RUBY AND SAPPHIRE PRODUCTION AND DISTRIBUTION: A QUARTER CENTURY OF CHANGE

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During the past 25 years, the corundum market has been transformed from one of medium- to high-priced gems to one that encompasses nearly all price ranges. This transformation was caused by the discovery of a number of large deposits and the development of treatment processes that enhanced the color and clarity of huge quantities of previously noncommercial sapphire and ruby. More recently, however, controversial treatments have undermined confidence and prices in some material, while political events and press scrutiny have affected the supply chain for rubies and sapphires from localities such as Myanmar and Madagascar.

Gem corundum—ruby and sapphire—has been among the most coveted of colored stones for millennia, historically favored by ancient Indian nobility and Asian and European aristocracy. Today, these gems continue to be sought by jewelry consumers worldwide (see, e.g., figure 1). Over the past 25 years, they have evolved from rare, generally high-priced goods to arguably the world's most widely sold colored gemstones, accounting for approximately one-third of all global colored stone sales by value (BUZ Consulting, 2009). This transformation began in the early 1980s when cutters and dealers, primarily in Thailand, began heat treating vast quantities of low-grade material from deposits in Australia, Sri Lanka, and (in the 1990s) Mong Hsu, Myanmar, to produce attractive blue and pink sapphire and ruby. As sales outlets expanded—notably to television shopping networks and the internet—the strong demand set off a surge in exploration that uncovered many new sources of rough and spurred the introduction of new treatments to transform even larger quantities of marginal material into goods attractive enough for jewelry use. While some of these treatments caused difficulties in the market that remain unresolved, prices for fine, untreated material have soared to record highs, even since the onset of a global recession in 2008.

The popularization of corundum was further sparked by the discovery of large quantities of gem rough (or treatable gem rough) at previously unknown sources in regions such as Madagascar and eastern Africa, as well as continued mining at historic localities such as Myanmar, Sri Lanka, and Thailand.

In more recent years, social and ethical issues similar to those that affected the diamond industry in the late 1990s have affected corundum as well. In

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Figure 1. Fine rubies and sapphires are among the most coveted of all gems. This ruby and diamond necklace is set with 39 unheated Burmese rubies (83.73 ct total weight; the largest is 5.00 ct). Courtesy of Mona Lee Nesseth Custom and Estate Jewels and a private collector, Laguna Beach, California; photo by R. Weldon.

1999, for example, concerns over the environmental and social impacts of Madagascar's sapphire rush made international headlines. More recently, a number of countries have enacted sanctions against Myanmar, historically the world's most important source of high-quality rubies, because of that government's repressive practices.

This article reviews all of these developments, and provides results from two recent comprehensive studies of retail colored stone demand, to provide a mine-to-market analysis of corundum over the last quarter century.

GEM CORUNDUM SOURCES AND PRODUCTION

The locality of origin of a gemstone can exert a powerful influence on price and demand because of the unique attributes a specific source may impart to the material, from physical characteristics such as a distinctive color and inclusions, to the history, lore, and legend of certain gem-bearing regions. Several sources, traditional and newly found, have supplied goods to the ruby and sapphire market over the last quarter century, as detailed below.

This section is organized into three parts: The four traditional ruby and sapphire sources, most of which have been mined since antiquity; the newer major producers that have been developed within the last 25 years; and lesser sources, several of which hold promise to be commercially important in the future.

A caveat: We have made every effort to include production figures for the individual localities where such information is available. Unfortunately, most such data are notoriously unreliable or difficult to interpret, even when coming from mine owners or official government sources. For example, quantities of rough extracted are generally reported in kilograms (1 kg = 5,000 carats) with few specifics on the quality of the material. And export data, which rarely detail various gem types, are often skewed toward the financial advantage of the exporter (i.e., often less than the actual amount if there are export taxes) and do not take into account goods illegally smuggled out of the country (a com-

Figure 2. A Kashmir sapphire's prized soft, velvety appearance, seen in this 3.08 ct gem, is caused by microscopic inclusions. Courtesy of Joeb Enterprises, Chattanooga, Tennessee; photo by R. Weldon.

mon practice in many gem-producing nations). We have, however, made every effort to find the best figures available to provide a serviceable, if imperfect, profile of ruby and sapphire production.

Traditional Sources. These sources—Kashmir, Myanmar (Burma), Sri Lanka, and Thailand—have been producing high-quality material for literally centuries. All have been active over the last 25 years, but in some cases production has seen great highs and lows, and in others political concerns have played a key role in the gems' distribution to the global market.

Kashmir Sapphire. Among gem localities, Kashmir shares the pinnacle with Mogok (for ruby) and Colombia (for emerald). Classic Kashmir sapphires exhibit a velvety, lush blue color that makes top specimens among the world's costliest—and rarest—colored gems (figure 2). Sapphires were first discovered in Kashmir (in what is now the Indian part of the region) in 1881 after a landslide revealed the blue gems high in a Himalayan mountain pass in the Paddar area west of Srinagar (Atkinson and Kothavala, 1983).

Although the Kashmir district has been at the center of a hostile border dispute between India and Pakistan for some 60 years, limited material is still being mined in the area. However, these newer goods rarely show the distinctive velvety blue of "classic" Kashmir sapphires (Michelle, 2007). J&K Minerals, an enterprise run by the Indian state of Jammu and Kashmir to work the area around the original deposits, reported mining 15,000 kg of gem-quality sapphire between 1963 and 1998, 9 kg from 1998 to 2001, and 21 kg between 2002 and 2007—with colors ranging from near-colorless to dark blue ("Kashmir sapphire mines," 2008).

Kashmir stones continue to command some of the highest prices paid for any gem. Of the 150 top price-per-carat sapphires sold at the major auctions between 1979 and 2008, 121 were described as Kashmir (F. Curiel, pers. comm., 2008). On December 1, 2009, a private bidder paid $2.396 million for a 16.65 ct Kashmir sapphire at the Christie's Magnificent Jewels auction in Hong Kong—at almost $144,000 per carat, the most ever paid for a sapphire at auction (Christie's, 2009). In the four years prior to that sale, auction prices for top Kashmir sapphires ranged from $39,000 to $135,000 per carat (F. Curiel, pers. comm., 2009).

NEED TO KNOW

- New sources and new treatments have greatly expanded the supply of gem corundum.
- Myanmar and Sri Lanka remain major sources, and have been joined by Madagascar.
- Once a major producer, Thailand is now the world's cutting, treating, and trading center.
- Most ruby and sapphire requires treatment to be salable.
- Consumers will be increasingly concerned with social, environmental, and fair trade issues in the future.

Kashmir Ruby and Pink Sapphire. In 1979, rubies and pink sapphires were discovered on Nangimali Mountain on the Pakistani side of Kashmir (Kane, 1997, 1998). The mine, situated in extremely remote and rugged mountainous terrain, consists of two main workings (at 14,300 feet [4,360 m] and 12,500 feet [3,810 m]) that are accessible only from May to October because of the severe weather. It is one of the highest working ruby mines in the world, which helps explain why actual production did not begin until 1990.

Some of the output from this marble-hosted deposit is comparable in quality to material from Mogok. Although the rough is commonly small, one facet-grade crystal weighed 17 g (85 ct; Kane, 1997, 1998). It is believed the mine was still operating as of 2008 (R. Kane, pers. comm., 2009), but reports of more recent production are sketchy given the remoteness of the deposit and military activity in the region.

Myanmar. Burma (known as Myanmar since 1989) has been known as a source of fine ruby for more than a millennium. At the time of the first Burmese Empire in 1044, the gems were already an integral part of the kingdom's economic activity (Themelis, 2000). It has been estimated that at various periods in recent years Myanmar supplied perhaps 90% of the world's rubies (Robertson, 2007).

The term *Burmese ruby* traditionally has denoted the vivid red colors and medium-to-dark tones that were mined from the Mogok region, in Burma's Mandalay Division. These are sometimes described as "pigeon's blood red" in the trade (figure 3). Over the years, such features have given Burmese ruby a cachet similar to that of Kashmir sapphire. Since the mid-1990s, large deposits of lower-quality ruby have been found and worked at Mong Hsu, in Shan State (Peretti et al., 1995). Recently, however, all of Burma's gem riches have been the focus of negative press, with ruby and jade subject to trade bans (see Political Aspects, below).

