An Overview of Production of Specific US Gemstones

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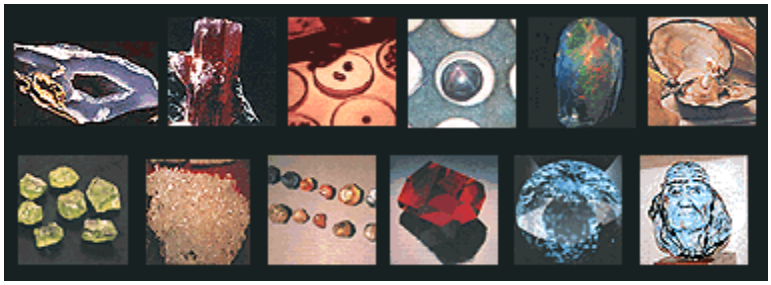
GEMSTONES

California Tourmaline
(Photo courtesy of Smithsonian Institution)



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Abstract

This report presents an overview of the production of specific gemstones from deposits within the United States. The U.S. Bureau of Mines (USBM), Department of the Interior compiled and analyzed the information contained in this report. The report should be viewed as a current "still photograph" of a dynamic system. The information presented on a specific gemstones or for a specific State can and will change with time. This overview presents historical and reference information on the principal gemstones and their production in certain States. The report is not a definitive work on gemstones within the select States or United States.

Introduction

Webster's defines a gem "as any jewel, whether stone, pearl or the like, having value and beauty that are intrinsic and not derived from its setting; a precious or, sometimes, a semiprecious stone cut and polished for ornament. A stone of value because it is carved or engraved, as a cameo or intaglio." Additionally, the dictionary states that gemstones or gem material is a stone or material from which a gem may be cut. In short, a gem, gemstones, or gem material may be described as materials used for personal adornment, display, or objects of art because they possess beauty, rarity, and durability.

gemstones produced in the United States and other producing countries are of three types; natural, synthetic, and simulant. The natural gemstones included minerals used as faceting, lapidary, or carving rough, and specimen. Natural gemstones also include organic materials such as amber, coral, fossil, ivory, mother of pearl, natural and cultured freshwater pearls, and natural saltwater pearls. Laboratory grown synthetic gemstones have essentially the same appearance, optical, physical, and chemical properties as the natural material that they represent. Synthetic gemstones produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Simulants are laboratory grown gem materials that have an

appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gemstones simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gemstones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced.

Data Sources

U.S. gemstones production data are from different sources. The reliability and accuracy of the data vary from source to source and even within the same source. The data are reliable for general policy and economic decisions, but may not be applicable for site-specific or project-specific decisions.

U.S. Production

The USBM collects U.S. gemstones production data from the "Natural and Synthetic Gem Material Survey," a voluntary survey of U.S. operations. Typically, the survey includes approximately 400 operations of which between 80% and 90% responded, accounting for more than 95% of the total production. Additionally, the USBM staff estimates unreported production by nonresponding operations, professional collectors, and amateur or hobbyist collectors. The basis for these estimates is information from published data, conversations with gem and mineral dealers, and analyses of gem and mineral shows and sales statistics. In the formal voluntary survey and the informal surveys, the USBM is dependent upon the cooperation and honesty of the producers, brokers, dealers, and collectors.

Value of natural gemstones produced from deposits within the United States for the past 5 years, by year are $51.1 million, 1993; $66.2 million, 1992; $84.4 million, 1991; $52.9 million, 1990; and $42.4 million, 1989. Production values for U.S. synthetic gemstones for the same period are $19.5 million, 1993; $18.9 million, 1992; $17.9 million, 1991; $20.5 million, 1990; and $18.8 million, 1989.

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Chalcedony

Chalcedony is a catch all term that includes many well known varieties of cryptocrystalline quartz gemstones. They are found in all 50 States, in many colors and color combinations, and in sedimentary, igneous, and metamorphic rocks. Chalcedony includes carnelian, sard, plasma, prase, bloodstone, onyx, sardonyx, chrysoprase, thundereggs, agate, flint, chert, jasper, petrified wood, and petrified dinosaur bone just to name a few of the better known varieties.

Because of its abundance, durability, and beauty, chalcedony was, except for sticks, animal skins, bones, plain rocks, and possibly obsidian, the earliest raw material used by humankind. The earliest recorded use of chalcedony was for projectile points, knives, tools, and containers such as cups and bowls. Early man made weapons and tools from many varieties of chalcedony including agate, agatized coral, flint, jasper, and petrified wood.

The move from using certain items as weapons and tools, to using the same items for ceremonial and personal adornment is very easily made. It was only natural for early man to use his finest looking knife for special occasions or to attach a special lance point or arrowhead to his tunic. In fact, agate and petrified wood may have simply been elevated to gems from common and functional weapons or tools.

All 50 States produce some variety of chalcedony, but the material from some States is better known than that from others.

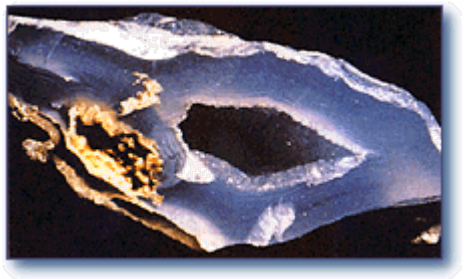

Figure 1 -- "Mojave Blue" agate from California.
(Photo is courtesy of Mr. Bill Nicks.)

Alaska -- The State has several varieties of chalcedony found at different locations, including agates, jaspers, and petrified wood. Various types of agates can be found in gravel pits and gravels of stream and river beds at several locations in the Chicken Creek area near the border with the Yukon Territory.

Agates, jasper, and petrified wood can be found on many beaches, including those on the islands of Adak, Admiralty, Attu, Kuiu, Kupreanof, Nelson, Popof, Tanaga, Unalaska, and Zarembo. These same materials can be found in the gravels or in many of the streams and rivers of the State. Other well known sources are the outlet of Becharof Lake, Little Nelchina River, and Caribou Creek.

Arizona -- Arizona is well known for its petrified wood because of the Petrified Forest National Park, and petrified wood ranks third in value of commercially produced gemstones. It is generally accepted that the Park contains the most colorful examples of silicified logs in the world.

Petrified wood occurs in every county in the State, but the commercial production is essentially from privately owned lands in Navajo and Apache Counties near the Petrified Forest. Federal regulations restrict collecting petrified wood on public lands to 250 pounds plus one piece per person per year, none of which is supposed to be sold commercially. The regulation essentially eliminates production from federal lands. Pieces as small as 1/4-inch to sections of logs 5 feet in diameter are recovered from the surface of the ground or with minimum excavations for use in the lapidary trade.

Arizona petrified wood has the broadest range of applications of any gem material produced in the State. The material is suitable for tumble polishing for use in baroque jewelry or for cutting into cabochons for jewelry and display. Freeform and calibrated slabs are polished for pen and pencil set bases and bases of other items, and polished slabs are used for clock faces. Additionally, large blocks, limb sections, and geometric shapes are used as bookends and decorator pieces. Objects of art, principally carvings, are produced, and furniture such as coffee and end tables are made from the petrified wood.

Arizona is the only State currently to have commercial production of fire agate. Fire agate is a form of chalcedony which contains inclusion of iron oxides that result in a play of colors much like that of precious opal. Eleven operations in Arizona report either commercial production of fire agate or dig-for-fee production. The material is produced in Graham, Greenlee, Maricopa, Mohave, and Yuma Counties.

Fire agate is cut into freeform and calibrated cabochons for use in the manufacture of silver and gold jewelry. The material is popular in the southwest and with hobbyist lapidaries throughout the United States. Fire agate also has been used and is currently used in Indian style jewelry.

California -- California's "Mojave Blue" agate has gained a great deal of attention in the past several years. This pastel blue or blue-gray agate cuts into attractive cabochons for jewelry and, in the hands of an expert carver, makes outstanding carvings.

Colorado and Utah -- These States have deposits of fine quality jasper, agate, petrified wood, and agatized dinosaur bone. These deposits are found over a large area of both States and on both sides of the continental divide in Colorado.

Florida--The famous silicified coral, first found in the Tampa Bay area around 1825 is the only gemstone of note from the State. Since its discovery in Tampa Bay, the agatized coral also has been found at Tarpon Springs, south of New Port Richey, near the town of Kathleen, and along the banks of the Suwanee River in Hamilton, Columbia, and Suwanee Counties. The material is found in two forms, as geodes, which represent partial replacement of coral, and as solid pieces which represent total replacement.

The coral is replaced by a waxy, translucent, botryoidal, varicolored chalcedony. The geodes are most often used as mineral specimens, but cabochon and tumbled gems can be made from the thin geode lining. The total replaced coral can be cut into attractive cabochons. The material can be blue, red, brown, amber, white, black, or a combination of these colors.

