CHAPTER I

MYSTERIES

> The most highly valued of human possessions, let alone gemstones, is the "adamas," which for long was known only to kings, and to very few of them.
>
> PLINY THE ELDER, *Natural History*, Book XXXVII

DEEP WITHIN THE EARTH DIAMONDS GROW. Diamonds the size of footballs, diamonds the size of watermelons – countless billions of tons of diamonds wait for eternity a hundred miles beyond our reach.[1]

Thousands of years before the invention of science, humans treasured the glistening, hard stones they found among the gravels of exotic rivers, without knowing exactly what they were or how they came to be. Some said diamonds were pieces of stars fallen to earth, or perhaps the remains of water frozen for too long, while others spoke of crystals grown at ocean depths or formed in the path of lightning bolts. Despite people's curiosity, the true origin of diamonds remained a mystery until early in this century.

Humans have always prized these bits of matter for their unrivaled physical properties.[2] They sparkle as the most brilliant of gems, dispersing light better than any other precious stone. Diamonds last almost forever, withstanding the most corrosive salts and acids for aeons. Pure diamonds provide superb electrical insulators, while they conduct heat energy more efficiently than any other substance. They boast exceptional chemical purity, often more than 99.9% carbon. And, of course, diamond is the hardest known material – almost twice as hard as any other natural or synthetic creation.

Ancient artisans recognized at least some of diamond's unique characteristics, and were probably the first to study the stones' physical properties. If struck forcefully, they found, diamonds could be broken into chips and shards of great hardness and utility. Diamond-edged knives and engraving tools have been used by stone workers for millennia, and some ancient warriors are thought to have embedded diamonds in their edged metal weapons.

Yet as useful as they may be, diamonds have long been coveted as much more than mere physical curiosities. They are the stuff of magic and legends. Mystics and alchemists ascribed wondrous attributes to the stones, which were said to grant the wearer awesome strength on the battlefield, as well as potency in the bedroom. Wise men proclaimed diamond to be a protection against evil, an antidote to poison, a cure for insanity, and a charm for women in childbirth.

Flamboyant stones possessing unusual size and quality have long had a special mystique.[3] Large diamonds weighing a hundred carats or more (a carat being a fifth of a gram, or about the weight of a single small pea) traditionally are given glamorous names, and some notable stones have even developed reputations. The magnificent Orloff diamond, a 190–carat gem that adorns the imperial Russian scepter, was stolen by a French deserter from the Indian foreign legion, in a sacrilegious exploit that has served as a prototype for countless dime-novel and adventure-movie plots. He disguised himself as a devout worshiper and plucked the gem from the eye socket of an idol of the god Sri-Ranga. The stone was smuggled to France, and there purchased by Russian Prince Orloff as a tribute to Catherine the Great.

The breathtaking, deep-blue Hope Diamond, now the most popular exhibit of the Smithsonian Institution in Washington, D.C., is said to carry its own curse. Brought to Europe from India in the seventeenth century (some say it, too, was stolen from the eye of a vengeful idol god), the striking 112–carat stone from which the Hope was cut had many unfortunate owners. Louis XIV of France, Marie Antoinette, Queen Maria Louisa of Spain, and a sad sequence of wealthy, ill-fated Americans all possessed and wore the gem before New York diamond merchant Harry Winston acquired the Hope and sent it to the Smithsonian's National Museum of Natural History.

To these well-known stories can be added dozens more. The 410–carat Regent Diamond was reputedly smuggled to Europe by an Indian slave who sliced open his own leg and buried the diamond deep in the wound. The great stone adorned the hilt of Napoleon's sword and the crown of Charles X, and now serves as the centerpiece of the French Crown Jewels at the Louvre. The Grand Sancy Diamond, also at the Louvre, became a favorite turban adornment of the prematurely balding King Henry III of France. Striking colored diamonds – the Chantilly Pink, the Dresden Blue, the Florentine yellow, the Tiffany golden diamond, and dozens more all have their stories. And then there are the giant stones – the 726–carat Vargas with which a slave woman won her freedom in 1850 Brazil, the 995–carat Excelsior found in a shovel full of gravel at Jagersfontein in South Africa, and of course the Premier Mine's fabulous 3106–carat Cullinan, the largest gem diamond ever found.