Mogok. Many of the notable rubies mounted in royal jewels, and now seen in museums, had their origins in the mines that operate throughout the historic Mogok Stone Tract. Top-quality Mogok rubies continue to command astounding prices in the marketplace. On February 15, 2006, Christie's Geneva sold an 8.62 ct Burmese ruby (figure 4) for \$3.64 million, or about \$422,000 per carat. Of the more than 150 rubies that have achieved prices over \$50,000 per carat at the Christie's auctions, only 12 were not Mogok stones (F. Curiel, pers. comm., 2009). Although the ruby and other gem mines and official sales were nationalized in 1969 (Themelis, 2000), in an attempt to curtail illegal mining the Myanmar government began authorizing citizens to apply for joint-venture mining leases in the ruby and sapphire districts as well as jadeite mining areas in March 1990 (see, e.g., Kane and Kammerling, 1992). Today, joint ventures between the Myanmar government and private entities still exist in Myanmar's mining areas, including Mogok and Mong Hsu, though percentages of ownership are difficult to ascertain (R. Schluessel, pers. comm., 2009). Ruby and pink sapphire are the primary products from Mogok, but significant amounts of fine blue sapphire are also recovered.

Figure 3. This "pigeon's blood red" Burmese ruby (~1 ct) and Old Mine cut diamond ring was manufactured circa 1910. After the 1885 annexation of Upper Burma by the British, rubies began to enter the European gem markets in earnest. Courtesy of Frank Goodman & Son, Los Angeles; photo by R. Weldon.

Figure 4. The Graff Ruby, an 8.62 ct Burmese stone set into a ring by Bulgari, sold for a record \$3.64 million—about \$422,000 per carat—at the Christie's February 2006 auction in St. Moritz. Photo by Denis Hayoun/Diode SA; courtesy of Christie's International.

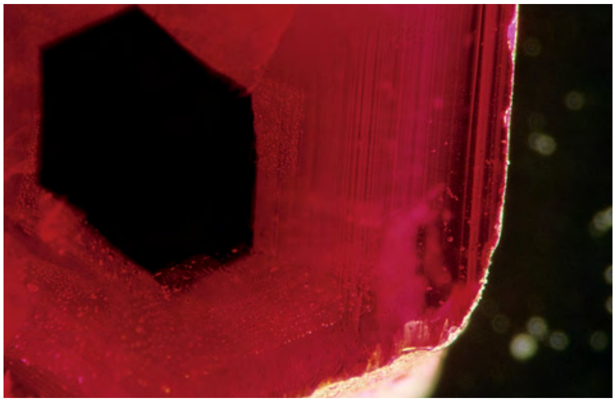


Figure 5. Mong Hsu crystals typically have a red rim surrounding a violet to dark blue core. Heat treatment causes the blue coloration to disappear, resulting in a uniformly red (ruby) crystal. Photomicrograph by Edward Gübelin.

Figure 6. This 6.21 ct ruby from Mong Hsu is heat treated, as are most stones from this locality. Courtesy of Pillar & Stone International, Tiburon, California; photo by R. Weldon.

Mong Hsu. In late 1992, rumors of a new discovery of corundum in Myanmar began circulating in the trade, and vast quantities of gems appeared in Bangkok, though the color tended to be much lower in quality than that of traditional Mogok material (Peretti et al., 1995). Mong Hsu quickly became the world's largest supplier of corundum during the early and mid-1990s. Articles reporting on and describing the new material—vastly different from that of Mogok—began circulating in trade journals and scholarly publications (e.g., Kane and Kammerling, 1992; Peretti et al., 1995; Schmetzer and Peretti, 1998; Drucker, 1999b). In fact, the gems from Mong Hsu were so different from the Mogok material that the phrase *Burmese ruby* acquired a qualifier in the trade: *Mogok* or *Mong Hsu*.

Mong Hsu's corundum was often difficult to characterize because the crystals had unique color zoning: transparent red outer rims with cores that typically appeared violet to dark blue (e.g., figure 5). Heat treatment improved the salability of this material by converting the violet and dark blue cores to yield uniformly red stones (e.g., figure 6). It also produced characteristic features, such as inclusions of white particles easily seen with magnification. Note, too, that Mong Hsu rubies typically contain cavities and fissures that may be filled with glass during the heating process (Hughes and Galibert, 1998). A similar process (with borax as a flux) had been widely used decades earlier during the heat treatment of Burmese and Thai rubies (Kane, 1984).

Since 2004, production from Mong Hsu has dwindled considerably (R. Schluessel, pers. comm., 2009). The primary reason is that easily accessible areas of the deposit have been exhausted, but the government reportedly has also relocated large numbers of workers to other mining projects such as for gold and uranium (Helmer, 2008).

Nanyaseik (Namya). In 2001, a rumor circulated among gem dealers regarding a gem rush in an area near Hpakant in Shan State (Peretti and Kanpraphai, 2003). It soon became a short-lived new source of extremely fine-quality rubies—as well as sapphires and spinels—not unlike those from legendary Mogok. Experts say most of the material was quite small, but with rich, "true" colors not affected by gray or brown secondary hues (W. Larson, pers. comm., 2009). Stones in the 2–5 ct range were uncommon, and fine 10+ ct gems were very rare (Peretti and Kanpraphai, 2003). The area was exploited heavily between 2001 and 2004, but production has slowed to a trickle since then (Hlaing and Win, 2008).

Political Aspects. In recent years, *Burmese ruby* has acquired some negative socio-political connotations, particularly in the United States and Europe. The source of this is the well-documented human rights abuses—of ethnic minorities and common citizens alike—committed by Myanmar's ruling generals (see, e.g., U.S. Department of State, 2009). Further, many of these abuses have been linked to the gem trade (Jewelers of America press release, 2007; Newell and Gadner, 2007). It has been widely reported by the same sources and numerous mass media (see, e.g., Associated Press, 2007; Walt, 2007) that the military junta—the State Peace and Democracy Council—owns a controlling interest in the mining and sale of gems that are exported officially.

In 2003, the U.S. Congress responded by enacting the Burmese Freedom and Democracy Act, ostensibly to ban trade with Myanmar. However, the law had a loophole that permitted Burmese gemstones to be legally imported into the U.S. if they were cut (i.e., markedly transformed) in and exported from another country. Since so much Burmese material is processed in other countries, particularly Thailand, this had the effect of exempting many Burmese gems from the ban. The European Union also passed a series of economic sanctions, including an embargo on the importation of gems from Myanmar (Human Rights Watch, 2008). A few years later, the U.S. Congress closed the loophole in the 2003 legislation with passage of the Tom Lantos Block Burmese JADE Act of 2008, which specifies that any ruby and jadeite *mined* in Myanmar cannot be imported into the U.S. for commercial purposes. Other gems, such as sapphire, are not included, though importation of rough sapphires is still prohibited by the 2003 act.

The intent of the JADE Act and the EU legislation was to deny the junta revenues from gem sales (though the junta's primary source of funds is natural gas). The sanctions were also aimed at encouraging the government to free pro-democracy activist Aung San Suu Kyi, the 1991 Nobel Peace Prize winner, who has been held under house arrest (or in Myanmar's notorious Insein prison) for 14 of the last 20 years (Tran, 2009). Nevertheless the sanctions have generated some controversy in the gem trade. On the one hand, U.S. retail jeweler Tiffany & Co. ceased buying and selling Burmese gemstones after the passage of the 2003 Act (Tiffany & Co., 2009), and Jewelers of America worked to make its members aware of the political ramifications of continuing to buy gems from Myanmar. On the other hand, some gem dealers have argued that the sanctions would actually harm Myanmar's artisanal gem miners ("ICA criticizes Burma ban," 2008; Rosenbusch, 2008).

The sanctions have resulted in the closing of nearly 50 ruby mining sites, while official sales of all gems fell from 7.2 million carats in 2007 to 6.5 million carats in 2008 (Kyaw-Zaw, 2009). Nevertheless, official Myanmar figures tallied nearly $647 million in gem exports in the fiscal year 2007–2008 (Moe, 2009); the majority of those revenues were from jadeite, not rubies and sapphires. Reports also stated that buying by foreign dealers fell 50% after the introduction of the U.S. trade ban (Moe, 2009). Note, though, that it is impossible to obtain true production numbers because a large percentage of the corundum mined in Myanmar is smuggled into Thailand (Elmore, 2005).

