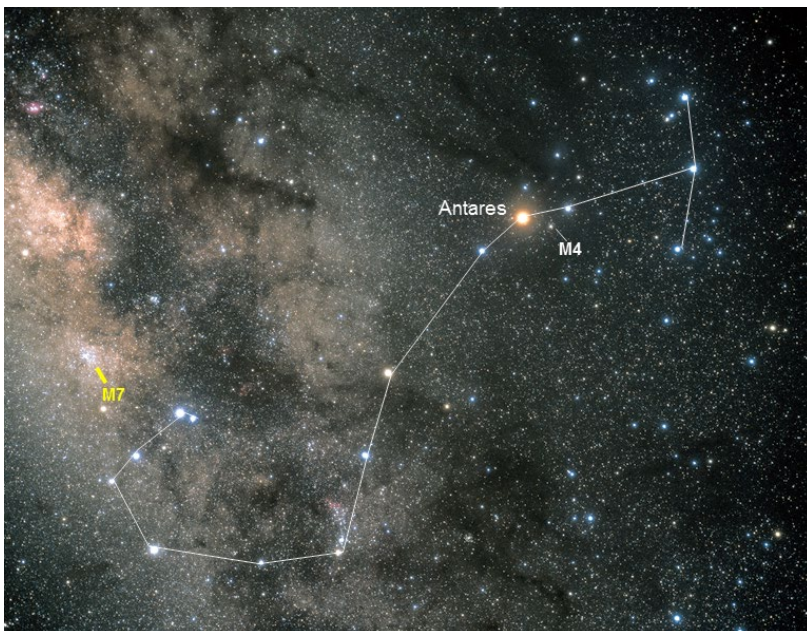
*Figure 1.1. Observing with the 25" reflecting telescope.*

The light gathered by the huge, curved mirror reflects as a narrowing cone that gets redirected out the side of the upper truss by a small slanting mirror suspended in the middle of the tube. From there it is magnified and focused with an eyepiece to go through the pupil of a human eye. A telescope is a light concentrator; the bigger the mirror the fainter the object that can be seen. This telescope is like having an eyeball pupil over 2 feet wide.

The drive motors and electronics come to life in response to wireless commands from the little control box hanging around my neck. I happily notice no trace of clouds to diminish the spectacle soon to emerge above. The star clouds of the Milky Way will soon billow across the whole eastern sky. It is an amazing sight no longer visible to most of the world's population now living in light polluted cities. Perfect so far!

I have come to this site tonight specifically to observe the brightest and densest part of the Milky Way, the very core of the giant galaxy we live in. It will rise as high in the sky as it gets at this latitude shortly after midnight. There is time before that to work down my endless observing list of galaxies, glowing clouds of gas, star clusters, and other splendors that make up the visible universe. In all my years of observing, views into the star clouds toward the center of our galaxy have been frustrated by lights from distant cities or the quivering atmosphere that turns pinpoint telescopic star images into wiggling blobs. I am determined to experience this telescopic marvel from an optimal dark-sky site on an optimal night with the very best and largest optics possible. The sky is remarkably steady tonight, the telescope is working great, and the views are wonderful now that the lingering twilight has faded. I keep glancing with anticipation toward the southeast at the increasingly bright star clouds of the galactic core now rising well above the ragged horizon line of distant mountains.