Idaho -- Jasper mining was beginning to make a comeback in the State, particularly with the operation of the Willow Creek jasper mine when in 1992, the untimely death of one of the partners mining the property, resulted in jasper mining reverting to hobbyist and professional collectors. Production of the various jaspers should be adequate to meet demand for the foreseeable future.

Montana -- Montana moss Agate is the grayish-white to gray translucent chalcedony containing dendrites. The black, brown, or red tree-like or scenic dendritic growths are actually included minerals of manganese and iron. Most of the moss agate is found as water worn cobbles in the Yellowstone River or its drainages between Billings and Sidney. The material can be collected in Yellowstone, Treasure, Rosebud, Custer, Prairie, Dawson, and Richland Counties. The agate has long been a favorite of hobbyist and professional cutters because of the beautiful and highly variable patterns, the durability, and ease in cutting and polishing.

New Mexico -- Varieties of agate, jasper, chert, or petrified wood are found in 15 of New Mexico's 32 counties. An area of about 100 hectares near Deming, New Mexico Rockhound State Park, is set aside for the non-commercial collecting of agate, jasper, and petrified wood.

Oregon -- The State is known for the production of various picture and scenic jaspers, agates, thundereggs, and petrified wood. Graveyard Point, Priday, and Polka Dot are names that are familiar to most agate collectors rockhounds, and many lapidaries. These are also names that are uniquely associated with Oregon and with beautiful agates. The same is true for the relationship between the names Biggs, Deschutes, and Sucker Creek and high quality picture or scenic jasper.

Oregon's State rock, the "thunderegg," may be the best known gem material from Oregon. Thundereggs were not, as believed by some people, ejected from volcanos, but

formed in very soft and friable volcanic ash beds. Solutions containing silica permeated the cinders until favorable points for chalcedony deposition were achieved. Aggregations of chalcedony were deposited, but before the material could fully solidify the center of the concretion split apart, possibly because of shrinkage, permitting the later introduction of additional materials. The resulting star-shaped centers of chalcedony may be in the form of agate, jasper, or in some cases different varieties of opal.

Thundereggs are used in a number of ways. One of the most common uses is to simply saw the thunderegg into two pieces, polish the sawed face of each half, and use it as a display or decorative piece; bookends are also made in this fashion. Also, the thundereggs are sawed into slabs from which calibrated and freeform cabochons are cut. Additionally, at least one firm in the United States is manufacturing gem spheres from thundereggs.

South Dakota -- The State's best known chalcedony is its colorful and beautiful Fairburn agates. Named after a community near a very prolific agate deposit in Custer County, these brightly colored banded agates are similar to Lake Superior agates found in Michigan and Dryhead agates from Montana. The color patterns are alternating bands with one of the bands always white. The colors that alternate with white include yellowish-brown, dark red, salmon pink, black, yellow, grayish-blue, and milky-pink.

The agate nodules range in size from about 20 millimeters in diameter to some that weigh as much as 20 kilograms. The nodules are recovered from the weathering of the Chadron formation in an elongated belt covering parts of Custer, Pennington, and Shannon Counties, with the community of Fairburn at about the center of the belt. Nodules similar to the Fairburn nodules weather out of a limestone formation in an area that includes parts of Custer and Fall River Counties.

Other varieties of agate are found in the State. Moss agate, much like the famous Montana moss agate, can be found in river gravels of the Little Missouri River system in Harding County. A wide variety of agate can be found in the gravel pits in the entire eastern part of the State.

Tennessee -- Agates can be collected from many different locations and geological formations across the State. The material includes golden tone agate from Hawkins Co., agatized oolites from Greene Co., carnelian, blue, ivory, pink, finely banded, dendritic, moss, iris and Fairburn style agate from Bedford Co., and Lake Superior type agate and agatized corals and sponges from Shelby Co. All of the material is suitable for cutting and takes a good polish.

Texas -- Some of the best agate, jasper, chert, and petrified wood (particularly petrified palm wood) found in the nation comes from Texas. Blue banded, moss, and red and black plume agates are found near Alpine in Brewster County. Similar agates are found in Jeff Davis, Hidalgo, Hudspeth, Presidio, Reeves, San Patrico, and Starr Counties. Petrified wood can be found in Amarillo, Bastrop, Brazo, Comal, Duval, Fayette, Gonzales, Lavaca, and Uvalde Counties, with fine-quality palm wood coming from Live Oak and

Webb Counties. Good-quality chert can be found in limestone formations in McCulloch, Moore, and San Saba Counties. The material from Moore County also is called Alibates flint and was used by prehistoric and modern-day Indians to make weapons and tools. The quarry from which the Indians obtained their flint is now Alibates State Park.

Washington -- Washington' s petrified woods are some of the finest in the nation. The woods not only represent a broad range of colors and patterns, but also represent a wide range of identifiable species. Species identified include redwood, oak (more than 10 varieties), cypress, elm, maple, willow, cedar, poplar, chestnut, alder, birch, persimmon, laurel, and ginkgo. The preserved woods have been used to make cabochons, table tops, pen bases, and other objects of art.

Deposits in the State also furnish a selection of agates that include moss, blue, and carnelian. The blue agate from Kittitas County, known as Ellensburg Blue, is highly prized by local lapidaries.

Wyoming -- Wyoming's claim to fame is its fine-quality agates and petrified wood. Deposits across the State supply a variety of seam, moss, banded, fortification, and turritella agates. Colorful and attractive specimens of petrified wood can be found in many areas in the State.

Others -- This is by no means a complete summary of chalcedony production in the United States. Flint from Flint Ridge, OH, and Lake Superior Agate from the Great Lakes were not discussed, nor was many other agates or jaspers from individuals favorite collecting locations. But in the space available, the better known or commercial producing locations were mentioned.

In 1993, U S. production of gem chalcedony was valued at about $1.9 million, according to the USBM. The production and use of U.S. chalcedony as a gemstone will continue to grow because the material is beautiful, abundant, durable, reasonably priced, and the variability is nearly unlimited.

Collector or Specialty

Each year hundreds of thousands of dollars worth of collector or specialty gems are purchased in the United States. Many of these gems are cut from gemstones produced from foreign deposits, but tens of thousands of dollars worth of these gems are cut from gemstones from U.S. deposits. Not finding a definition of collector or specialty gems in the literature, the author contacted several dealers recognized by the gemstone industry as experts in the cutting and marketing of these gems. Based on these discussions it appears that a good working definition of collector/specialty stones would be: "Collector or specialty gems are rare, unusual, or unique gems that are not normally seen by the gem buying public. These stones may be gem materials that are common to the market place, but are unusual or unique because of their large size or unusual color."

Some of the collector/specialty stones are suited for use in jewelry or limited use in jewelry, but most are not durable enough for use in jewelry. The stones suited for limited use can be used in earrings, pins, and pendants, but not for rings or bracelets. The nondurable stones are too soft, therefore subject to scratching and abrasion, are brittle or contain cleavages, therefore are fragile and subject to breaking, or are both soft and fragile. Some of the rare collector/specialty stones from U. S. deposits are rare because of production practices at the mines. Production from these deposits could be significantly increased in the future. If this were to occur, then these stones might no longer be as valuable as collector/specialty stones. Collector/specialty stones vary in value from a few tens of dollars per carat to more than $1,000 per carat. Production of collector/specialty stones by State is discussed below.

Figure 2.--Red beryl from Wah Wah Mountains of Utah.
(Photo is courtesy of Smithsonian.)

Alaska.--Small dark green to dark brown to black colored stones have been cut from material from the epidote deposit on Prince of Wales Island.

Arizona.--Large, fine-quality brownish to yellow colored stones have been cut from scheelite crystals from a deposit in the Hualapai Mountains in Mohave County. Some of the finest-quality, bright red facet grade wulfenite in the world comes from the Red Cloud Mine in Yuma County.

California.--Deposits in the State are blessed with a variety of collector/specialty stones. Stones have been cut from fine-quality, pink apatite from San Diego County. Some small colorless stones have been cut from analcine, but the location from which the material was recovered is unknown. Fine-quality, brown colored stones have been cut from axinite from deposits in Calaveras, Madera, Riverside, and San Diego Counties. Benitoite, the State gemstone, is the collector/specialty stone for which the State is best known. San Benito County is the only source of this fine, blue colored gem. Large, fine-quality, light to medium green colored stones can be cut from fluorite found in Los Angeles County. Large, colorless stones are cut from scheelite from deposits in Kern and Inyo Counties. Nearly flawless, colorless stones have been cut from natrolite from San Benito County.

The author also has seen natrolite stones that were labeled as being from Los Angeles County. Deposits in the State also yield fine-quality, brown epidote, colorless calcite and colemanite, and augelite.

Colorado.--Light yellow colored stones are cut from apatite recovered from a deposit in Eagle County. Large fine-quality colorless stones are cut from barite from nodules found in Mesa County and fine-quality, blue colored stones are cut from barite found in Weld County. Some colorless stones have been cut from phenakite from White Mountain and Mount Antero in Chaffee County. The finest-quality, bright red colored facet-grade rhodochrosite is found in Park County. Deposits in the State also produce fine-quality, facet-grade sphalerite.