Figure 7. Sri Lanka is the source of many colors of sapphire. This multicolored suite (1.47–7.34 ct) was cut by Mark Gronlund using concave faceting techniques. While concave faceting has traditionally been used with inexpensive gem materials, innovative cutters increasingly use it with corundum. Courtesy of Mark Gronlund, Umatilla, Florida; photo by R. Weldon.

Sri Lanka. It is believed that the very first sapphires known to Europeans came from Ceylon (now Sri Lanka) after Alexander the Great invaded the Indian subcontinent in 325 BC. A flourishing commerce in sapphires and rubies from that island nation took root later, during the Roman Empire, when active trading along the famous silk route existed between Rome and India (Hyrsl, 2001).

Today, many colors of sapphire (e.g., figure 7) and occasional rubies continue to be found in riverbeds and other alluvial deposits in Sri Lanka , and the island nation is still a preeminent source for star sapphires and rubies (Robertson, 2002; figure 8). Although the government has recently granted

Figure 8. Sri Lanka is known for producing corundum's phenomenal varieties, including asteriated gems. This collection of star sapphires (and one ruby) ranges from 2.65 to 15 ct. Courtesy of Rafco International, New York; photo by R. Weldon.

some licenses for mechanized mining in a section of the Kalu Ganga riverbed, near Ratnapura, much of the country's production still comes from small-scale rudimentary operations (Berenger, 2009).

Even though Sri Lanka, like Myanmar, continues to be a major producer of high-quality sapphires and rubies, this fact is often obscured by the extensive production of low-value whitish corundum (*geuda* sapphire). This material first became meaningful in the 1970s when Thai dealers discovered that it could be heat-treated at high temperatures (1500°C and above) to achieve greater transparency and pleasing blue colors (Nassau, 1981). Vast quantities of geuda were purchased and exported to Thailand for treatment. The importance of this development in the corundum marketplace cannot be overstated, both because heat treatment remains a critical factor in the corundum market today and because it functioned as a precursor to other types of heat-related treatments. The 1980s marked the point at which the treatment of previously worthless material suddenly resulted in the widespread availability of appealing blue sapphires.

Sri Lanka has sought in recent years to regain its stature as the source of high-quality sapphires of many colors, including the rare pinkish orange "padparadscha" (figure 9), and ruby, as well as star ruby and sapphire (Hughes, 2003). The country's National Gem & Jewellery Authority, noting that sapphire accounts for about 50% of total earnings from gem exports, announced initiatives in 2008 described as "differentiating and positioning Ceylon sapphires at the top end of the sapphire spectrum in all categories" (Prematilleke, 2008b, pp. 63–64). These initiatives focused on creating a brand for the country's small percentage of untreated sapphires above 3 carats, in order to attract more global buyers.

Unfortunately, supplies of Sri Lankan sapphires in general—but untreated in particular—had diminished in the years immediately preceding the initiatives, resulting in dramatic price increases. Production of blue sapphires, the principal object of Sri Lanka's branding efforts, declined 66.9% between 2006 and 2007, from 472,961 carats to 156,486 carats, while the price per carat rose 18.9%, according to the report, and per-carat prices for untreated goods soared (Prematilleke, 2008a). Additionally, the supply issues in Sri Lanka coincided with decreased availability of material from Madagascar after the spring of 2008—leading to a general scarcity of sapphire supplies worldwide.

Figure 9. Sri Lanka is also an important source of pinkish orange "padparadscha" sapphires, like this untreated 88.11 ct gem. Courtesy of Evan Caplan, Los Angeles; photo by R. Weldon.

Figure 10. Small sapphire mining operations, such as this one in Chanthaburi, are still active in some parts of Thailand. Photo taken in July 2008 by R. Shor.

Thailand. *Mining and Production.* Accounts of rubies from the Kingdom of Siam, as Thailand was called until 1949, date back to the 15th century, and figure importantly in reports from European travelers and traders who visited the area between 1600 and 1800 (Hughes, 1997). Historically, most of these early accounts referred to the area that straddles the border between present-day Thailand and Cambodia.

Although the sensational quality of Kashmir sapphire would overshadow the traditional Siamese goods, the kingdom was still regarded as the most important source of blue sapphire, by quantity, until 1907 when it was forced to cede its eastern provinces, including Pailin (now in Cambodia), to the French colonial regime in what was then Indochina. In the 20th century, other areas of Siam were opened to corundum mining, and by the mid-1930s, Siam was reportedly producing half the world's sapphires (Gravender, 1934).

Mining apparently halted in the region during World War II and its aftermath. It eventually resumed on a small scale until 1978, when a large deposit was discovered that yielded dark blue colors after heat treatment. Not quite as dark as Australian goods (see below), most Thai sapphires found their way to the better end of the commercial market (Hughes, 1997). The deposit, located close to Bo Phloi in western Thailand, attracted several large, mechanized mining operations. Nine years later, in 1987, geologists reported that the Bo Phloi deposit was much more extensive than previously believed, and the opening of several more major mines made the region one of the world's largest sources of blue sapphire. Production began to decline in the mid-1990s, with less than 200 kg recovered annually from 1995 through 2005, a tiny fraction of the world total (Yager et al., 2008). In recent years, only one large Thai-based concern, SAP Mining Co., has continued to operate in the Bo Phloi area, along with scattered smaller operations elsewhere in the country (e.g., figure 10).

Thailand's ruby production, mainly in Trat Province, was sporadic through the early years of the 20th century. In the 1960s, production rose steadily to make Thailand a leading source until the Mong Hsu discovery. Like much of its blue sapphire, Thai ruby tended to be darker than what most dealers consider optimum, though heat treatment could often lighten the color by removing purple or brown secondary hues (Nassau, 1981; Keller, 1982). Production from the three mining areas in Trat peaked in the 1980s, as mechanized operations took over. By the 1990s, most of the known deposits had played out, with production estimated at 15–30 kg yearly through 2005 (Hughes, 1997; ICA 2006 World Gemstone Mining Report, 2006; Yager et al., 2008).

Thailand as a Gem Cutting and Trading Hub. Even as the country declined as a gem producer, mem-

Figure 11. While there are still crowds of dealers and buyers at the open gem market in Chanthaburi, political and economic events as well as supply problems have diminished both the quantity and quality of goods offered. Photo taken in July 2008 by R. Shor.

bers of the Thai industry moved aggressively to retain and expand their role as the world's primary dealers and distributors of corundum. They did this by buying the majority of corundum production from other sources, such as Sri Lanka, Australia, Tanzania, and Madagascar, and by developing treatment methods that allowed them to process much greater quantities and quality ranges of material.

Today, an estimated one million Thais make their living from the gemstone industry through cutting, trading, and treating ("Thailand government waives VAT. . . ," 2009). Approximately 70% of the world's sapphires and 90% of its rubies pass though Thailand. Most are treated and cut in Chanthaburi, where the weekend gem markets still draw thousands of buyers and sellers (figure 11), and are then exported through Bangkok (ICA 2006 World Gemstone Mining Report, 2006).

Figures published by the Gem and Jewelry Institute of Thailand (2009) indicate that polished gemstone exports in 2008 totaled approximately $254.89 million, of which sapphire represented 46.7% and ruby 40.62%. Although the export value of cut gemstones increased nearly 50% between 2007 and 2008, imports of rough declined 13% ($22.9 million to $19 million) for the same period.

Recent advances in treatment, such as beryllium diffusion (see the Effects of Treatments section below), caused a severe crisis in confidence, sending demand and prices for some colors (mainly yellow to orange) of commercial-quality treated sapphire to historic lows (Shor, 2008). Additional challenges have been created by a 2008–09 embargo on exports from Madagascar, the U.S. and EU bans on ruby from Myanmar, the global economic downturn, and political instability in Thailand (Shor, 2008).

Even before these issues arose, the Thai trade began to see problems. Early in 2007, the country's two major trade associations, reacting to the closure of many cutting operations, petitioned the government for assistance (Shor, 2007b). After gemstone exports plunged by one third, from $130.5 million during the first half of 2008 to $88.2 million for the corresponding period of 2009 (Gem and Jewelry Institute of Thailand, 2009a,b), the Thai Ministry of Commerce waived the value-added tax on rough and cut gemstones from countries that did not have a trade agreement with the government and crafted a loan package totaling $148 million to assist small- and medium-sized businesses ("Thailand to become. . . ," 2009). At this writing, the program has not been in effect long enough to determine its impact.