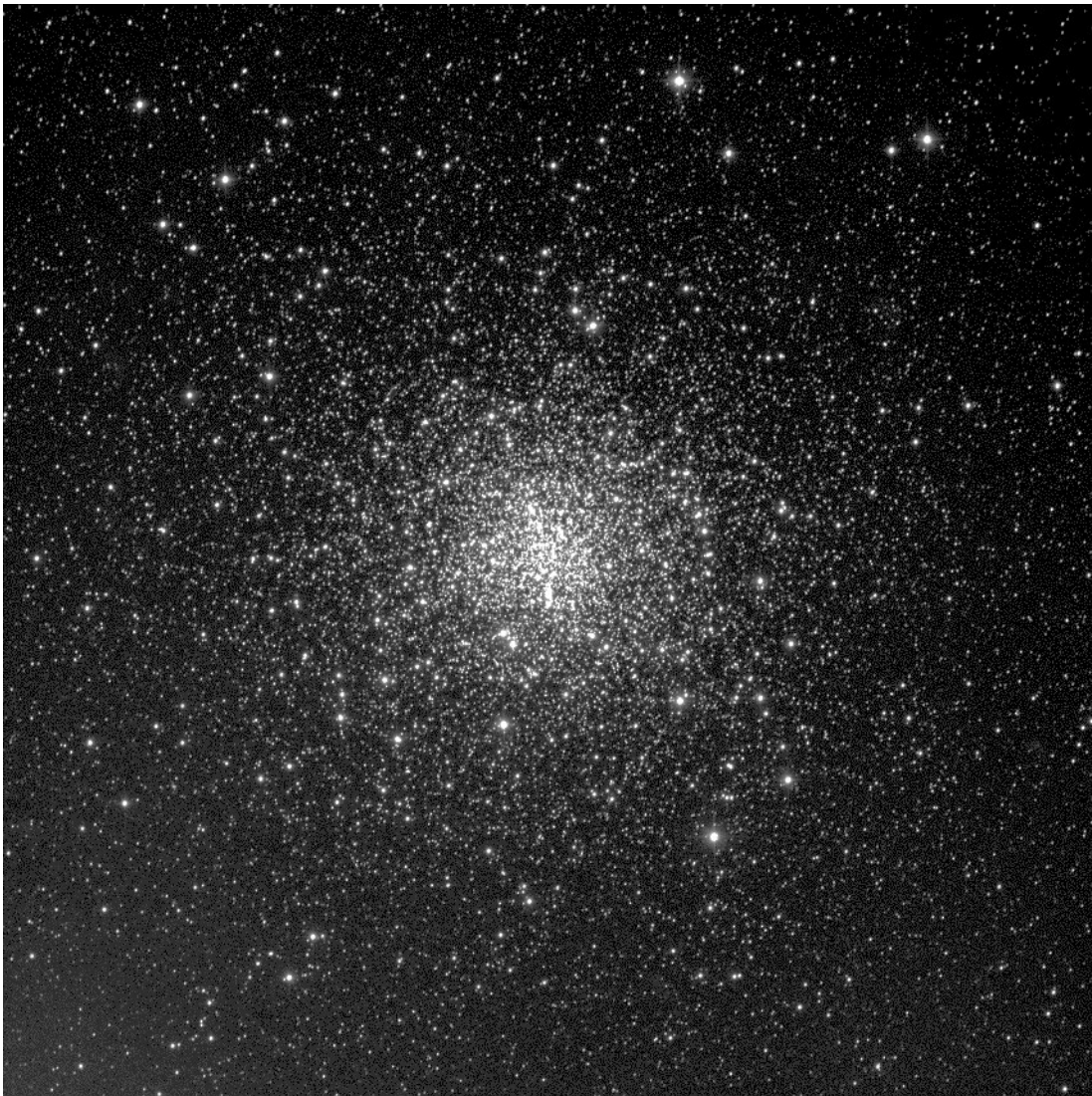
The striking constellation of Scorpius stands on end along the vertical meridian that divides the sky into east-west. The scorpion pincers point upward, and the great hooked stinger appears to support the whole thing like an umbrella standing on its curved handle. Blazing away at the heart of the scorpion is the brilliant red star Antares (Fig 1.2).



*Fig. 1.2 Scorpius with Antares, globular cluster M4, and open cluster M7. The core of the Milky Way galaxy is behind the dark clouds of dust and gas just above and to the right of M7. Dense star clouds near the core peep out to the left and right of the intervening clouds. Original image by ESA/Hubble (Akira Fujii)*

This is a star so large that the Earth would be inside if it were substituted for our sun. Being able to sense Antares as a relatively cool red star made brilliant only by its enormous size puts me into that special frame of mind where we use the results of scientific investigation to re-picture what we are seeing. I see it mentally as a star so far away it is just a point of light, and yet it is bright because it is an enormous star not far from the Earth as stars go. Suddenly, the image of a scorpion vanishes and all I see is a highly luminous red star standing in front of stars much farther away. The 3D effect is striking. Science has informed the view and changed how a human can meaningfully experience it. Forget the silly two-dimensional scorpion pattern, the actual universe is at hand.

Close to Antares is a telescopic object known as globular cluster M4, an extraordinary concentration of over 100,000 stars all clumped into a spherical ball (Fig 1.3).