Illinois.--The fluorite mines in Hardin and Pope Counties produce a variety of different colors of facet-grade fluorite. A mine in the State furnished the material from which the world's largest, faceted yellow fluorite was cut.

Idaho.--Yellow and blue colored facet-grade opal is recovered from deposits in Custer County.

Maine.--John Sinkankas, in Gemstones of North America Vol. 1, reported that the finest, gem-quality purple apatite in the world was from Mount Apatite in Androscoggin County. Oxford County is the only known location for gem-quality beryllonite, and this location has produced only very small colorless or light yellow stones. Pegmatites in the State have produced colorless and pale yellow herderite crystals from which small gems have been cut. Oxford County deposits have produced colorless, facet-grade phenakite from which small to medium stones have been cut. Small to medium sized, colorless to slightly pinkish stones have been cut from pollucite recovered in Oxford County.

Massachusetts.--Blue or violet colored diaspore crystals of gem-quality large enough to cut small stones have been recovered from the emery mines and mine dumps in Hampden County. Hampden County deposits also produce fine, facet-quality faintly greenish colored datolite.

Montana.--Facet-quality calcite and sphalerite are recovered from deposits in the State.

New Hampshire.--Large pieces of facet-grade, green transparent fluorite, as fine as any found anywhere in the United States is mined from deposits in Cheshire County. Gem-quality herderite and phenakite also are recovered from deposits in the State.

New Jersey.--Although the State is not often thought of as a gem producing State, deposits in New Jersey do furnish a number of collector/specialty stones. Facet-grade, colorless analcine is recovered from the Watchung basalt flows, facet-grade datolite is recovered from basalt flows in Passaic and Bergen Counties as is gem-quality natrolite, and deposits in the State also produce gem-quality epidote. The world famous zinc deposits near Franklin and Ogdensburg in Sussex County produced gem-quality sphalerite, willemite, and zincite.

New Mexico.--The only facet-quality dolomite in the United States is colorless material recovered from a deposit in New Mexico. Gem-quality fluorite is produced from deposits in Bernalillo, Catron, Dona Ana, Grant, Hidalgo, Lincoln, Luna, Rio Arriba, Socorro, Sierra, and Taos Counties. Facet-quality linardite is recovered in Socorro County. The finest, facet-quality moonstone in the United States comes from a deposit in Grant County.

New York.--A few nice-quality stones of actinolite have been marketed from an undisclosed deposit in New York. It is not clear whether the actinolites are from the deposits in St. Lawrence County that produce the fine-quality, purple tremolite. Deposits in the State also produce facet-quality calcite, celestite, chondrodite, diopside, dravite, fluorites, and sphalerites.

North Carolina.--Deposits in Yancy County produce fine-quality, bright blue facet-grade kyanite. These beautiful stones are some of the finest in the world. Deposits in Alexander County produce some of the finest-quality hiddenite in the world. The same deposits produce small amounts of bright red, facet-grade rutile.

Ohio.--Deposits in the State produce fine-quality, facet-grade fluorites, celestites, and sphalerites.

Utah.--Deposits in the Wah Wah Mountains and the Thomas Range Mountains are the only known deposits in the world to produce fine-quality, bright red facet-grade beryl. Deposits in the State also produce facet-grade fluorite, scheelite, and sphalerites.

Other.--Other States are known for the production of certain collector/specialty stones. They include brown barite from Meade County, South Dakota; yellow calcite from Elmwood, Tennessee; actinolite from Vermont; celestite from Maybee, Michigan; and diaspore from Pennsylvania.

Firms that cut and market collector/specialty stones include the following:

Coast-to-Coast Rare Stones
P.O. Box 7467
Nashua, NH 03060

Coast-to-Coast Rare Stones
P.O. Box 188
Martville, NY 13111

Coast-to-Coast Rare Stones
P.O. Box 727
Missoula, MT 59806

Kaufman Enterprises
861 6th Ave. Suite 710
San Diego, CA 92101

K & K International
P.O. Box 8172
Falls Church, VA 22041

Jonte Berlon Gem
P.O. Box 1063
Poway, CA 92074

Feldspar

Of all of the minerals in the Earth's crust, the aluminosilicate, feldspar, is the most common. It is a very useful industrial mineral that finds applications in making glass, plumbing fixtures, tile and pottery. These uses in the United States accounted for about 630,000 ton of U.S. produced feldspar valued at about $27.4 million. It is also a gemstone.

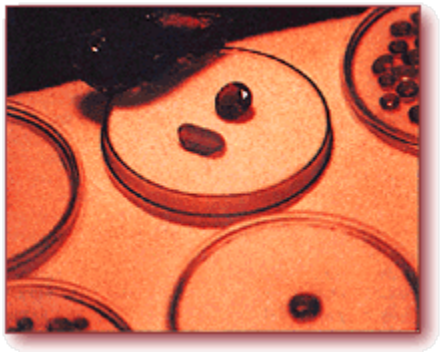

Figure 3. - Oregon sunstone from the Ponderosa Mine.
(Photo is courtesy of Ponderosa Mine.)

Production of gem-quality feldspar in the United States increased rapidly in the past 5 years, declined slightly in 1993, but should continue to increase significantly in the future. Production was valued at more than $0.7 million in 1993. In the United States, gem feldspars are found in igneous, metamorphic, and sedimentary deposits from coast to coast and border to border.

The feldspar group has nine species; there are varieties within some of the species, and there are also intergrowth of species resulting from the unmixing of solid solutions. All of these species, varieties, and intergrowths can be gemstones. Additionally, there are feldspars that have general names because of unique optical phenomena; these are

sunstones and moonstones. Fine, gem-quality feldspar is very rare and some species and varieties are more common as gems than others.

New Mexico.--The quality of the adularia moonstone from Catron County is comparable to the best material from India and Sri Lanka. The best of the New Mexico material is water clear, nearly colorless, with only a hint of a soft-tan or brown tone, and has a wonderful blue or silver sheen. Unfortunately, only about 10% of the moonstone has the more desirable blue adularescence. The deposit has produced eye-clean, blue sheen, faceted stones as large as 5 carats, silver sheen faceted stones of almost 10 carats, and good-grade cabochons of 15 to 20 carats. The deposit is not currently being worked, but the author knows of material that is available from work done in the late 1960's.

Oregon.--The premier U.S. gem-quality feldspar is the red labradorite, known as sunstone, mined in Oregon. Large quantities of gem-quality labradorite, most of it water-clear, straw yellow, or yellow sunstone, has been produced from deposits in southeastern Oregon for many years. In sunstone, the labradorite contains millions of copper platelets that reflects the light with varying intensities resulting in a golden-red play of color known as schiller. Although the common color of Oregon sunstone is straw-yellow, it also can be pink, peach, red, salmon red-orange, red-green, and blue-green. It also can be bicolored and tricolored in combinations of yellow, red, and green, and a small percentage is di- and tri-chroic.

In 1988, the availability and quality of sunstone, other than the standard yellow Oregon variety, drastically increased with the discovery of the deposit that was to become the Ponderosa Mine. The vivid-red faceted stones and velvety-red cabochons from this mine set a new world standard for beauty, not just for red sunstone, but for any sun-stone. The opening of the mine also increased the supply of peach, salmon red-orange, red-green, green, blue-green, and bicolored and tricolored in combinations of yellow, red, and green. For the first time ever, there was a continuous U.S. supply of the more desirable colors in most of the calibrated sizes up to several carats needed by the jewelry industry. The largest faceted high-quality red sunstone is over 10 carats. The supply from this and other developed deposits will continue to be adequate for many years into the future.

Virginia.--The red Oregon sunstone is not the only gem feldspar produced in the United States that sets the world standard for quality. Amazonite from Amelia County, Virginia, also falls in this category. The deep, blue-green, translucent amazonite from the Morefield and Rutherford Mines is the finest in the world. The Morefield Mine is currently operated both as a commercial gemstone mine and as a fee-for-dig mine. The Morefield Mine ensures an adequate supply of high quality amazonite for cabochons, beads, carvings, and spheres. High-quality material from the Morefield is available in pieces over 0.5 kilogram in weight. The Rutherford Mine is open only a single weekend per year on a fee-for-dig basis. Colorado, California, and Montana also have deposits of amazonite. Of these locations, the mineral specimen-quality amazonite from Colorado is the best known.

Others.--There is production of various gem feldspars from other deposits in the United States. Small to medium-sized pieces of light brown bytownite from Arizona and New Mexico can be faceted into 0.5- to 2-carat, eye-clean stones. In addition to the Oregon deposits of faceting-grade labradorite, gem-quality material has been recovered and cut from deposits in California and Nevada. Pale-yellow to colorless andesine is recovered from deposits in north-eastern Idaho. The material is found as eroded crystals more than 5 centimeters in length that can cut stones of more than 10 carats. Other States have reported deposits or finds of gem-quality feldspar. Currently, none of these deposits are commercially mined.