Newer Major Sources. These sources—Australia, Madagascar, and Vietnam—had a major impact on world corundum production over the last quarter century. While only Madagascar continues to be a major source of sapphire and, to a lesser extent, ruby, all played a significant role during this period.

Australia. Australia's prolific sapphire production from the late 1970s through the 1980s helped, along with Sri Lanka, to usher in the era of mass-market corundum, with vast quantities of lower-priced, inky blue material that became a staple in popular calibrated-cut-stone jewelry (Hughes, 1997).

Actually, the country was one of the world's premier sapphire sources early in the 19th century (Coldham, 1985). The Anakie deposit in central Queensland proved to be the largest, with some 2 tonnes of corundum mined there by 1913. However, production waned after World War I, as the prime-color material was mined out and the vast majority of what remained was clouded with silky inclusions and deemed too dark for commercial use. During the 1960s, however, the Thais refined heat treatment effectively enough to remove these silky inclusions

Figure 12. Madagasca has been an important source of sapphires since 1993–94. Many have come from hand-dug pits such as this one at Ilakaka. Photo taken in July 2003 by Brendan M. Laurs.

and thus somewhat lighten the stones, making the Australian material more commercially viable (Coldham, 1985; Hughes, 1997).

Thai traders established buying operations in Australia in the late 1960s, spurring expanded production. In addition to restarting the Anakie fields, miners began working Invernell, a known sapphire source in New South Wales that was subsequently discovered to be part of a much larger deposit later called the New England gem fields. A third area, Lava Plains, in Queensland, produced significant quantities of sapphire for several years from the late 1980s until 1993. The introduction of modern, mechanized sapphire mining meant that large quantities of material entered the market in a short period (Hughes, 1997). During the 1970s and through the early 1990s, Australia produced an estimated 70% of the world's sapphire. The best qualities were often separated out and marketed as "Thai," "Sri Lankan," or "Cambodian" (Beard, 1998).

Production from Australia peaked in the mid-1980s but remained high through the next decade as smaller deposits, particularly in the New England area, in addition to Lava Plains, were discovered and worked to exhaustion after a few years ("Australian sapphires," 2005). However, rising mining costs and tough environmental restrictions, coupled with the continued low prices, discouraged further exploration to replace areas that had been played out (Beard, 1998).

From 1995 to 2005, Australia's sapphire production declined by some 60%, from an estimated 13,000 to 5,500 kg (Yager et al., 2008). However, a number of areas remain open to "fossicking" (hand digging), and in late 2007 the Queensland government indicated that some mechanized production might restart at Lava Plains (Neville, 2007).

Ruby was mined along the Gummi River north of Sydney between 2004 and 2006, with the mine operator, Cluff Resources, reporting that 440,000 carats of cabochon- and some facet-grade material were extracted. The company suspended operations early in 2007 after local governments declined to approve a request to extend mining operations to a broader area (Cluff Resources, 2007).

Madagascar. *Sapphire.* Madagascar has developed into the most important source of sapphire, blue and fancy colored, within the past two decades (see, e.g., figure 12). Corundum finds there were minor until 1993–94, when attractive blue sapphires were found in the Andranondambo area of the island's southeast corner. The deposit proved lucrative, with some 1,200 kg exported to Thailand annually for the next three years and a number of 15–20 ct stones cut. A very high percentage of this material responded well to heat treatment, and some of the best-quality goods were compared to Kashmir sapphire (Schwarz et al., 1996).

The first truly major find came in 1996, in the Antsiranana region at the extreme north of the country. Within two years, the area became one of the world's most productive sources of commercial-quality sapphire, as an estimated 10,000 miners worked small claims with hand tools while traders from Thailand and Nigeria bought and exported the production (Schwarz et al., 2000). However, in 1998 the government temporarily halted activities in the area after miners encroached on the nearby Ankarana nature preserve ("Sapphire mining halted," 1998). The ban was lifted within a few months, but by then discovery of an even-larger sapphire deposit had enticed the miners and dealers to travel more than 1,200 km south to the small village of Ilakaka.

What made the Ilakaka find so notable was its immense size—huge amounts of sapphire (some 4,500 kg; Yager et al., 2008) entered the market very quickly in 1999—as well as the attractive blue color of some of the material and the fact that it generated international headlines. The hundreds of pits dug in the area (again, see figure 12) also yielded other colors (Johnson et al., 1999; figure 13). Although much of the production was small (less than 1 ct) and of commercial quality, some of the material rivaled the best Sri Lankan sapphires. Pink sapphires from that area supported the market through a wave of popularity in the mid-2000s (Pardieu and Wise, 2005). The Ilakaka discoveries came at a fortuitous time. As noted above, the traditional sapphire sources in Thailand were nearing depletion and the large Australian deposits were winding down, so most of the stones reaching the market came from Sri Lanka and relatively small workings in Myanmar and Tunduru, Tanzania. Ilakaka is still producing material, but mining activity was severely curtailed during a 2008–09 export embargo and by the fact that the easily worked areas were depleted (T. Cushman, pers. comm., 2009).

Figure 13. The sapphire production from Madagascar (here, 0.45–1.99 ct, primarily from Ilakaka) is notable for the broad range of colors produced. Courtesy of Robert Kane/Fine Gems International, Helena, Montana; photo by R. Weldon.

Because a high percentage of the sapphires produced were smuggled out of Madagascar, production statistics tend to be incomplete and contradictory. One report said that by 2005, Madagascar was responsible for an estimated 50% of the world's sapphires (Tilghman et al., 2007). However, a U.S. Geological Survey (USGS) study placed Madagascar's sapphire output at 25–40% of world share between 2000 and 2005 (Yager et al., 2008). Note, though, that the USGS study was based on voluntary responses to questionnaires and did not include material smuggled from any source country including Madagascar. In addition, the USGS reported that Madagascar's sapphire production climbed from 140 kg in 1995 to over 9,500 kg in 2000, receding to 4,700 kg in 2005 (Yager et al., 2008). But the stated value of legally exported material was far lower than such large quantities would indicate. Tilghman et al. (2007) reported that the overall value of "precious stones" (the vast majority of which were sapphires) produced in and legally exported from Madagascar was only $7.63 million in 2005, up from $5.84 million in 2001 and $2.61 million in 1998. This may be explained by a claim that 50 kg of sapphire were smuggled to Thailand each week, supported by a World Bank estimate that the country saw less than 5% of its potential revenues from sapphire exports ("Getting stoned," 2005).

Ruby. Madagascar also has been an important source of rubies. One major find, in September 2000, was in Vatomandry near the eastern coast. The material was high quality and generally pinkish red to red (e.g., figure 14), with the finer goods comparable to Mogok rubies. About 30–40% was marketable without heat treatment (Leuenberger, 2001). Fearing a repeat of Ilakaka's uncontrollable gem rush, government authorities quickly sealed the area to miners and divided it into concessions, though by 2005 most miners had left the area because all the easily worked deposits were played out (Hughes et al., 2006).

Figure 14. In their best qualities, rubies from Madagascar's Andilamena deposit (above, cut stones 4.85 and 5.02 ct) have bright refractive qualities and slightly orangy red hues. Vatomandry rubies (below, cut stones 1.78 and 2.03 ct) show desirable pinkish red to red colors. Courtesy of Allerton Cushman & Co., Sun Valley, Idaho; photo by R. Weldon.

About the same time, a second deposit was discovered in north-central Madagascar, near the town of Andilamena in a difficult-to-access rainforest. Again, a boomtown appeared nearly overnight, with an estimated 40,000 miners descending on a previously uninhabited locality. The government tried to seal the area, but was stymied by the challenging logistics. Although the material was quite plentiful and the best stones were a bright, slightly orangy red (again, see figure 14), the commercial stones tended to be over-dark and most of the rough was fractured and—at the time—unmarketable as gems (Leuenberger, 2001). That would soon change.