*Fig 1.3. Globular Cluster M4. This is roughly the same size in the sky as the moon. It contains more than 100,000 stars all clumped together. The visual view through the 25" strongly resembles this image except that the stars are infinitesimal points of light rather than blobs. (Original image NOAO/AURA/NSF)*



After marveling through the eyepiece at this wonder, I irresistibly slew the telescope slowly eastward toward the rising Milky Way. The outer reaches of the Milky Way are recognizable here not as an increase in the number of stars in the telescopic view, but a decrease! This is because dark clouds of dust and gas wrap around the core, and my line of sight is almost directly toward one of them. Although I cannot see a discrete cloud, I am able to see variations in the cloud density as the telescope slowly moves and the abundance of stars comes and goes. It reminds me of a nighttime landing approach where city lights peep in and out through low scattered clouds as the plane descends toward the airport. I know a city is down there, so I know what those lights signify behind the clouds rushing past. Similarly, through the eyepiece, my mind's eye recognizes the black areas vacant of stars as obscuring clouds of dust and gas simply blocking a myriad of stars behind. Irregular boundaries of the black clouds are thus discernable as abrupt changes in the background star density. The eyepiece view now takes on a more profound meaning.

A tiny globular cluster moves into the field of view. It is the last peep at something distant and outside the galaxy before the dark clouds and massed stars between us and the core become too dense to see through. The field stars largely vanish as I drive the telescope eastward through a markedly dense cloud patch. The obscuring clouds often reflect nearby starlight to appear as a faint haze, but I am not content to linger amidst the near-invisible. So instead, I decide to zig-zag the telescope downward along an imaginary line known as the meridian that extends north-south right across a point directly overhead to await the core's transit across it. Objects low in the south are best observed as they cross the meridian because they are then highest above the thicker atmospheric disturbances closer to the horizon. I make repeated side treks with the telescope to admire loose star clusters that look tonight like assortments of glistening gems.

The atmosphere is so clear and steady I can raise the magnification and look at the intricately detailed "Butterfly" Nebula, as it is called by us amateur astronomers (Fig 1.4).