Late in the afternoon on January 2, 1905, a mineworker alerted the Surface Manager, Fred Wells, to a brilliantly shiny object that caught the setting sunlight high on the wall of the diggings. Wells carefully inched his way to the spot and used his pocket knife to pry out the colossal stone; his understated reaction, according to a bystander, was that the mine's principal owner Colonel Thomas Cullinan, "will be pleased when he sees this!" Wells hurried to the mine office to have the epic find weighed, but the office staff was unimpressed. "This is no diamond," the inspector said, and threw the stone out the window.

Wells went back outside to retrieve the diamond (fig. 1), which was eventually authenticated and logged in at more than one-and-a-third pounds – more than three times larger than any other known diamond. Upon examining the mass, awestruck geologists realized that the Cullinan represented just a small piece from what must have been a much larger, eight-sided crystal. For two years the giant diamond was

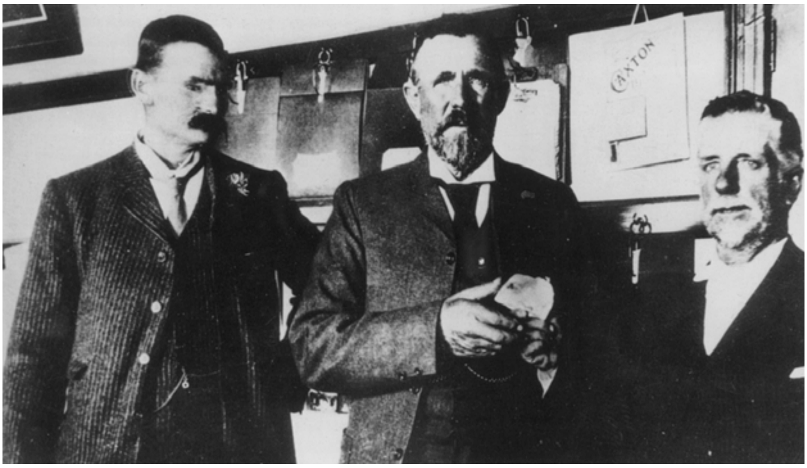

Fig. 1 The magnificent 3106-carat Cullinan diamond, the largest ever found, was at first tossed aside by a mine official who thought it a worthless piece of rock. The stone's discoverer, Fred Wells (right), stands with the Premier Mine manager William McHardy (center) and owner Thomas Cullinan. (Courtesy of F. R. Boyd.)

exhibited to prospective buyers at a London bank in its natural state; in early 1908 the stone was cleaved to yield nine principal faceted gems. The two largest faceted diamonds in the world, both cut from the Cullinan, now grace the Imperial Sceptre and State Crown of Great Britain.

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As fascinating as the human histories of individual gemstones may be, they pale beside the natural saga of diamond's unimaginably ancient birth and improbable epic journey to human hands. The realization of diamond's superlative properties and the discovery of its violent origins frame a marvelous scientific adventure.

Today, most people admire diamonds for two exceptional attributes: their hardness and their brilliance. Scholars knew of diamonds' unrivaled hardness since antiquity, but its unique optical properties went unrecognized until comparatively recently. The natural diamonds that were hoarded by potentates of old have little of the visual drama that we associate with today's faceted gems. Deeply colored rubies, emeralds, and sapphires were far more prized as adornments. Owners accumulated the seemingly indestructible diamond pebbles, as found in their unpolished natural state, as talismans against defeat and symbols of their own "manly" virtues, without ever seeing diamonds as objects of beauty.

When unearthed, most diamonds appear roughly rounded with perhaps a hint of regular crystal form. Many are colorless, but most are pale shades of yellow; red, orange, green, blue, brown, and even black diamonds are also found. Raw, uncut stones lack the exuberance of jewelry store gems, and can appear quite ordinary; Brazilian gold miners of the eighteenth century cast aside a fortune in unrecognized diamonds while panning for the precious metal. Diamond's familiar ornamental role represents a relatively recent development – a consequence in part of scientists' growing understanding of the nature of light.