In 2004, large quantities of lead glass–filled ruby began filtering into the market, much of it from the Andilamena deposit. This treatment was different from the borax-based glasses and flux residues mentioned above. The infusion of lead glass disguised the fractures and transformed pale, opaque material into attractively colored, translucent rubies. The stones were competitively priced, between $2 and $20 per carat, and proved easily identifiable (McClure et al., 2006). As the Andilamena deposit was mined out, however, the quality of the material deteriorated even further, with the result that many "rubies" reaching the market consisted more of lead-glass filler than actual corundum ("Gem treatments. . .," 2009; see also the Effect of Treatments section below).

Environmental and Social Challenges. The government's concern about Madagascar's gem rushes was justified, as the boomtowns attracted more than miners, gem dealers, and news media. Stories of violence, corruption, disease, and environmental damage rapidly became an integral part of the international reporting on the Ilakaka sapphire rush (see, e.g., Hogg, 2007).

In addition to the problems documented at Ilakaka, reports have also cited the extensive damage to the country's rainforests and nature preserves by miners digging for gems, often abetted by corrupt officials who sometimes have a vested interest in mining activities ("Getting Stoned," 2005; Tilghman et al., 2007). Environmentalists are particularly concerned because an estimated 80–90% of Madagascar's indigenous plant and animal species exist nowhere else (Tilghman et al., 2007).

And, as noted above, the gem rushes have failed to bring commensurate benefits to Madagascar's treasury because of smuggling.

In 2003, the country's newly elected president, Marc Ravalomanana, moved to reform national gem mining policies in hopes of reducing illicit exports and gaining more revenues. He also sought to limit environmental damage by controlling gem rushes and enforcing bans on gem mining in national parks. The policy reforms simplified the complex system for licensing gem mines, established gemological training programs, and permitted foreign companies to mine and export gems. While winning praise from the World Bank and other development agencies (Duffy, 2005), the reforms stalled early in 2008 after the Secretary General of Mines banned all gem exports (Shor, 2008). In July of that year, a delegation from Thailand, including several government officials and members of key Thai gem trade associations, met with Malagasy officials to have the ban lifted. They succeeded in eliminating the ban on cut stones, but not that on rough, which remained in effect until mid-2009, though an unknown quantity of goods still exited the country illegally. So many dealers and miners reportedly left Ilakaka that the town shrank to one-fourth its peak size (T. Cushman, pers. comm., 2008).

In March 2009, Mr. Ravalomanana was forced from office in a coup, and on July 17, the ban on gemstone exports was completely lifted by the minister of mines for the interim government, Jean Rodolphe Ramanantsoa. He noted that the 19-month ban ultimately cost the government $39 million in revenue and affected the livelihoods of more than 100,000 Malagasy artisanal miners (Cushman, 2009).

Vietnam. In the late 1980s, rumors of a major ruby find in Vietnam began circulating through the world's gem centers. To help manage the newly discovered deposits, the Vietnamese government created the state-owned Vietnam National Gem and Gold Corp. (Vinagemco) in 1988 to engage in prospecting, mining, processing, and trading of gem materials. From November 1989 to March 1990, an estimated three million carats of ruby were mined from the Luc Yen district, north of Hanoi. Described as "Burmese color," the ruby began hitting the Bangkok gem markets in 1990 and 1991 (Kane et al., 1991).

In 1991, the Vietnamese government established a joint venture with a Thai operation, B. H. Mining Co., to begin mechanized extraction in the Luc Yen area. By 1994, mechanized operations had ceased because the deposits were no longer economic (Kammerling et al., 1994). In general, the Luc Yen ruby, and its small quantity of blue and pink sapphire, was of good color but relatively low clarity—only a small percentage was eye clean.

Several hundred kilometers to the south, at the top of the Ho Chi Minh trail, discovery of rubies in the Quy Chau area attracted thousands of local diggers in the early 1990s before the government moved in to organize operations. A third major find occurred in 1994 at Tan Huong, about 80 km south of Luc Yen. From 1994 to 1996, hundreds of kilograms of rubies and star rubies were mined illegally and sold to foreign dealers until the deposit was taken over by Vinagemco. As at Luc Yen, the rubies were red to purplish red. Sapphires—orange, blue, and violet—were also found in these two areas, though in much smaller quantities than ruby. Several relatively small deposits of blue sapphire were located during the 1990s in the southern and central portions of the country (Van Long et al., 2004).

Most of Vietnam's corundum deposits, while yielding large quantities of material in a fairly short time, were no longer commercial after a few years (Van Long et al., 2004). For example, Vietnam's sapphire production soared from an estimated 40 kg in 1996 to 1,700 kg two years later, but by 2001 production was down to 70 kg (Yager et al., 2008).

By 2006, these areas were mainly worked by local diggers who extracted relatively small quantities of material, illegally in some cases, and sold them to Thai dealers (ICA 2006 World Gemstone Mining Report, 2006). Most reports note the promise of more deposits awaiting discovery, but to the best of our knowledge the government has yet to undertake a detailed geologic survey.

Lesser Producers. A number of other countries produce ruby and sapphire from generally small- to medium-sized deposits. Several, however, may have the potential to develop into significant producers.

Cambodia and Laos. In Cambodia, most sapphire production over the years has come from Pailin, near the border with Thailand. Pailin was known for yielding commercial quantities of blue sapphire as well as much smaller amounts of purplish to orangy red ruby (ICA 2006 World Gemstone Mining Report, 2006). During the 1950s through the 1970s, the nation was sealed to the outside world as the war in Vietnam raged, until late 1978 when the Khmer Rouge were driven from power by the Vietnamese army.

Subsequently, some former senior Khmer Rouge army officers took control of the local sapphire deposits, selling mainly to Thai dealers. Although the amount produced was no longer significant (Yager et al., 2008), Pailin's association with the architects of the Khmer Rouge regime attracted unfavorable international publicity for sapphires at a time when the diamond and tanzanite industries were similarly under fire. In 2002, enough sapphires were coming out of the ground that a British Broadcasting Corporation (BBC) report described Pailin as a "Wild West" type gem market, with "hundreds of thousands of dollars" worth of goods on display (Pike, 2002). The gems shown in the BBC report were nearly the last to come from the area because, by 2006, it had essentially ceased production (ICA 2006 World Gemstone Mining Report, 2006).

In Laos, sapphires have been mined at Ban Houay Xai, an area adjacent to the intersection of the Thai-Burmese border, since the 1890s. Not until 1995, however, was an attempt made to systematically mine the deposit. An Australian company, Gem Mining Lao, operated the mine for several years, producing primarily dark blue material, before the local government seized its assets in December 2000 in a dispute over concession areas and royalties (Radio Free Asia,, 2000). By 2005, the area was worked by only a handful of small-scale miners (Pardieu and Senoble, 2005).

China. A farmer reportedly found the first Chinese sapphires on Hainan Island in the early 1960s (Galibert and Hughes, 1995). However, China's sapphire deposits are mostly located in the eastern side of the mainland. Much of its production is characterized by dark-toned blue colors, though greens, blue-greens, and yellowish greens are also found. The basalt-hosted material found at Mingxi in Fujian Province (Keller and Keller, 1986; Guo, 1992) and Changle in Shandong Province is comparable to the dark-toned sapphires from Australia. Supplies are sporadic because of informal mining techniques (Weldon, 2009). Nevertheless, the Chinese government apparently believes in their potential, as it has committed enormous resources to developing infrastructure, such as the Gem City Complex in Changle, to support sapphire mining and processing in the future. Thus far, the sapphires have been intended for local consumption and for the tourist trade; however, the Gem City Complex will accommodate thousands of miners, cutters, jewelry factories, and retail outlets. Officials have noted that other gems will also be processed at these facilities (Weldon, 2009).

Figure 15. This pendant (named La Jenna) and matching earrings are set with Greenland rubies and pink sapphires (37.45 carats total weight). Courtesy of True North Gems, Vancouver, BC, Canada; photo by R. Weldon.

Greenland. The world's largest island, Greenland, has a potentially interesting ruby source under development. True North Gems, a publicly traded Canadian company, began exploring a large area (823 km^2) on the southwest coast in 2004, producing pink sapphires and rubies, mostly less than 1 ct. True North reported recovering 1,297 kg of near-gem ruby and pink sapphire, and about 65 kg of gem-quality material (Weston, 2009). A limited amount of this material has been set into fine jewelry (e.g., figure 15).