The production of gem-quality feldspar in the United States is increasing, as is the use of U.S. gem feldspar. This increased demand will improve prices for rough and thus provide the incentive for people to spend the time and money to mine the high-quality deposits in the United States. It is only a matter of time until additional deposits are mined on a commercial basis.

Garnet

Garnet, the January birthstone, derived its name from the Latin word granatus, meaning like a grain, which refers to the mode of occurrence wherein crystals resemble grains or seeds embedded in the matrix. Garnet is a family of minerals having similar physical and crystalline properties. They all have the same general chemical formula, $A_3B_2(SiO_4)_3$, where A can be calcium, magnesium, ferrous iron, or manganese, and B can be aluminum, ferric iron, or chromium, or in rare instances, titanium.

The formulas and names of common garnet species are:

Uvarovite:	$Ca_3Cr_2Si_3O_{12}$
Pyrope:	$Mg_3Al_2Si_3O_{12}$
Grossularite:	$Ca_3Al_2Si_3O_{12}$
Almandite:	$Fe_3Al_2Si_3O_{12}$
Andradite:	$Ca_3Fe_2Si_3O_{12}$
Spessartite:	$Mn_3Al_2Si_3O_{12}$

Some rare species of garnet are known that illustrate the wide range of substitution that the garnet crystal structure can accommodate. They include:

Hydrogrossular:	$Ca_3Al_2(SiO_4)_{3-x}(OH)_4$
Henritermierite:	$Ca_3(Mn,Al)(SiO_4)_2(OH)_4$
Goldmanite:	$Ca_3V_2Si_3O_{12}$
Kimzeyite:	$Ca_3(Zr,Ti)_2(Al,Si)_3O_{12}$
Knorringite:	$Mg_3Cr_2Si_3O_{12}$
Majorite:	$Mg_3(Fe,Al,Si,)_2Si_3O_{12}$
Schorlomite:	$Ca_3(Fe,Ti)_2((Si,Ti)O_4)_3$
Yamatoite:	$Mn_3V_2Si_3O_{12}$

There are a number of trade and variety names for garnet, most of these names are for

particular colors of a specie. Hessonite is the variety name for a fine orange, cinnamon brown, or pinkish variety of grossularite, while tsavorite is the trade name for fine dark green grossularite. Melanite is a black titanium bearing variety of andradite and demantoid is a rich green variety. Malaya is a trade name for a pyrope-spessartite that varies in color from red, through shades of orange and brownish orange to peach and pink. Rhodolite is a purplish red pyrope-almandite solid solution garnet. Fine-quality pyrope garnets from Czechoslovakia are often called Bohemian garnets. Almandite and almandite-pyrope solid solution garnets are the best abrasive types, but andradite, grossularite, and pyrope also are used. All species of garnet have been used as gemstones.

Figure 4. Star garnet from Idaho.
(Photo is courtesy of the author.)

Garnet displays the greatest variety of color of any mineral, occurring in every color except blue. For example, grossularite can be colorless, white, gray, yellow, yellowish green, various shades of green, brown, pink, reddish, or black. Andradite garnet can be yellow-green, green, greenish brown, orangy yellow, brown, grayish black or black. Pyrope is commonly purplish red, purplish red, orangy red, crimson, or dark red; and almandite is deep red, brownish red, brownish black or violet-red. Spessartite garnet can be red, reddish orange, orange, yellow-brown, reddish brown, or blackish brown. A few garnets exhibit a color-change phenomenon. They are one color when viewed in natural light and another color when viewed in incandescent light.

The use of garnets as a gem or gemstone can be traced to prehistoric times. However, the first industrial use of garnet appears to have been as coated sandpaper manufactured in the United States by Henry Hudson Barton (founder of Barton Mines Corp.) in 1878. Its use has grown from that single sample of garnet coated sandpaper, to world industrial uses of more than 110,000 tons per year. In 1994, United States production of industrial garnet was valued at about $14 million, while gem garnet production was valued at only about $233,000.

Many deposits within the United States produce fine gem-quality garnets and three deposits are mined for industrial garnet. A State-by-State review is presented below.

Alaska.--Garnets from deposits along the Stikine River, often called "Wrangell garnet" after the nearest town which is located on Wrangell Island, are famous as mineral specimens because of their near perfect crystalline form. The garnets have limited use as gemstones because of their deep red color, however some cabochons are cut from them.

Arizona.--Arizona is one of five States that has commercial production of gem garnets. Arizona's gem garnet is red pyrope from two locations in the extreme northern portion of Apache County on the Navajo Indian Reservation. One location is at Garnet Ridge which is about 8 km west of the town of Mexican Water, and the other location is in Buell Park on the Arizona and New Mexico border, about 16 km north of Fort Defiance. Faceted stones cut from materials from these locations average 1/2 to 1-1/2 carats in size, but stones as large as 5 carats are known from these locations. Additionally, fine-quality andradite specimens, some suitable for cutting, are available from an area near Stanley in Graham Co.

California.--Gem- and specimen-quality white to pale green grossularite garnet occurs on Indian Creek in Siskiyou County and along Traverse Creek near Georgetown in Eldorado County. Other locations for these types of grossularites are the south side of Watts Valley in Fresno County, near Selma in Tulare County, near Big Bar in Butte County and near El Toro in Orange County. Some of the finest quality spessartite garnet known come from pegmatites in San Diego County. Spessartites have been found on Gem Hill near Mesa Grande and in mines in the Rincon and Pala Districts. The most productive area with the finest quality garnets is on the western side of Hatfield Creek Valley near Romona. Near Indian Head Hill in San Diego County is a deposit of fine-quality hessonite garnet, and another deposit is near Dos Cabezas.

Colorado.--Faceting-grade spessartite garnets can be found in the gas cavities in the rhyolite flow on Ruby Mountain near Nathrop, Chaffee County. Large specimen-grade garnets are available at the abandoned Salida Copper Mine.

Connecticut.--Garnet in mica schist near Roxbury and Roxbury Falls in Litchfield County was once mined, although not recently, for use in abrasive applications and for mineral specimens. The andradite garnet was found as well-formed dodecahedral crystals that separate easily from the host schist.

Idaho.--Alluvial deposits of almandite garnet were discovered in the early 1880's near Fernwood in Benewah County, but commercial gem and industrial mining did not start until the early 1940's. The deposits are on Emerald, Carpenter, and Meadow Creeks about 6.4 km from a mica-garnet schist formation. The garnet-bearing gravels are about 1 m to about 1.2 m thick and contain 8% to 15% garnet. These deposits are the basis of the largest industrial garnet mine in the nation and also produce gem garnet. Additionally, star garnets are produced from the placers of Purdue Creek in Latah County.

Idaho's deposits also are the only ones in the world, besides India, that produces significant amounts of star garnets. These almandite garnets are translucent, purplish-red stones that show four- or six-ray stars when cabochon cut, or are transparent, deep red stones that can be faceted. The asterism is the result of silky rutile inclusions.

Gem-quality garnets also are produced commercially from an area of the Little North Fork and North Fork of the Clearwater River in Clearwater County. They range from purplish rose-red to a highly prized "special pink." Gem-quality garnets occur at a

number of other locations in Idaho and are periodically mined by hobbyists or professional collectors for the gemstone market.

Montana. -- Several alluvial deposits of almandite-pyrope garnet are located on the drainages of the Ruby River in Madison County. One such deposit, the Alder Gulch deposit, is in the alluvial fan formed where Alder Gulch joins the Ruby River Valley. The deposit contains about 40 million tons of old placer gold tailings that grade 4.5% almandite-pyrope garnet. The alluvium consists of high-energy, fluvial, well-rounded material, approximately 50% of which is +9 mm in size. The source of garnet along the Ruby River is highly metamorphosed Archean rocks in the Tobacco Root and Greenhom Mountain Ranges to the east. The garnets are present mostly as broken fragments of crystals which were originally as much as several centimeters in diameter. Some of the garnets from this industrial garnet deposit are of gem quality.

Bright red and orange red, to reddish-pink pyrope-almandite garnets are found associated with sapphires in the gravels of the Missouri River near Helena in Lewis and Clark County.

Nevada.--An alluvial deposit of almandite garnet is found along Hampton Creek Canyon in White Pine County about 3 km from the mouth of the canyon. No production history is available for the deposit. The source of the garnet is quartz-garnet-mica-staurolite schist that forms a portion of the walls of the canyon.

Spessartine garnets can be found at several locations in White Pine County. Most of the dark brown crystals are of interest only as specimen, but a few will cut very small clear stones.

New Hampshire.--A garnet deposit is located near North Wilmont in Merrimack County, where small alrnandite crystals are found in a biotite, quartz, and albite feldspar matrix. The crystals range up to about 19 mm in diameter but average only 6 to 10 mm in diameter.

New York.--Deposits of industrial garnet are found at two locations in New York. In the Gore Mountain area, industrial garnet is mined as the primary product; and near the town of Willsboro, byproduct of it is recovered as wollastonite mining.