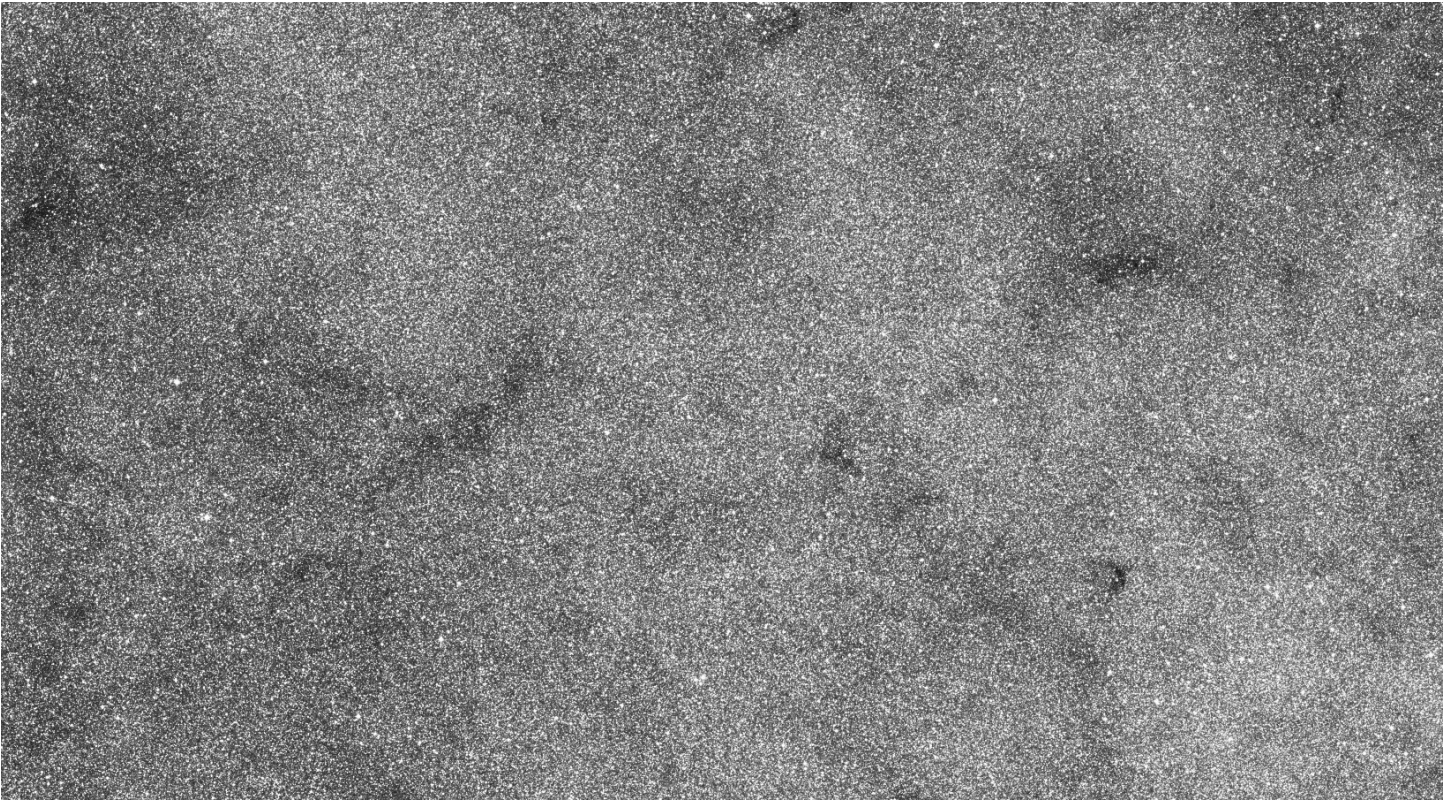


*Fig.1.4 The Butterfly Nebula--expanding clouds of hydrogen and other gases ejected from the polar regions of an unstable star. Visually, the object is somewhat fainter than the photographic impression and appears slightly greenish from ionized oxygen atoms which glow at wavelengths that the human eye is exceptionally sensitive to. (Original image by ESA/NASA & Romano Corradi)*

Forget the butterfly appearance of this striking object. The star at its center has violent goings-on in its core and has jetted out swaths of glowing gases from its polar regions. This ejected material will eventually travel outward and mix with the nearby darker clouds of dust and gas. These expanding strands visible to my eye have the fingerprint in astronomical instruments of oxygen atoms glowing from the radiation of the central star. It is luminous for the same reason a familiar neon lamp glows, but it is oxygen atoms here that are glowing so prominently. Cameras sensitive to faint red light show that the glowing gas is mostly hydrogen atoms glowing red, but night vision of the human eye is not sensitive to color.

The view takes on new meaning when I reflect on theories that oxygen atoms are forged from hydrogen atoms in the deep interiors of stars and then get strewn about the galaxy by objects like this, and even more prominently when a giant star blows itself apart in a great supernova explosion. Solar systems like ours probably formed when dense regions of these interstellar clouds long ago were seeded and enriched in these newly created elements and then gravitationally collapsed to create a new star with leftover debris forming into planets. The oxygen atoms I just inhaled in my last breath were once floating around interstellar regions just like the ones I am looking at! So were the carbon atoms in the molecules that make up my fingers now focusing the eyepiece. Carbon atoms do not visibly glow in the Butterfly Nebula, but they are there according to sensitive light detectors that astronomers use. The oxygen atoms making the glow I see may someday be breathed by an organism on some distant planet in some distant region of the galaxy. A person can look at the Butterfly Nebula, notice its interesting shape, and imagine a cricket, beetle, or a Kafka cockroach. Looking at it with the current scientific understanding yields something more profound that can leave a sensitive person a bit stunned and certainly thrilled.

Around 2 am, the Milky Way Galaxy core reaches the meridian. It is now as high above the horizon as it is going to get. I pull off the drive clutches, grab the truss, and just sweep slowly, field by field with a new wide-field eyepiece that costs by itself as much as a sophisticated camera. Normally in telescopes, this region appears visually as a bright haze of unresolved distant stars behind innumerable foreground stars. However, tonight I am startled to resolve the background haze as an immense glowing veil of stars, each a little infinitesimal point of light. They are so numerous that there is hardly any space between them. It is not just the amorphous glow that I was expecting, but rather a glow made up of uncountable discrete points of light that I never saw before as such. Against this background of seemingly infinite pinpoints, the brighter, closer stars form a separate and noticeably smaller population. But the astounding thing is the dark stringers, elongated patches, and discrete blobs of jet-black obscuring clouds of all sizes and shapes silhouetted against this luminous curtain (Fig 1.5).