The project is currently in a dispute with the Inuit people over their ability to prospect in areas controlled by True North, which the Inuit consider their right under Greenlandic mineral law. True North is also prospecting the Beluga sapphire project on Baffin Island (Carpin, 2009; Weston, 2009).

Kenya. The John Saul mine, located in the Mangare area not far from the tsavorite deposits, has been Kenya's most important and productive ruby mine (ICA 2006 World Gemstone Mining Report, 2006). Operated by Rockland Kenya Ltd., it is also Africa's largest mechanized ruby operation, producing mostly cabochon-grade material that is heated to produce saturated red colors. About 200–500 kg of mixed-grade material (figure 16) is recovered monthly, with only a small percentage achieving top-grade cabochon quality (Laurs, 2008). Other deposits of jewelry-grade ruby have been found in Kenya, notably the Baringo deposit north of Nairobi, discovered in 2005, and the Simba deposit found in 2007. Both are promising, with their finest qualities of pinkish red rubies exhibiting great transparency. However, investment funding, logistical problems, and—in the case of Baringo—disputes over mine licenses, have limited the output from both mines to very small quantities (N. Pattni, pers. comm., 2009).

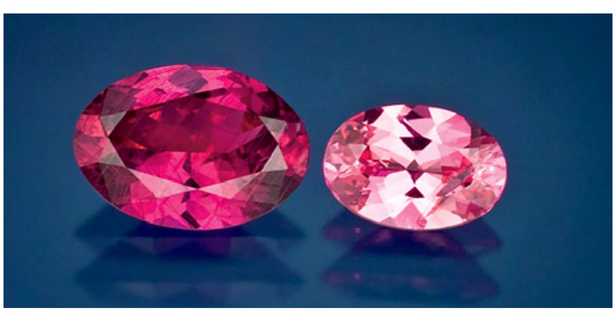
Malawi. Corundum was discovered at Chimwadzulu Hill, in southern Malawi, in 1958 (Rutland,

Figure 16. Pavel Sobolev (left), a buyer from Russia, examines an assortment of rough ruby at the John Saul mine in Kenya, one of Africa's most productive deposits, while the company's sorters process the goods. Photo taken in May 2007 by R. Weldon.

1969). Today, the production tends toward pink, red (e.g., figure 17), and purple (much of which does not require heat treatment), in sizes yielding a maximum of 2–3 ct gemstones (Rankin, 2002). Some 4–5 kg of material have been mined annually in recent years (ICA 2006 World Gemstone Mining Report, 2006). More recently, approximately 50–100 kg of yellow and blue sapphires have been produced, though the blue sapphires are routinely heated (E. Braunwart, pers. comm., 2009).

Tanzania. Ruby and sapphire deposits in East Africa have been known since the early 1900s (see, e.g., Dirlam et al., 1992). In late 1994, a variety of alluvial gem rough began appearing in Tanzanian gem markets in Mombasa and Arusha (Weldon, 1995). Farmers had discovered these gems in riverbeds near Tunduru, and the area was soon hailed as one of East Africa's major gem finds. The corundum included pink-to-red, dark red, yellow, blue, violet, green, and color-change varieties. (The deposits also yielded other gems such as beryl, chrysoberyl, diamond, garnet, quartz, tourmaline, and zircon.) The gems were derived from the massive geologic province and gem-bearing complex known as the Mozambique Belt (Johnson and Koivula, 1996; Henn and Milisenda, 1997).

Figure 17. Ruby (here, 1.51 ct) and pink sapphire (0.73 ct) were first found in Malawi half a century ago. Today they are being mined in accordance with fair trade principles that use company-devised protocols at all levels of the gems' supply chain. Courtesy of Columbia Gem House; photo by R. Weldon.



Additional deposits were soon found about 140 km west of Tunduru in the region of Songea. Interestingly, gems from the two areas shared similar characteristics, although Songea produced significantly more rubies (Johnson et al., 1999b). Material from Songea acquired a different notoriety in 2001, when quantities of pinkish orange to red-orange sapphires, said to come from this locality, began to enter the market. Dealers had not previously seen such material at the source, so a new treatment was suspected (Hughes, 2001). The suspicions were correct, as the stones had been diffusion treated with beryllium to create padparadscha and other colors (Emmett et al., 2003). Ultimately, thousands of the treated stones were sold without disclosure (see Effect of Treatments, below).

In 2007, ruby and sapphire from Winza, in central Tanzania, began to enter the market. These gems were mined from primary as well as secondary deposits (figure 18). This happened at a time when supplies of corundum and other rough were low because of the situations with Madagascar and Myanmar. The extraordinary transparency and bright color of the best Winza rubies have prompted comparisons to top Burmese material, with some stones as large as 20.46 ct (Schwarz et al., 2008; Wise, 2008a; figure 19). Winza's gem corundum ranges from blue to red, sometimes with both colors exhibited in the same crystal. A significant percentage of Winza gems are not heat treated, which has contributed to their desirability. Winza also produces ample quantities of lower-grade ruby and sapphire suitable for cabochons (Peretti et al., 2008; Schwarz et al., 2008). Attempts to heat treat this material have not resulted in significant improvement.

Pakistan, Afghanistan, and Elsewhere in Central Asia. Rubies from both Pakistan and Afghanistan

Figure 18. Rubies and sapphires from the Winza deposit in central Tanzania are recovered from primary deposits as well as from eluvium, which is wet-sieved using water from the adjacent seasonal river. The miners employ portable gasoline-powered pumps to make pools of water during times of low rainfall, as in this June 2008 photo. Photo by Brendan M. Laurs.

are hosted by marble and generally found in small sizes (Gübelin, 1982). The best stones can resemble gems from Myanmar, Vietnam, and Sri Lanka (Hughes, 1997). There are several challenges to mining these deposits, beyond those inherent in this war-torn region: tribal rivalries, rugged terrain, and an almost nonexistent infrastructure (Snee, 2006). Bringing steady supplies to market under such conditions is daunting at best.

In Pakistan, rubies have been mined from marbles on Nangimali Mountain (see Kashmir section above) and from a few deposits in the Hunza Valley near Ahmadabad (e.g., Laurs, 2007). Production from the Hunza Valley has remained small throughout its history, though reserves appear large; investment in heavy machinery and infrastructure is needed to develop these hard-rock deposits ("Pakistan's gemstones. . . ," 2005). Small deposits of rubies and predominantly purple sapphires have been found in the Basha Valley (northern Pakistan; Laurs, 2007) and Batakundi (North West Frontier Province; Quinn and Laurs, 2004).

In neighboring Afghanistan, marble-hosted rubies and sapphires occur mainly at Jegdalek, some 60 km southeast of Kabul. According to a 2009 status report on the Afghan gem industry (Bowersox et al., 2009), a government-imposed moratorium on gem mining has resulted in scant production in recent years. Flooding at Jegdalek has also halted activity at some of the sites. Nevertheless, some two dozen mines are on the verge of becoming operational in Afghanistan's Jegdalek region today. It is expected that, once the Afghan government issues mining licenses, some 2,000 people will return from refugee camps to work these deposits (Bowersox et al., 2009). Afghanistan's Vardak Province has produced a small amount of blue sapphires (Quinn and Laurs, 2004).

The first rubies from the Himalayan Mountains were discovered in east-central Nepal in the 1980s.

Figure 19. The Winza deposit in Tanzania has attracted the attention of serious connoisseurs because of the superb rubies it can produce. This 14.97 ct gem is courtesy of Mona Lee Nesseth Custom and Estate Jewels and a private collector, Laguna Beach, California. Photo by R. Weldon.

The Chumar and Ruyil deposits in Nepal have produced pink-to-red corundum and some violet-to-blue sapphire (Smith et al., 2007). Rubies from Tajikistan are comparable to some of the world's finest, ranging from pinkish red to red (Pardieu, 2007). Production is sporadic due to the lack of infrastructure and the high altitude of the deposit.