The deposit near Gore Mountain is an almandite-bearing diorite of uncertain, igneous or metamorphic origin. The garnet is present as imperfectly developed crystals surrounded by a rim of coarsely crystalline hornblende. The crystals range from about 1 millimeter to almost 1 meter in diameter but average about 100 millimeters in diameter. The garnet has a pronounced laminated structure, which enables it to naturally break into thin plates from about 2 to 6 millimeters in thickness. Garnet fragments maintain this platy particle shape even as they are crushed smaller and smaller.

These same deposits in Warren County contain good to fine quality facet-grade garnets. The garnet is a solid solution of pyrope-almandite-grossularite that results in a pleasant

deep brownish-red material which often has an orange cast. Beautiful small stones can be cut, but larger stones are too dark to be attractive.

North Carolina.--Large deposits of almandite and rhodolite garnet of gem and abrasive quality are known in Clay, Jackson, Macon, Madison, and Burke Counties. Abrasive-grade garnet was produced from some of these deposits from 1900 to about 1926, but no production has been recorded recently. The deposit of almandite garnet in Clay County is in a hornblende gneiss at Penland Bald on Buck Creek.

Fine red colored, gem-quality pyrope garnets have been found in the wastes from placer gold operations in Burke, McDowell, and Alexander Counties. Rose-pink rhodolite garnets are recovered from gravels in Cowee Creek near Franklin, and Mason's Branch near Iotla, both in Macon County. Rhodolite can be found in situ on Mason Mountain.

Pennsylvania.--Almandite garnet crystals are found in a quartzose mica schist about 1.6 km west of Chelsea in Delaware County. Near the surface the schist is badly weathered and the garnets, which comprise as much as 75% of the rock locally but average much less, are easily recovered. Abrasive-grade garnet was produced from this deposit prior to 1900, but no production has been recorded since the turn of the century.

Small trapezohedral crystals of almandite garnet are scattered through-out a badly decomposed gneiss near Chester Heights, also in Delaware County. An attempt was made to mine this deposit years ago by means of a shaft and underground workings.

Utah.--Large specimen-grade, apple-green grossularite garnets have been found in western Beaver County. Two locations southeast of Mexican Hat, San Juan County produce pyrope garnets similar to the bright red pyropes from Arizona and New Mexico.

Virginia.--A deposit of garnet is located on a steep bluff on the northeast side of the Tyle River about 6.5 km south of Arrington in Nelson County. The small, dull-red garnets are found in a sericitic schist. Attempts were made to mine the deposit in the past, but there is no record of commercial production.

Two mines in Amelia County account for the majority of the production of gem-quality garnet, they are the Morefield and Rutherford. The spessartine from these mines, primarily the Rutherford, are etched-crystal masses and fragments, not individual perfect crystals. The pieces range from pea size to as large as a grapefruit. In 1991, a single piece, dubbed the Rutherford Lady, was found that weighed more than 2,800 carats. Color varies from a fantastic light pure orange, almost yellow to shades of red-orange, red, and brownish-red, but the orange overtone always is present.

U.S. production of gem-grade garnet will continue to increase and additional deposits will be brought into production in the coming years.

Opal

Figure 5 -- Contra luz opal from Oregon.
(Photo is courtesy of Kevin Lane Smith.)

Opal is brittle, heat sensitive, and breaks and scratches easily; additionally, some varieties self- destruct through the loss of water. Even with these drawbacks, opal's unsurpassed beauty guarantees its status as a premier gemstone. The derivation of its name even adds to its position. Reportedly, opal's name evolved from the Roman word *opalus* from the Greek word *opallios* meaning "to see a change of color." The Greek word was a modification of the ancient Indian Sanskrit name for opal, *upala*, which meant "precious stone." If one spoke in mixed tongues, then opal would be *opallios upala*, "to see a change of color precious stone."

As indicated by the derivation of its name, opal has centuries of history as a treasured gemstone. Historically, beliefs associated with the wearing of opal have varied. The early Greeks thought that opals gave their owners the powers of foresight and prophecy, and the Romans adored it as a token of hope and purity. Eastern people regarded it as sacred, and Arabs believed it fell from heaven. In the nineteenth century, superstitions grew about the bad luck or fate that could befall one for wearing opal if it were not the wearer's birthstone. Today, these superstitions have diminished, but some people still believe it is bad luck to wear opals.

Opal has over one hundred variety and trade names, but the list of accepted or commonly used names is much shorter. The most important and most widely known opal is the precious opal. Precious opal may be subdivided further by color modifiers, white, black, pinks, and blue, which describe the body color of the opal. Australia is famous for its white and black precious opal. Fire opal, the bright red, reddish-yellow, orange, or brownish-red body colored opal is the second most important opal commercially. Until recently, the best fire opal came from Mexico.

Arizona.--Two commercial mining operations in Arizona produce blue precious opal. The body color is a light or pale blue with strong play of color in red, blue, green, and

orange. The two operations sell most of its material as finished stones at the Tucson Gem and Mineral show and other local gem shows.

Idaho.--In Idaho, opal is the second largest contributor to the total value of gem material produced. The varieties produced include precious (white and pink), yellow, blue, pink, and common. The Spencer opal mine, the largest privately owned gem stone producer in the State, is the major producer of opal. At Spencer the precious opal occurs as one or more thin layers within common opal partially filling gas cavities within a rhyolite-obsidian flow. About 10% of the material is thick enough to cut into solid gems; the remainder is fashioned into doublets and triplets. The Spencer Mine is the source of pink common opal and pink precious opal.

Louisiana.--The reported precious opal from Louisiana is a sandstone/quartzite with precious opal cement and matrix. It has blue or purple play of color. The material could be cut into cabochons for jewelry and other items of interest. To date, most of the material has been cut into large (over 2-inches in diameter) gemstone spheres.

Nevada.--Nevada is known for precious opal from Virgin Valley. The first discovery of precious opal in the Virgin Valley area was in 1905 or 1906. Since then a significant quantity of the highly prized opal has been recovered. Virgin Valley opal is comparable to any in the world for its vivid play of color and in terms of the size of material available. Individual pieces weighing over 3 kilograms have been recovered from the Virgin Valley deposits. In 1993, miners found a 100-kilogram opalized log containing precious opal. The material varies in body color from deep pure black to brown to yellowish-white to white to colorless. The play of color includes all colors common to precious opal, red, blue, green, yellow, orange, etc. The opal occurs primarily as replacement of wood, or sometimes, as replacement of conifer cones. Some opal does occur as nodules filling void spaces in clay. The wood replacement is so complete, that generally the wood grain and banding are no longer visible. The exception to this would be that often the exterior wood texture is still present as a brown or black rind.

The uses of the opal can be restricted because of crazing. Crazing is the breakdown or deterioration of opal by the development of very fine cracks all over the surface that extend until they intersect. In the worst cases, the surface of the opal deteriorates into a crumbling sand-like material. Because of the crazing the opal is not well suited for use in jewelry, but displayed in water, glycerine, mineral oil or other liquids makes remarkably beautiful mineral specimens. The mineral collections of most of the better museums contain very fine pieces of Virgin Valley opal. Many museum pieces are crazed from exposure to the air.

During the summer months, at least two dig for fee mines in Virgin Valley are open to individuals. One mine is operated by the Hodson family and the other by the Wilson family. Individuals pay a daily fee to dig and keep all the opal that they find. Other mines in the area are commercial opal producers.

Two other locations in Nevada also have produced precious opal. The opal does not have as good a play of color as that from Virgin Valley and it has the same crazing problem. One location is south of the Virgin Valley in the Calico Mountains of Humboldt County, and the other is near Gabbs in Nye County. The three precious opal locations and many other locations around the State produce common opal and opalized wood.

Oregon.--During 1988, West Coast Gemstones, Inc., began mining and marketing a variety of very fine-quality opals from Opal Butte in Morrow County, OR. The varieties produced includes hyalite, rainbow, contra luz, hydrophane, crystal, fire, blue, and dendritic. Exquisite stones as large as 315 carats have been cut from contra luz rough from this deposit.

The deposit at Opal Butte has been known since the late 1800's. It was of interest only to hobbyists until recently because people believed most of the opal was unstable. Stability can be a problem with the opal, crazing can occur when stresses are created from shrinkage due to water loss. West Coast has developed methods of drying the opal that greatly reduce crazing. Even with the drying procedures, the stability varies from 20% to 90% depending upon the variety.

The opals are found in rhyolite geodes (thundereggs) in a perlite that has altered to a pastel colored clay. The geodes that contain gem-quality opal are only about 10% of the total geodes mined and only about 1% of the geodes contain gem-quality opal with play of color. The remaining geodes contain agate, quartz crystals, or common opal. The geodes vary greatly in size, from a few centimeters in diameter to over a meter.

The deposit continues to produce a supply of very fine quality opal for cutting and carving. Currently, a company has launched an American gemstone jewelry line based on the Opal Butte's opal. Plans are to operate the mine for at least the next 5 years.