*Fig 1.5. Telescopic view of dense star clouds near the core of the Milky Way galaxy. Visually, the stars are almost infinitesimal points so dense there is hardly space between them. The black clouds are visually sharper and more intricate than how they appear in images. (From original image by ESO/Digitized Sky Survey 2/ Davide De Martin)*

Big ones can be seen in binoculars, but here are telescopic fields of small stringy jet-black filaments, swirls, and patches sharply delineated against the stellar multitude--everything spangled with brighter foreground stars with their subtle color differences. The boundaries and shapes of the dark clouds are distinct, vivid, and intricate beyond verbal description. Even photographs cannot show what I am seeing because stars are always little blobs in images. Just when I get my breath from one view, the next one moves in with even more spectacular, infinite detail. It goes on and on as I sweep field after field. In every view, the number of discrete stars seen in one gulp overwhelms the senses.

Moving along, obscuring strands appear that have that steely gray sheen indicating they are reflecting starlight or glowing from the radiation of immersed stars. They are especially noticeable when they grade into jet black counterparts in the same field. For nearly an hour, I can only marvel, gasp, and exult over what I am seeing. I put in a higher power eyepiece and find even more detail in these dark networks! Unbelievable! I have swept these areas a hundred times with my older telescopes and even twice with this newer 25" mirror, but never with expensive eyepieces like these or on a steady night like this. This is all new and glorious. For an interval, I feel like I am on top of the Mount Everest of amateur astronomy. Even of human existence. How many eyes have seen sights like this? Who even imagines it is



possible? All the effort to acquire the biggest transportable optics, to bleed money for the best eyepieces, to get everything finally working, and to opportunistically travel to distant dark sky locations when conditions are optimal is here yielding a payoff beyond what dreams are made of. A big, bright, loose star cluster known as M7 (Fig 1.6) moves into the field as I push the telescope along.



*Fig 1.6 Open Cluster M7 in front of star clouds and dark clouds of gas and dust closer to the core of the Milky Way galaxy. Visually, the bright stars of the cluster are piercing points of light with subtle color making this and other open clusters resemble glittering baskets of jewels. (Credit: N.A.Sharp, REU program/NOAO/AURA/NSF)*

I see it in palpable 3D in front of more distant, innumerable stars seen around and through this brilliant cluster. A uniquely ring-shaped jet-black cloud catalogued as Barnard 294 floats into view with the background stars shining in the middle hole with undiminished intensity. What vagaries of galactic history led to this remarkable and unusual shape?

At length, the climax along the meridian is over. The low-lying galactic center is now rapidly sinking into the southwest while the slanting, more northerly band of the Milky Way rotates higher into view. Standing back, I see the telescope silhouetted against the sky made bright by countless stars. Computer controlled motors work continuously to hold its position in space while the Earth rotates under it. A meteor flashes as a luminous streak which quickly fades. Then another-- all in total silence. Deep sensations emerge in this profound stillness alone amidst the cosmos... deep...a kind of spiritual ecstasy. But now it is coming up on 3 am. The sky will soon brighten with morning twilight. There are numerous splendors yet to see, but I am too physically and emotionally exhausted to carry on safely.

I wake up around noon to warm winds and broken clouds. Still seared and shell-shocked by cosmic views of unsurpassed splendor, the long afternoon drive back to human civilization in the Phoenix area is bewildering. All seems so picayune. Then, going through road cuts of ancient explosive volcano deposits west of the town of Globe, sunlight flashes off a myriad of tiny crystal faces of feldspar minerals reminding me that these rocks are made up mostly of silicon and oxygen atoms bonded together--elements that were cooked up inside of stars long before the Earth formed. How those atoms along with six other common atoms ended up in these crystals in these rocks at this place is the story of geology. By profession, I'm a geologist, so I quickly rattle off in my mind's eye the history of those atoms as we think we understand it going back through geologic eons in this specific area all the way to the origin of Earth, and finally to atoms floating in the kinds of black clouds that so stunned me last night. An incredible yearning sets in, a longing for something hard to define that can never be. Or can it? Wait a minute...

Can a person go to the Mount Everest summit of natural history altogether like I feel I did last night during visual observation of the galactic core region? How can I experience the history of the Earth, life, and all nature itself in a like manner? Where and how can a person experience in limited gulps the grand themes of geology, history of the Earth, and the history of life insofar as we think we understand it? Where can I look with human eyes and say, "how many eyes have seen this?" And by that to mean seeing not just an amazing scene but the scientific meaning and significance as well. Where do these grand themes erupt with abundance, clarity, and magnificence like nowhere else? What human emotions and insights might body forth?