A few scientific ideas have become part of our folklore. The equation $E=mc^2$ is one – a cultural icon as much as it is a statement of the equivalence of mass and energy. Another of these commonplace science snippets tells us that the speed of light is a constant. A T-shirt slogan popular in physics departments proclaims "186 000 miles per second:

It's not just a good idea, it's the law!" But as for many other legal systems, there's some fine print most people ignore. You have to add the rather mundane words, "in a vacuum." When light travels through matter – air, water, glass, or diamond, for example – it travels slower than 186 000 miles per second. The actual explanation, having to do with the way light interacts with the electrons present in every atom, is somewhat complex, but you can visualize this slow-down by thinking of light rays having to make little detours every time an electron gets in the way.[4]

Most clear and colorless objects retard light only a modest amount. The air we breathe has only a trifling billion-trillion atoms per cubic inch. Spaces between atoms are much greater than the size of the atoms themselves, so air reduces light speed by just a few hundred miles per second – not enough to notice under most circumstances. In water and ice, which have thousands of times more atoms per cubic inch than air, light travels about 140 000 miles per second – 30% slower than in a vacuum. Window glass drops light speed to 120 000 miles per second, similar to the travel time through most common minerals, whereas lead-containing decorative glass, the kind used in chandeliers and cut glass, slows light even more, to about 100 000 miles per second (lead has lots of electrons that get in the way). Diamonds put the brakes on light like no other known colorless substance. Diamond is crammed with electrons – no substance you have ever seen has atoms more densely packed – so light pokes along at less than 80 000 miles per second. That's more than 100 000 miles per second *slower* than in air.

Most people never have reason to notice the variable speed of light, but you experience one of its consequences every day. Each time light passes from one clear substance into another with a different light speed, the light rays have a tendency to bend. You've probably noticed the distortion of people and objects in a swimming pool, which occurs when light waves have to change direction as they pick up speed coming out of the water. Ripples on the pool's surface compound the angular distortion. If you wear glasses or contact lenses, which "correct" the way light bends into your eyes, you take advantage of this useful optical phenomenon.

Light does not always bend when passing between different materials. If light rays strike a clear substance head on or at a modest angle – like the path of light coming through your window – most of the rays will travel straight through without bending. You can look down from a boat at the nearly undistorted bottom of a calm, clear lake or pond because sunlight enters the water from overhead and then comes back through the transparent water almost vertically to your eyes. But try as you might, you can't see the bottom of even the clearest lake standing on the shore, because you are at too low an angle to the water. Almost all of the light reaching your eyes has been reflected off the water's surface. That's why you can see the beautiful mirrored reflection of trees on the opposite shore of a glassy lake early in the morning.

Diamond plays this reflecting trick better than any other colorless substance. Light enters a faceted gemstone from all sides, but it may bounce back and forth several times inside before it finds a clean, straight shot out. All this changing direction accomplishes something very dramatic, because so-called white light actually contains all of the rainbow's colors. Each color – red, orange, yellow, green, blue, and violet – bends and reflects inside the diamond slightly differently. The farther the light travels, the more the colors separate, or "disperse." Bounce light inside a diamond just two or three times and the colors disperse spectacularly. Diamond-like substitutes, including "cubic zirconia," a crystalline compound synthesized from the elements zirconium and oxygen, attempt to mimic this light-dispersing property, though they fall short of diamond's brilliance and unrivaled hardness.

If you look closely at a faceted diamond, you can see that it soaks up white light and breaks it apart like a prism, dispersing it into a rainbow of colors. Diamonds sparkle and dance with colored light; each of its dozens of facets produces its own dazzling display. Other natural gemstones disperse white light to some degree, but none comes close to diamond's ability to reveal the rainbow.

No one can say for sure when faces were first cut and polished on a diamond, but we are certain that the process was extremely tedious.[5] Only diamond powder possesses the hardness to polish diamond facets effectively, and achieving a smooth surface by hand is a lengthy and exacting task. Diamond cutters, who cleave and polish natural stones, are thought to have been active in India a thousand years ago, while Parisian documents record such artisans working in France as early as the fourteenth century. The original motivation for imposing flat faces on rough and rounded stones was probably simply to remove unsightly impurities. But, perhaps quite by accident, diamond finishers found that faceting accomplished much more than simple cleaning. Faces enhanced the beauty (and value) of their pebbles, and transformed human perceptions of diamond.