United States. Sapphire has been known in Montana since 1865, with significant mining since the late 19th century (see, e.g., Emmet and Douthit, 1993). Four major sources comprise Montana's alluvial sapphire deposits: the Missouri River (including El Dorado Bar), Dry Cottonwood Creek, and Rock Creek. The American Gem Corp. undertook large-scale mining efforts at Rock Creek between 1994 and 1996, producing more than four million carats of gem-quality rough—and, for a brief period, making Montana one of the world's largest sources of sapphire. This production has thus far yielded more than one million faceted gems (Kane, 2003). Today, mining operations at Rock Creek are mostly small. Montana's alluvial sapphires are often subjected to heat treatment, resulting in a variety of more marketable colors (Emmett and Douthit, 1993).

Yogo Gulch, discovered in 1895, is Montana's only primary sapphire deposit. Yogo sapphires are uniformly blue (often described as "cornflower blue") and do not need heat treatment. However, the rough typically yields small, melee sizes. Some market analysts say the material is simply not large enough to cover production costs, especially compared to other corundum sources worldwide (Austin, 2001), although the present owners believe it is sufficiently viable to continue to develop the property (Baiz, 2009).

FACTORS AFFECTING VALUE

New sources and treatments have been critical to expanding the market for ruby and sapphire to a broader base with more commercial jewelry (figure 20). However, market prices for ruby and sapphire are based on a number of interrelated factors: geographic origin, color (subtle differences in hue create large differences in price), clarity, cut quality, supply, demand, type of treatment, extent of treatment, public confidence in the product, and exchange-rate fluctuations. All of these factors have come into play during the past decade for both corundum varieties, with particular emphasis on country of origin, treatments, and cutting.

Figure 20. Greater quantities of sapphire and ruby have become available to a much larger market in attractive yet affordable jewelry (here, the ruby is 0.50 ct). Courtesy of Pauling Blue Fire Diamonds, Carlsbad, California; photo by R. Weldon.

The Significance of Country of Origin. The source of an important ruby or sapphire historically has been a critical factor in gauging its potential demand and ultimately value. In fact, international auction houses have depended heavily on laboratory determination of origin to obtain premium prices for certain rubies and sapphires (F. Curiel, pers. comm., 2008).

This has not occurred without controversy. In 1990, GIA chairman Richard T. Liddicoat wrote that the beauty of a gemstone—not its origin—should be the primary factor in determining its value. "Why should someone pay more for an inferior ruby because it came from Burma?" he asked (Liddicoat, 1990, p. 247). Liddicoat also cited the technical challenges of determining source locations with reliable certainty at that time. New sources of corundum discovered since then have underscored these challenges.

Gemstones from different locales do have characteristic features (e.g., three-phase inclusions in Colombian emeralds, rutile silk in Burmese rubies, and "sleepiness" due to inclusions in Kashmir sapphires), but difficulties arise with materials that do not exhibit telltale signs or that share features with stones from other localities—particularly in the higher qualities. Indeed, a spate of reports indicating significant overlaps of appearance and characteristics in high-quality sapphires from Sri Lanka, Myanmar, and Madagascar began to surface as

Madagascar's sapphire bounty reached markets in the mid-to-late 1990s and early 2000s (see, e.g., Roskin, 2005).

Yet demand by the trade and public to differentiate among corundum from various sources also grew during this period—perhaps precisely because such overlaps caused confusion (Roskin, 2005). As a result, requests for differentiating localities became increasingly common. More recently, the need to determine origin has been tied to political concerns, such as the U.S. government's ban on rubies from Myanmar.

Technology has also advanced in ways that make such determinations far more certain than at the time Liddicoat wrote his editorial. Today, several gemological labs around the world offer services to determine the origin of important gemstones, which they do by analyzing a combination of properties such as inclusions, trace-element chemistry, spectral characteristics, and internal growth structures (Kane et al., 2005). They also typically stress that such determinations are expert opinions only.

The Effect of Treatments on the Corundum Market. Several treatments designed to change the appearance, and thus the perceived value, of rubies and sapphires have been practiced for decades—and in some cases for centuries. Historically, sapphires and rubies have been coated with substances to enhance their color, or dipped in oil to improve apparent transparency. Such practices—as applied to a variety of gems—were described by Pliny the Second two millennia ago (Nassau, 1984). Although the coating of sapphire and ruby may not be as common today, the introduction of dyes into surface-reaching fissures is now routine, particularly in low-end beads.

More-sophisticated treatments—particularly high-temperature, atmosphere-controlled heating of corundum—are now commonplace. Combined with full disclosure throughout the supply chain, heat-treated rubies and sapphires have found their niche and price points within the market. Even this treatment, however, faced considerable controversy when it was first revealed, especially when not disclosed. The introduction of heated *geuda* sapphires, for example, seriously disrupted the sapphire trade almost 40 years ago. But once the controversy settled down, this treatment helped expand consumer demand for sapphires by making them more available and affordable to the mass market (Drucker, 1999a; figure 20). Heating also became the stepping stone for two significant new treatments that have radically altered the appearance of corundum and its perceived value over the last decade in particular: beryllium diffusion and lead-glass filling.

Beryllium Diffusion. In late 2001, large amounts of pinkish orange "padparadscha" sapphires—represented as natural color—began to appear on the market. While prominent gemologists soon suspected a form of diffusion, there was no understanding at the time about what elements might cause the "padparadscha" and orangy colors on a consistent basis. Thorough investigation proved that a diffusion treatment was indeed being used, and that beryllium was the element being diffused at extremely high temperatures (Emmett et al., 2003). The sudden appearance of these treated sapphires (figure 21), combined with their clandestine release into the marketplace, caught gem dealers and gemological laboratories by surprise (Henricus, 2002). These stones also caused substantial disruption in the gem community, at least temporarily, because the treatment was difficult to detect (Emmett et al., 2003).

The controversy eventually reached the consumer press. A report in *The Wall Street Journal* described the new treatment as a "scandal," going on to remark that "heat treatments and additives turn lesser sapphires and rubies into facsimiles of

Figure 21. This group of beryllium-diffused sapphires (1–2 ct) is typical of the colors seen on the market. GIA Collection no. 30858; photo by R. Weldon.

Figure 22. These lead glass–filled rubies (2.47–3.18 ct) show the range of color of treated material from Madagascar. Courtesy of Real Creation, Los Angeles; photo by R. Weldon.

rare beauty" (Mazurkiewich, 2003, pp. B1 and B3). The article noted that prices quickly fell and some gem wholesalers lost $30 million. The release of these gems caused a minor disruption in the collector market as well: *All* padparadscha sapphires became suspect until the diffused stones could be reliably identified (E. Caplan, pers. comm., 2009). Today, identification of this treatment—which is applied to produce ruby-like hues as well as blue and other colors of sapphire—is straightforward. However, it often requires advanced instrumentation such as laser ablation–inductively coupled plasma–mass spectrometry to establish the presence of beryllium (a light element not detectable by more commonly used analytical techniques such as EDXRF spectroscopy).

Lead-Glass Filling. Natural cavities and surface-reaching fissures in corundum have been filled with a borax-based glass compound for at least 25 years (Kane, 1984; Peretti et al., 1995). However, a new treatment involving glass with a high lead content entered the market in the early 2000s ("Lead glass impregnated ruby. . . ," 2004). It quickly became prevalent in low-quality corundum—mostly rubies. Because of the lead glass's higher refractive index, filled fractures or cavities were more effectively concealed. Much of the starting material initially came from Madagascar's Andilamena deposit (Milisenda and Horikawa, 2006). Such low-quality cloudy pink corundum was transformed into "ruby"-red corundum exhibiting much greater transparency (e.g., Hänni, 2006; figure 22).

The filled material is readily identified with magnification (e.g., McClure et al., 2006). Low-quality, fractured material from any locality is susceptible to being treated with high-lead-content glass (Themelis, 2000). As with diffusion treatment, it is imperative that this material be disclosed.

Cutting. Traditionally, gems have been sold by weight, but jewelry manufacturers often faced difficulty buying large parcels of gemstones because proportions from hand cutting, even among pieces of nearly identical weight, varied too widely for automated setting and jewelry casting operations. The 1990s brought new lapidary technology, in the form of computer-guided shaping and cutting, that allows for precision-cut ruby and sapphire compatible with jewelry manufacturers' mass-production requirements (Kremkow, 1997; Weldon, 2004).