Pearls

Native Americans of the Atlantic Coastal areas and the Mississippi River Basin were the first to collect and use U.S. freshwater mussel pearls and shells. Pearl pendants and ear pendants were worn by both sexes and both pearl and shell were used for decorative purposes on articles of clothing. Some of the tribes used pearls as tributes, reportedly Powhattan (Pocahontas' father) had large stores of pearls received as tribute. Additionally, armlets, pendants, and gaming pieces were made from mussel shell.

Natural freshwater pearls are seldom perfectly round or even nearly round, more often than not they are baroque, slugs, or wings. Many pearls, both natural and cultured, have beautiful color and luster. Freshwater pearls are noted for their wide range of color, they can be found in white, silvery white, pink, salmon, red, copper, bronze, brown, lavender, purple, green, blue, cream, and yellow. Although white is the most common color, the

most desirable are the pastel pinks, roses, lavenders, and purples. The different colors are a function of the mussel species, genetics, water quality, and the position of the pearl in the shell. Generally, pearls assume the color of the shell in which they form. Problems can arise in putting together matched strands because of the wide range of pastel colors.

The shape of the nucleus and its position in the mussel determines the shape of the cultured pearl. The shapes recovered include rounds, pears, eggs, drops, buttons, domme, and baroques. In turn, the baroques include many recognized shapes such as, nuggets, dog tooths, wings, hammers, twins, barrels round-a-circle, and rosebuds. The baroques are becoming popular for use in the manufacture of rings, earrings, and pendants. Cultured pearls come in all of the same colors as natural pearls.

Freshwater shell and pearl mussels are from the family Unionidae, from which about 20 different species are commercially harvested. The common names of the most prolific species include the ebony, washboard, heelsplitter, pimple back, elephant ear, mapleleaf, three-ridge pigtoe, pistol grip, and butterfly. Peak commercial fishing is from April through September, when hundreds of independent divers operate in the rivers, streams, and lakes of the Eastern, Southern, and Central United States.

The fishing and marketing of freshwater pearls and mussel shells by other than Native Americans has a long history in the United States, with the earliest recorded production probably coming from New Jersey. The formal freshwater mussel fishing industry has been established since the mid-1850’s.

A very profitable fishery supported a large shell button industry until World War II when plastic buttons displaced shell buttons. The fishery fell into disorganization and was dormant until the early 1950's. The mother of pearl industry and bead nucleus for the Japanese culture pearl industry have supported the fishery since the 1950's. During the 1990's, the value of U.S. mussel shell exports to Japan started at more than $50 million annually but has declined to about $35 million annually. Prior to 1992, freshwater pearls were primarily a byproduct of the shell industry. This changed with the coming of freshwater cultured pearl farms in Tennessee and California, and the increasing popularity of freshwater pearl jewelry with the U.S. consumers.

The first experimental U.S. freshwater cultured pearl farm was established in Tennessee by John Latendresse in 1963. Latendresse is the father of U.S. cultured freshwater pearls, having spent nearly 30 years and more time, money, and effort than anyone else in the research and development of the industry. Since proving the technology for culturing freshwater pearls in the late 1970's, Mr. Latendresse has established five freshwater pearl farms. James Peach, who once worked with Latendresse, has established a single farm. Additionally, a single farm has been established in California using mussels from the Southeastern United States. These farms are the foundation of the U.S. freshwater cultured pearl industry, and the cultured pearl is the heart and future of the U.S. pearl industry.

The ultimate size of the cultured pearl industry depends on a number of factors. The acreage of pollution free water available that is suitable for farms could decide the size of the industry. Yet, even before the limitation of available suitable water comes into play, two main factors, demand for cultured freshwater pearls and the supply, or the ability of the producers to meet this demand with acceptable goods routinely, will decide the future of the industry. Some individuals have already likened these two factors to the chicken and egg question; does the demand for the pearls come first, or does the adequate supply of acceptable goods come first. Indications are that both factors are currently complementing each other, and they are contributing to the healthy growth of the young industry.

Demand for U.S. freshwater pearls is a function of quality. Quality is determined by the size, color, shape, degree of translucency, texture, ability to match and blend, and luster. Usually, the quality of U.S. freshwater pearls is as good or better than any other pearl. The possible exceptions are the availability of round pearls and the ability to match colors. Yet, it is thought by some that these exceptions are not detrimental, but that the variety of shapes and colors available are advantageous and are positive selling points.

To date, 31 different States have reported production of freshwater pearls and shell. During 1993, 18 States reported production, they were Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, and Wisconsin. The bulk of the shell and pearl production came from Tennessee, Arkansas, Alabama, and Louisiana.

Figure 6.--Freshwater, Pearls from Tennessee.
(Photo is courtesy of American Pearl Co.)

There is some U.S. production of saltwater pearls. Abalone from along the Pacific Coast, primarily California, produce both blister and free pearls and their shells are used for inlay in jewelry and other items. The pearls are green, blue-green, yellow, or pink in color and may have high luster, but the texture is always coarser than that of other pearls. Some of the pearls are very large, as large as 60 carats each.

To date, all of the abalone pearls have been natural, but a move is underway to culture pearls in the farms where abalone are raised for their meat. Many of the abalone farmers

are afraid of losing animals because of the culturing and have not entered the program. Possibly, in the near future an abalone cultured pearl industry may become a reality.

It also appears that attempts are underway to start a saltwater cultured pearl industry in Hawaii. The Hawaiian industry would be based upon saltwater oysters. Only time will tell of the success or failure of the abalone and Hawaiian cultured pearl programs.

It appears that the U.S. freshwater shell and pearl industries are well and growing. The pearls are beautiful, valuable, and the consumer is willing to purchase and wear them. The oldest of U.S. gemstones is doing well and its future is bright.

Peridot

Figure 7.--Peridot from the San Carlos Apache reservation in Arizona. (Photo is courtesy of ICA/Bart Curren.)

Peridot is the best known gem variety of olivine, a species name for a series of magnesium-iron rich silicate minerals. This bright yellow-green to green gemstone has caught the fancy of humans for thousands of years. Some historians even suspect that at least some of the "emeralds" worn by Cleopatra were actually peridot. Much of its recent popularity can be explained by its currently being recognized as the birthstone for the month of August, people wear the stone because it is supposed to bring the wearer success, peace, and good luck.

The United States was for many years the largest producer of peridot, the value of production in 1993 was estimated to be about $1.5 million, according to the USBM. The United States is getting major Competition from China and Pakistan for the title of world's largest producer.

The earliest recorded production of peridot was in about 70 A.D. from St. Johns Island in the Red Sea, about 54 kilometers off the coast of Egypt. Most of the earliest known peridot gems came from this location and small amounts of material are still being produced from there today. Later, very large, fine-quality peridot was produced from deposits in Myanmar (formerly Burma). These deposits were well known for their 20- to

40-carat cut stones of superb color and clarity, but since the socialist government came to power, the supply of Burmese peridot has been curtailed to such a point as to no longer be a factor in the industry. One can only guess as to whether the deposits are mined out, or if government policies have resulted in the shortage of material.

Arizona.--Currently, the United States is the basic suppler of peridot to the world gemstone industry. Deposits in Arizona are the major source of U.S. peridot. Faceted Arizona peridot is highly prized locally, but also enjoys widespread popularity for the manufacture of birthstone and other jewelry. The bright green, yellow-green to olive-green peridot is used both as a faceted and tumbled gem. The faceted stones are used in rings, earrings, pendants, bracelets, and as accent stones. The tumbled gems can be set in baroque jewelry, drilled and strung as beads, used in mosaics, and in the manufacture of gem trees.

Peridot Mesa, located on the San Carlos Apache Indian Reservation east of Globe in Gila County, is the most productive locality for peridot in the world. A second Arizona location from which peridot is recovered is Buell Park Apache County, Arizona, about 16 kilometers north of Fort Defiance. However, it is estimated that 80% to 95% of the world's production of peridot comes from the San Carlos Reservation.

The peridot occurs as individual grains and aggregates of grains in a basalt which is about 3 to 35 meters thick that forms the top and sides of Peridot Mesa. The material is recovered after it has weathered out of the basalt, in the gullies and canyons which lead down the sides of the Mesa or it is recovered in place in the basalt. The latter method of recovery requires drilling and blasting. The peridot grains that are commercially recovered are typically 6 to 13 millimeters in size. Therefore, the faceted stones produced from this material are generally about 1 carat in size; 2 to 3 carat stones are not uncommon, but stones, particularly flawless ones, 5 carats and over are unusual. Stones as large as 15 and 22 carats have been cut from San Carlos peridot.

On the Reservation, peridot can be mined only by individual Native Americans or by individual families of Native Americans from the San Carlos Reservation. In the past, the miners have not marketed the peridot directly to the gemstone industry. They marketed the material in random size lots, from as small as a coffee can full to as much as a 55-gallon barrel full, to local brokers or mineral dealers. These local brokers/dealers may or may not sort and grade the material, but they do tend to market to the industry in uniform size lots. Currently, some of the large volume miners are marketing the material directly to the industry and are also contracting for cutting services and are marketing cut stones.