Everyone can be overcome with emotion and visions of beauty in certain scenic locations or even with light just shining through the leaves of a dense forest. But can the Earth loudly proclaim its nature and actual history in a transcendent way not dependent only on human sensitivity but also on what scientific investigation has revealed? Can the subjective self really perceive and repeatedly feel the history of an objective reality going back through time and



space? Philosophers, theologians, and big-picture science thinkers pursue this, but they all proceed along completely different mental tracks that I have trouble identifying with. For what I am after, you need to be in the right places, the right frame of mind, think critically, have experienced the perils and tribulations of the scientific endeavor, and know a lot of hard geological and paleontological context.

Geologists commonly lapse into a reverie standing before a rock exposure that is best interpreted as an ancient volcanic eruption, a landslide, a storm deposit millions of years ago, or once-molten rock that squeezed its way upward through cracks in solid layers. A pile of rock rubble strewn over a landscape can provoke visions of great ice sheets that once bulldozed through the area. Paleontologists spot a bone fragment in a sedimentary rock and fly mentally into a past world of giant animals roaming the landscape. Chunks of rock are brought back to labs where they are analyzed microscopically, sliced, crushed, vaporized, and then analyzed on high tech instruments to reveal a story of past climates, evolving life forms, drifting continents, and the rise of mountain ranges now long eroded away. In bits and pieces, visions of natural history that actually happened materialize. They have been the story of my own professional life, but it was never as emotional or as meaningful as last night. And, having participated professionally all my adult life in the scientific endeavor to understand nature, I know that it is not telling an unquestionable or necessarily complete story. Science is a method of investigation that produces a body of likely knowledge subject to constant revision. Sometimes, big revisions. Many results survive the tests of time; others do not. Trust science too much and your search for significance can go seriously awry. Without it, there is no meaning with a basis in natural history.

As I approach home, I realize that throughout my career I have been along stretches of a possibly epic journey that could pull it all together. I have learned and experienced enough now to try to climb the Mt Everest of natural history in a unique way. I will go to the east end of the Grand Canyon and raft again on the Colorado River westward through the awesome rock layers and bedrock I know so well to where they transition into the Great Basin. There, they have been broken into great blocks, tilted, heaved upward, and pulled apart. Volcanic explosions larger than any known in modern times have erupted up between and over these tectonic blocks. Solidified lava, ash, and rock debris slowly but inevitably washed off and are still eroding off the uplifted blocks to fill up space created by all the disruptions. In Death Valley and its surrounding areas, all this complexity is laid out with astounding clarity--like a CT scan of the Earth and its history. Continuing westward, an enormous mountain range of granite, the Sierra Nevada has risen out of the ground like a great monument. The same sedimentary and volcanic deposits once extended there from the east but were buried and then engulfed in giant masses of molten granite that solidified and rotated up to form a mountain range standing as high as 14,000 feet today. Remnants of the layers still survive within the granite having been stretched like taffy, reconstituted into altogether new minerals, and mangled almost beyond recognition. This uplifted "Range of Light" that consumed and resolved all the chaos was exquisitely sculpted and polished by glaciers just before humanity

arrived on the scene. The history of all this past geologic deposition, tectonic mayhem, and subsequent transformation is exposed with flagrant clarity in these places. The natural history of the world and of life itself as revealed in the fossil record cannot be read better anywhere than along this traverse from the east end of Grand Canyon to the crest of the Sierra Nevada.

I will do this journey in a single traverse and follow the rocks. I will immerse myself in the grand themes of geology as currently understood following generations of geologists and paleontologists who deduced the most likely interpretation of the evidence. I have already done most parts of the route in segments, but I will do it now with new intent and as a continuous thread to hopefully release a deeper awareness. Just what can a person legitimately make of it all when viewed in terms of current science? The thread running through the Grand Canyon, Death Valley and the High Sierra is a history of reality. A route that will avoid even small cities that might break the spell takes shape in my mind before I reach home. I will go this time not as a scientist exploring, researching, or teaching, but as a pilgrim seeking the intangibles denied to those thinking only about what science currently suspects gave rise to these features exposed so gloriously. It will be a self-indulgent pilgrimage in the golden age of science. I resolve to do it and arrive home a new man with a mission.