One of the first precision cutters was D. Swarovski & Co., through its Swarogem subsidiary, which introduced small calibrated ruby and sapphires in 1997. These were primarily sourced from Mong Hsu (ruby) and Anakie (sapphire; Kremkow, 1997). The goods were cut in 0.25 mm increments, between 1 and 3 mm, for sale in large lots to jewelry manufacturers. Since then, other suppliers have introduced precision-cut gemstones for mass-market jewelry manufacturers—and some distinctive designers (figure 23).

Advances in cutting technology also have widened the scope of traditional gemstone shapes and styles, as evidenced by such well-publicized cutting competitions as the American Gem Trade Association (AGTA) Cutting Edge and Spectrum awards (e.g., figure 24), and the German Award for Jewellery and Precious Stones (Weldon, 2006). Finally, cutters such as Mark Gronlund, John Dyer, and Richard Homer have used concave facet cutting techniques that add brilliance, symmetry and beauty to corundum and other gem materials (Weldon, 2005; again, see figure 7), while lapidary Glenn Lehrer developed the Torus Cut, essentially a circle with concave and convex facet arrangements, which proved ideal for Montana sapphire pieces that were too flat to fashion into traditional gem shapes (Wheaton, 2000).

THE CORUNDUM MARKET TODAY

After export, most ruby and sapphire is sold through networks of small dealers and cutters who have no obligation, as public companies do, to report yearly sales. Similarly, retailers around the world, public or not, rarely separate out their sales figures for ruby and sapphire—or even colored stone jewelry.

It is safe to conclude that up to and through the 1970s, the market for faceted blue sapphire and ruby was small relative to the quantities in the jewelry industry today, simply because supplies were limited primarily to the low percentage of facetable goods (typically less than 5%) that came from the mines in salable colors. The introduction of effective heat-treatment techniques to improve the color and clarity of previously unsalable material, such as *geuda* sapphire from Sri Lanka and dark, "silky" blue stones from Australia, greatly increased the quantities of sapphire available to the market, particularly in the lower-priced commercial qualities. A similar situation occurred with ruby in the mid-to-late 1980s after the Mong Hsu deposit was discovered (Emmett, 2007). And not only did treatments greatly increase the proportion of facet-grade material available, but they also allowed development of deposits where there was little or no naturally occurring gem-quality material (Emmett, 2007).

Recently, two market research studies have shed light on sales of colored stones in general—and ruby and sapphire in particular—at wholesale and retail. They found—not surprisingly—that corundum represents the largest single share of the colored stone market. One study, published in 2009 in Dubai, reported that the world retail market (of which the U.S. accounted for 60%) for all "precious" gemstones was approximately $80 billion: $69.7 billion for diamonds and $10.3 billion for colored stones and pearls. Of the latter amount, ruby and sapphire accounted for 30%, while emerald was 12%. The remaining 58% comprised all other gems, including pearls (BUZ Consulting, 2009).

The second study, commissioned by True North Gems, pegged the pipeline (retail sales and inventory) for ruby at $2.1 billion and sapphire at $800 million ($58 million of which was pink sapphire), for a total similar to the approximately $3 billion cited in the Dubai study. The same source noted that emerald sales totaled $1.4 billion. The sapphire share is low in comparison to that of ruby because of the large quantities of low-quality and diffusion-treated sapphire in the market (Smith, 2009).

The Dubai study (prepared before the fall 2008 onset of the global economic crisis) predicted that sales of colored stones would grow an average of 6.1% annually around the world. However, that report and other sources (Emmett, 2007; Shor, 2007c) listed a number of challenges that could hamper growth in retail demand for colored stones, including corundum:

Figure 23. New cutting technology has led to better-cut, calibrated gems for manufacturing jewelers and designers alike. This stylized butterfly pin contains invisibly set princess-cut pink, blue, and yellow sapphires. Courtesy of Michael Schofield & Co., Clear Creek, Indiana; photo by R. Weldon.

- There are no universally accepted grading standards, which makes colored stones more difficult to describe and appraise than diamonds.
- Apart from tanzanite and several varieties of pearls, there are no coordinated large-scale marketing efforts, such as those that have helped spur diamond, gold, and platinum jewelry sales.
- Supplies can be unpredictable. Colored stone deposits tend to be relatively small and sporadically distributed, and thus many have a short life span.
- The perception of the financial community is that the colored stone industry is a "Wild West" environment, with few laws and extremely fragmented markets.
- The lack of documented information about the colored stone industry deters banks and other financial institutions from offering credit lines.
- Sales of colored stone jewelry are more closely tied to fashion trends than other forms of jewelry and thus are more volatile.

Figure 24. The AGS Cutting Edge Awards promote excellence as well as innovation in gem cutting. This unheated 4.53 ct pink sapphire from Nanyaseik in Myanmar won first place in the classic gemstone division for 2010. Courtesy of Robert Kane/Fine Gems International, Helena, Montana; photo by R. Weldon.

- Treatments remain an issue, and debates continue over "acceptable" and "unacceptable" treatments.

FAIR TRADE

Consumers in many countries are developing a greater awareness of social and environmental issues surrounding the products they purchase (Shor, 2009). Many of these concerns are grouped under the term *fair trade*: a trading partnership between producers and buyers seeking greater equity in international commerce through ethical labor practices, including gender equality and safety standards, sustainable environmental practices, ethical business practices, and poverty alleviation. A number of monitoring agencies have been created to certify fair trade practices for many consumer products, with those meeting the established criteria then labeled as "fair trade" products. In the gem and jewelry industry, the Responsible Jewellery Council is developing a certification scheme for diamond and gold miners and retailers. At this time, however, no official program exists for the colored stone industry (Weldon, 2008).

Some gem dealers are paying greater attention to these needs for a fair trade system. Columbia Gem House (Vancouver, Washington) has developed a system of protocols aimed at developing accountability—both financial and human—in every aspect of its gemstone supply chain (Weldon, 2004). The Madison Dialogue, a forum of cross-sector miners, association leaders, nongovernmental organizations, and World Bank executives, met in Washington, DC, in October 2008 to discuss how fair trade and sustainability programs can be applied to the jewelry business (Madison Dialogue. . . , 2008). Since then, committee members have begun to refine common principles and develop best practice initiatives in the mining of metals as well as diamonds and other gems. Also, the International Colored Gemstone Association (ICA) has examined the issues at several of its recent congresses, and members of the organization are active in gemstone steering committees of the Madison Dialogue. Separately, ICA directors are leading initiatives in Nigeria and Greenland aimed at developing fair trade models that could be used at other gem localities around the world (J. C. Michelou, pers. comm., 2009).

Demand for fair trade products is increasingly consumer driven, and has gained traction, especially among younger consumers who tend to be more inclined to do business with companies they see as upholding positive social and environmental objectives (Cone, 2007). The same consumers also require accountability and verification along a product's supply chain, administered or audited by independent third-party verification entities.

CONCLUSION

The advent of effective treatment methods, coupled with discoveries of significant new deposits of ruby and sapphire—many of which would have been uneconomic as gem sources without such treatments—has greatly expanded the world retail market for gem corundum. As with diamonds and other gemstones, however, world events, local conflicts, and political upheavals have affected supplies and, possibly, consumer attitudes toward ruby and sapphire.

The future of the ruby and sapphire market will depend on continued discoveries of new corundum-producing deposits as existing ones wind down. Increasingly, the search for, and exploitation of, new sources will be tempered by environmental concerns and fair labor practices. As the world becomes more connected and transparent, miners, cutters, dealers, and retailers will face increasing scrutiny. This is evidenced by the attention that governments and nongovernmental organizations have focused on the diamond and gold extraction industries.

Another key issue for the corundum industry remains both the understanding and disclosure of treatments. A number of treatments that substantially transformed low-value material have undermined trade confidence in recent years. The treatments were not disclosed upon their introduction to the market, with the result that prices for such goods, for a time, fell to extreme lows while the values of fine untreated goods rose sharply. While U.S. and international gem trade organizations require disclosure, some retailers, concerned that customers may not understand or accept treatments, remain reluctant to disclose when selling colored stone jewelry.

The market for corundum still holds significant future potential. Several studies point to increasing consumer demand for colored gemstones, which could outpace gold and diamonds in the coming years, particularly in emerging markets. Ruby and sapphire sales at the retail level will likely be tied to consumer-driven fashion trends and consumer confidence in the product as represented. Increasingly, the consumer will also require that the product embodies positive social, ethical, and environmental values.

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