New Mexico.--Gem-quality peridot can be found in deposits at three different locations in New Mexico. The deposits are in the Buell Park area in McKinley County in the northwestern part of the State and in Kilbourne Hole and Potrillo Mar depression, both near the Mexican border in the southeastern part of the State. The color of the material is brown, greenish-brown, yellowish-green, and the desirable peridot green. Some people believe the material from the Kilbourne Hole area is superior to the material from the famous Arizona location on the San Carlos Reservation. Currently, there is no

commercial production of material from any of the deposits in New Mexico, but "rockhounds" and other mineral collectors gather materials from these locations for their own use.

Quartz

Rock crystal quartz, the most common gem variety of quartz crystal, is, like all quartz, formed from the two most abundant elements in the earth's crust: silicon and oxygen. For centuries early civilizations believed that these pinhead size to nearly a meter in diameter rock crystals were permanently frozen ice. Quartz's high thermo-conductivity, which makes it feel cool to the touch, may have added to this belief. Regardless of what early people may have believed, historical records show the use of rock crystal for decoration and jewelry for at least 4,000 years. Tools and weapons were made from rock crystal long before it was used for decoration and jewelry.

During the late 1980's and early 1990's, metaphysical uses and applications of rock crystal resulted in an increase in its production and processing. The metaphysical market used raw crystal in jewelry, person power and healing devices, and as charms. Additionally, spheres, sculls, pyramids, and other metaphysical objects were made from rock crystal. During the height of the trend, these uses accounted for 40% or more of the rock crystal consumed in the United States and also resulted in price increases for most of the crystals. Today, the metaphysical market has declined from its peak and appears to have stabilized at about 15% to 20% of total rock crystal consumption.

The market for rock crystal carvings, objects of art, and spheres is still strong. One piece of evidence of the demand for quality rock crystal for these types of uses is the level of sales of high quality quartz crystals from the National Defense Stockpile (NDS). During fiscal year 1994, sales of quartz crystals from the NDS totaled 313.1 metric tons valued at about $6.3 million, of this total, 96.8 metric tons valued at $3.21 million were sold during 6 days of the Tucson Gem and Mineral Show in February. During fiscal year 1993, NDS sold 176.8 metric tons of quartz valued at $1.64 million.

A gem dealer who purchased NDS quartz in Tucson shared the following information with the author: A 3,412 gram piece of quartz was purchased for about $120. The purchaser blocked out a totally flawless piece that was sent to a U.S. sphere cutting operation to be made into a flawless sphere. The sphere factory charged $48 to cut and polish a high-quality 84 millimeter, 844 gram sphere. The dealer sold the finished sphere for $1,200. This is only one dealers reported success in using NDS rock crystal and may not represent the outcome of any of the other NDS quartz sales.

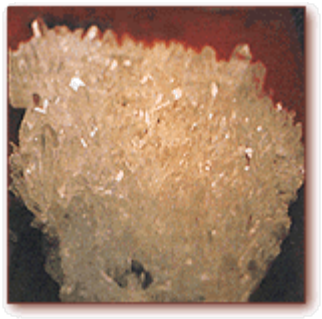

Figure 8.--Rock crystal from Arkansas.
(Photo is courtesy of the author.)

Arkansas.--To many in the gemstone industry, Arkansas and rock crystal quartz are synonymous. Mount Ida, Fisher Mountain, Hot Springs, and Jessieville names mean quartz crystals to many people, but in fact, they are towns or places in the Arkansas quartz belt. Not only is Arkansas the major producer of gemstone and decorative rock crystal but it is the only producer of "lascas" the feed material used to make synthetic quartz.

The rock crystals are produced from quartz veins in sandstones and shales of the central part of the Ouachita Mountains. The quartz belt is about 240 kilometers long and 24 kilometers wide, extending southwest from near Little Rock all the way to northern Oklahoma. The crystals are beautifully formed with lustrous faces, many have water clear, colorless terminations. Commonly, they are milky in appearance because of inclusions. On large plates of crystals the crystals are often short and stubby, but in smaller crystals it is not unusual for them to have a length that are at least 6 times their diameter. Many of these slender points are used as "gem points" in making earrings and pendants.

Historically, the demand for crystals was from tourists, collectors, interior decorators, carvers, sphere makers, and certain industrial and military applications. However, in recent years the increased use of quartz crystals in the metaphysical field has greatly impacted the demand and price for Arkansas quartz. Another market for the crystals is as feed material to be irradiated to produce smoky quartz. Most smoky quartz from Arkansas is not natural, but is irradiated rock crystal. Although its not the only U.S. producer of rock crystals, Arkansas is by far the largest, its quartz crystal mining industry is measured in millions of dollars per year.

California.--Deposits in California are another source of significant amounts of quality rock crystal. For many years cobbles and round crystals have been found in streambeds in Amador and Calveras Counties. The best quality, largest, and most abundant crystals come from ancient stream channels in the Mokelumne Hill area of Calveras County. Over the years, various mines in the area have produced thousands of kilograms of rock crystal, with some of the individual crystals weighing as much as 275 kilograms and many of the crystals measuring more than 600 millimeters in length and 250 millimeters in diameter. The American Museum of Natural History has a 150 millimeter sphere cut from a Mokelumne Hill rock crystal. Additionally, the pegmatites of Hiriart Hill, San

Diego County, have produced hundreds of kilograms of fine-quality rock crystal from which a number of 60 to 90 millimeter spheres have been cut.

New York.--Herkimer County, NY, is nearly as famous for its rock crystals as is Arkansas. The most productive area for "Herkimer diamonds", as the well-formed, mostly doubly-terminated rock crystals are known, is the rock outcrops and associated soils in a belt between the towns of Middleville and Herkimer, NY. The belt extends about 5 km south of Middleville. At least two other areas in the Middleville area also produce "Herkimers." Most mineral collectors feel their collection is incomplete without at least one Herkimer. The crystals are faceted, raw crystals are mounted to be used as pendants and earrings, and crystals are even bored to be strung as beads.

Currently, the crystals are not mined commercially but are collected by hobbyist and professional collectors. The crystals are found loose in the soil where they have weathered from the underlying rock or they are taken from cavities in freshly broken rock. The cavities maybe so small as to contain only a single 4 to 5 millimeter crystal or large enough to contain hundreds of crystals with some of the crystals over 100 millimeters in diameter. The smaller crystals, 4 to 12 millimeters, tend to be the best and some of the crystals contain inclusions of carbonaceous material and liquid- or gas-filled voids.

Others.--Arizona, Colorado, Idaho, Georgia, Montana, Nevada, North Carolina, South Carolina, and Washington all produce some rock crystal each year. Most of the material ends up in mineral collections, but some are cut into stones for jewelry and a small amount is used for carving. The market for large, fine-quality rock crystals appears to be strong and every indication is that the strong demand will continue, because of the increased demand for carvings.

Sapphires

Figure 9. -- Sapphire from the Missouri River in Montana.
(Photo is courtesy of Robert Weldon.)

The production of gem-quality sapphires in the United States is not new or recent. In 1865, the first U.S. sapphires were found in the gravels of the Missouri River in Lewis

and Clark County, Montana. This was followed by subsequent discoveries on Dry Cottonwood Creek in Deer Lodge County in 1889, on Rock Creek in Granite County in 1892, and in Yogo Gulch in Judith Basin County in 1895. Additionally, small amounts of sapphire are recovered from Quartz Gulch in Granite County, Pole Creek in Madison County, the Missouri River in Chouteau County, and Brown's Gulch in Silver Bow County. Furthermore, corundum crystals, from which star sapphires have been cut, are found in Beaverhead and Madison Counties. Also, in 1895, the first sapphires were produced from the Cowee Valley in Macon County, North Carolina. But until very recently, with the exception of Yogo Gulch material, the commercial gemstone industry has had limited interest in U.S. sapphires.

Montana.--Mining of Yogo Gulch sapphires began within a year of their discovery in 1895 and continued for 39 years. In 1923, the mine was damaged so badly by rain that it could not economically recover. Other attempts have been made to commercially mine the deposit, but to date, all of these attempts have ended in economic failure.

Yogo's are unique among the world's sapphires. They lack the color zoning so prevalent in other sapphires, their uniform "corn-flower blue" color is natural (not the result of heat-treating), and their clarity is uniformly high. These features rank them among the world's finest sapphires. Unfortunately, the rough is both small and flat, wafer-like in shape. The majority of the crystals or pieces of crystals recovered are too small to be cut, most are less than 1 carat and finds of over 2 carats are rare. Reportedly, the largest crystal was a 19 carat stone found in 1910 that was cut into an 8-carat stone. The size of the cut stones greatly restrict the market for Yogo's, they are beautiful, small, very expensive sapphires.