The shaping of a raw diamond into a pleasing geometric form represents a painstaking and nerve-racking process. The diamond cutter first examines the stone for cracks and impurities, then designs a strategy for extracting the largest possible gem. Every diamond possesses some internal planes that are slightly weaker than others – cleavage planes that the diamond cutter hopes to find and exploit in shaping a stone. To cleave a gem diamond, the craftsman first uses a diamond-tipped instrument to inscribe a slight groove on the outside of the gem along the desired splitting direction. The cutter then places a sharp chisel on the groove and strikes the chisel with a swift, sharp hammer blow. Diamond cutters do not take their task lightly, for there is always a chance that a diamond, if improperly "read" or poorly struck, will shatter into small pieces. The largest diamonds often require years of planning before cleaving is attempted. Rough stones can also be sawed with a thin wheel coated by diamond dust and oil, but this tedious process requires many hours for even the smallest stones.

Once a gem has been roughly shaped by cleaving or sawing, the slow process of polishing facets begins. A metal plate, its surface impregnated with diamond dust, spins at high speed while the diamond is precisely oriented for the creation of each of its many faces. In ancient times, cutters arranged their faces haphazardly, with little effort to compute the most favorable angles to achieve maximum light dispersion and a pleasing symmetrical cut. The oldest known cut stones, recorded and illustrated by the French traveler and pioneer diamond merchant Jean Baptiste Tavernier in the mid-seventeenth century, appear crude and ungainly compared to modern jewels. But even ill-cut facets made diamonds more attractive, and people began to prize the gems for being beautiful as well as durable.

Popular history records that in the 1450s King Charles VII of France became the first European to give a gift of diamond jewelry to a woman, the beautiful Agnes Sorel. That the woman was his mistress, not his wife, may have delayed the adoption of the custom of the diamond engagement ring, but plenty of women, wives and mistresses alike, proved willing and eager to display the new symbols of wealth and fashion. In a twinkling, the gemstone of choice for powerful men became the adornment of choice for powerful women.

Demand for diamonds soared and, for more than two centuries, India successfully met that demand. European diamond cutters sought to create ever more striking diamond jewelry by devising new ways to cut and polish the brilliant gems. Symmetrically faceted stones, championed by the Belgian craftsman Louis de Berquem, became the norm by 1500. Others added extra facets and introduced fancy new shapes – emerald cut, pear shape, marquise, and the popular 57–facet brilliant cut – to the diamond cutter's repertoire. More facets, they found, produced a more dramatic play of colors, while a variety of pleasing shapes let them make the best use of irregular stones. Carefully chosen angles between flat faces – first discovered by trial and error, but eventually calculated with mathematical precision – increased a diamond's ability to disperse white light into colors and thus enhanced its beauty even more. Master diamond cutters learned the secrets of sculpting magnificent gems from crude, irregular pebbles. Spectacular rings, bracelets, necklaces, and pins gave the very rich a new kind of bauble on which to spend their money – a new way to flaunt their wealth.

Making and selling diamond jewelry became a thriving business, so much so that by 1700 diamond demand had outpaced the dwindling Indian output from the almost exhausted alluvial mines. But, as luck would have it, miners discovered a major new source of diamonds in the Portuguese colony of Brazil in 1726. The diamond frenzy of the very rich continued unabated for another century.

Today, of course, the story has changed; now, almost everyone can own a diamond. Through a combination of new large-scale mining centers and brilliantly effective advertising, the once exclusive gemstone has become the symbol of love for people throughout the world. Today most people buy diamonds simply for their exceptional beauty, but the gem's particular mystique has not been lost. Diamonds are still sold as talismans by advocates of "crystal power," while seductive TV models look us in the eye and whisper, "Diamonds are love!" as though the hard, sparkling chips might somehow hold the power to alter our destinies.

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By the seventeenth century the Western world had learned of diamonds' strength and beauty, but great mysteries remained unsolved. Two puzzles framed the subsequent centuries of diamond research: Of what are diamonds made, and how do they form in nature?

The first clues came from researchers who subjected diamonds to light and heat. Sir Isaac Newton marveled at the unique optical properties of diamonds during his attempts to understand the nature of the sun's radiation.[6] The gem's well-known ability to break white light into rainbow colors – a trick diamond performed better than any other substance known at the time – provided Newton with a challenging puzzle. Assuming that oils possess the greatest light-dispersing powers, Newton speculated that diamond was "probably an unctuous substance coagulated" – a solidified oil. He also came to a startling conclusion – diamond, like oil, would be combustible.

Newton's speculation resolved neither of the two central diamond questions, nor were any of his contemporaries able to push any closer to the answers. A century later, scientists tackled the diamond mystery from a new perspective, using the young science of chemistry. All matter, chemists had found, forms from a few different kinds of building blocks, which they called atoms. Chemists had embraced the task of learning which combination of atoms forms each fragment of the material universe, and they approached their mission like destructively curious architects who rip apart buildings brick by brick, plank by plank, to identify the materials used in their construction. Tearing matter apart also gave them hints about how to put it back together – the chemist's second mission.

Chemists devised many new ways of analyzing their world, but their first, best tool was fire. Many materials burn, leaving behind an ash residue that researchers could identify using simple chemical tests. And yet, despite Newton's conjecture about the flammability of diamond, attempts to ignite the hardest known substance seemed futile. Ordinary flame didn't work, nor did most ovens, but chemists kept trying. Finally, in 1772, the brilliant French chemist Antoine-Laurent Lavoisier confirmed Newton's prediction when he focused sunlight onto a diamond.[7]

Lavoisier's private laboratory at his estate near Blois was a far cry from the high-tech chemistry facilities of modern research. He performed his experiments in elegant surroundings; his lab was filled with fine balances and microscopes and other instruments crafted of rich mahogany and polished brass. Hand-blown bottles with thick cork stoppers lined his shelves, and a sturdy wooden workbench supported an array of exotic beakers, burners, and other chemical apparatus. Lavoisier, resplendent in powdered wig and fine embroidered coat, conducted his experiments with great care while his wife, Marie, recorded the results.

The chemist prepared his diamond specimen by sealing it in a glass jar filled with oxygen. He selected a thick convex glass lens that concentrated the sun's heat many fold, and mounted the lens on a pivoting metal stand that would keep the light focused on the gem as the sun moved. Lavoisier watched the diamond glow and burn like a piece of charcoal, not just to ash, but completely and totally away. The only by-product, identified in the laboratory as the gas carbon dioxide, suggested a close chemical relationship between diamond and charcoal, which also produces carbon dioxide when burned. Unfortunately, Lavoisier did not pursue this intriguing discovery, turning instead to other chemical studies in a distinguished career tragically cut short by the guillotine of the French Revolution.

The English chemist Smithson Tennant expanded on Lavoisier's work, demonstrating conclusively that diamond is nearly pure carbon, differing from charcoal only in its external form.[8] By converting identical weights of charcoal and diamond to exactly the same volume of carbon dioxide gas, he established the chemical equivalence of the two dissimilar solids. Tennant's results, published in 1797, astonished the scientific world. How could it be that the toughest material on earth forms from pure and simple carbon, the element of coal and soot? Scientists knew that carbon usually forms graphite, a material so soft that it is valued as a lubricant, so black that it is employed in the finest pencil leads. Many scientists, especially those who suspected that diamond must conceal a second, as yet unidentified element, were reluctant to believe Tennant's conclusions. Not until two decades later, after many careful researchers duplicated Tennant's observations, were these results accepted by the scientific community at large. Smithson Tennant, like Lavoisier before him, had little chance to enjoy this vindication; in February of 1815, while examining fortifications in Napoleonic France, he was killed in a bizarre accident as his horse fell through a decaying drawbridge.

Carbon taunted the chemists. With the exception of a few obscure diamond-bearing streambeds in India and Brazil, carbon occurred as graphite. Why did nature produce two kinds of carbon? Could scientists reproduce nature's feat? For more than a century they tried and failed. Physicists and chemists used every trick they could think of to grow the gems. Some attempted to form diamond by evaporating carbon-rich