Currently, Yogo sapphires are produced from three sources: Rancor lnc., produces material from the original Yogo Gulch deposit; Vortex Mining produces from a recently discovered extension of the Yogo dike; and material is produced by individuals from privately owned lots in Sapphire Village. The first two producers market only cut stones and finished goods and the third is comprised essentially of hobbyists.

Historically, the amount of sapphires produced from the Missouri River and Rock Creek areas greatly exceeded that from Yogo Gulch. However, the value of the material produced from Yogo, reported to be in excess of $30 million, is significantly greater than that of the combined values of the other areas. This relationship is rapidly changing.

The combination of large volume commercial operations on the Missouri River, and to some extent Rock Creek, plus the advent of successful heat-treating techniques for the material has greatly enhanced the acceptance of these sapphires by the gemstone industry. This enhanced acceptance has resulted in a significant increase in the market for and value of U.S. sapphires. Unconfirmed reports have circulated that a parcel of select 3- to 10-carat material, suitable for heat-treating, was sold for as much as $40,000 per kilogram. A more realistic price for 3- to 10-carat, sorted mine-run material is in the range of $5,000 per kilogram, with many kilograms of mine-run rough selling for $1,000 per kilogram.

The sapphires from the Missouri River gravels in Lewis and Clark County are a mixture of rough and pitted crystals showing well defined faces and completely rounded and smooth-surface highly stream worn pebbles. The majority of the material is pale blue or blue-green, with deep blue stones quite rare. Stones also are found in pastel blue, green, pink, pale red, purple, yellow, and orange. Most of the stones recovered are less than 6.4 millimeters in diameter, but material 6.4 to 12.7 millimeters in diameter are not uncommon. Material greater than 12.7 millimeters in diameter is rare.

Currently there are seven operations on the Missouri River that commercially produce sapphires and/or operate a dig-for-fee area. Not all of these may be active in any one year. It is the author's understanding that one operation, currently inactive, (a self-propelled floating 16-inch suction dredge) is for sale. The mines operate from about the last week of May through the first week of September.

The Rock Creek sapphires are very similar to the sapphires from the Missouri River but differ in the general shape of the crystals. The stones are basically crude hexagonal plates about the same dimension in width and height, with a much higher percentage of the material being well rounded water worn pebbles. There appears to be more of the larger sized (greater than 12.7 millimeters) material. Additionally, it is reported that the Rock Creek material has a greater percentage of stones that can be heat-treated for color enhancement.

During the past several years, there has been only a single producer on Rock Creek. The producer operated both a commercial recovery plant and a fee recovery area. The fee recovery area sold buckets of gravel for washing and also offered, for a predetermined fixed fee, the output of one day's operation of the commercial wash plant. There is work underway which would result in a second, much larger producer, opening an operation on another deposit in the area. If things go as planned, the new operation on Rock Creek would be the largest sapphire producer in Montana.

There are a number of locations between Dillon in Beaverhead County and Ennis in Madison County that produce lavender, grayish-lavender, bluish-gray, and gray hexagonal sapphire crystals that, when cut, produce stones that contain four- or six-ray stars. At least one producer from the Dillon area is currently advertising the availability of this type of material. The remainder of the sapphire deposits in Montana appear to be operated by individual hobbyists.

More should be said about the effects of heat-treating techniques on Montana sapphires, and the variety of fancy colored sapphires available. Not all Montana sapphires are suitable for heat- treating because of variations in chemical composition. Also, the sapphires from the Missouri River respond to heat-treating differently than those from Rock Creek The response to heat-treating can vary also depending upon the method (individual) used to treat the sapphires.

The yield on treatment of Missouri River sapphires is lower than for Rock Creek. It is reported that 20% to 30% of Missouri River sapphires heat-treat from deep, well

saturated blue to pale, pale blue. The corresponding treatment rate for Rock Creek material is in the range of 60%. Heat-treating also yields or improves the color of fancy colored sapphires. Bright yellows and oranges are the result of heat-treating, whereas heat-treating improves the color of some pinks by removing colors that can interfere with the desirable pink shades. Montana sapphires can be diffusion treated, but because of their high iron content they are not particularly well suited for this form of enhancement.

North Carolina.--North Carolina is well known for its hobbyist production of sapphire. Sapphire have been produced from the Cowee Valley in Macon County since 1895 when the American Prospecting and Mining Co. systematically mined and washed the gravels of Cowee Creek. Today a number of dig-for-fee operations are located in the Cowee Valley. Each year many people pay to dig or purchase buckets of gravel to wash in hopes of finding a sapphire, garnets, and other gem materials. Many of the dig-for-fee operations have enriched the gravels with gem materials from other locations.

Every year articles appear in magazines and newspapers about large and valuable sapphires found at one or more of the mines in Cowee Valley. No doubt large corundum crystals and pieces of corundum are found each year. By the same token, valuable sapphires may be found, but the number of large valuable gemstones are far less than reported, and the values are generally not as great as reported. During the period when the area was commercially mined, gem material was found that would cut fine quality 3- to 4-carat stones, but the amount of quality gem material available has greatly declined. It is doubtful that North Carolina will ever again boast of commercial sapphire production, or that the commercial gemstone industry will seriously consider the State's sapphire deposits.

Synthetic and Simulant

Synthetic and simulant are terminology used by the USBM for laboratory grown gemstones. Others in the gemstones industry may use different terms to refer to laboratory grown gemstones. Laboratory grown synthetic gemstones have essentially the same appearance and optical, physical, and chemical properties as the natural material that they represent. Synthetic gemstones produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Laboratory grown simulants have an appearance similar to that of a natural gemstone but have different optical, physical, and chemical properties. The gemstone simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gemstones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced.

In the past few years, the use and consumer acceptance of synthetic and simulant gemstones have grown. Much of this growth is the direct result of the recognition of these

gemstones for their own merits, not just as inexpensive substitutes for natural gemstones. In 1993, the reported value of production of U.S. synthetic and simulant materials was $17.9 million, about a 5% decrease from that of 1992, according to the USBM. Since the USBM began collecting data on the value of production of synthetic and simulant gemstones in 1986, the U.S. production has averaged about $17.0 million per year, with a low of $10.3 million in 1986 and a high of $20.5 million in 1990. During the past 5 years, the annual value of production has averaged $18.8 million with annual increases or decreases from 5% to 13%.

Figure 10. -- Synthetic ruby.
(Photo is courtesy of J.O. Crystals.)

Synthetic and simulant gemstone producers use many different production methods, but they can be grouped into one of three types of processes: melt growth, solution growth, or extremely high-temperature, high-pressure growth.

The year 1902 saw the first production of synthetic ruby using the Verneuil flame-fusion process. Later, sapphire, spinel, rutile, and strontium titanate were grown with this technique. In this process, a single crystal, called a boule, forms in the flame of a simple, downward-impinging oxygen-hydrogen blowtorch. Pure oxides of aluminum (in the cases of ruby, sapphire, and spinel) or titanium (rutile and strontium titanate) are poured into the top of a small furnace and melted. Other oxides are added as needed for process control and to obtain the specific color desired. The melted material solidifies as a boule on a rotating fire-clay peg as the peg is slowly withdrawn. A boule has a very characteristic shape, with a rounded end, a long cylindrical body, and a tapering end. It is usually about 13 to 25 millimeters in diameter, 50 to 100 millimeters long, and weighs 75 to 250 carats.

Another melt technique is the Bridgman-Stockbarge solidification method, named for an American, P.W. Bridgman, and a German, D.C. Stockbarge, who, aided by three Russians, J. Obreimov, G. Tammann, and L. Shubnikov, discovered and perfected the process between 1924 and 1936. Currently, the method is used primarily for growing nongem halide, sulfide, and various metallic oxide crystals, one of the metallic oxides being aluminum oxide or sapphire.

The Bridgman-Stockbarge process uses a specially shaped crucible, which is a cylindrical tube open at one end and capped at the other by a small, pointed cone. The crucible is filled with the powdered chemicals necessary to grow a specific crystal and is lowered slowly through a furnace. The small, pointed end of the cone cools first because it is the first part of the crucible that moves from the hottest part of the furnace into cooler regions and it is the first part to emerge from the furnace. As the crucible cools, the molten materials solidify, hopefully in a single crystal, in the point of the crucible. The crystal then acts as a seed around which the remainder of the molten material solidifies until the entire melt has frozen, filling the container with a single crystal.

This process is simple, and crystals of various sizes can be grown. The crystals are typically about 50 millimeters in diameter and 15 millimeters in length, but large ones exceeding 890 millimeters in diameter and weighing more than 1,000 kilograms have been grown. The crystals have the same shape as the crucible.

The Czochralski pulled-growth method is used for ruby, sapphire, spinel, yttrium-aluminum-garnet (YAG), gadolinium-gallium-garnet (GGG), and alexandrite. Czochralski developed his method in about 1917.

In the Czochralski method, ingredient powders--nutrients--are melted in a platinum, iridium, graphite, or ceramic crucible. A seed crystal is attached to one end of a rotating rod, the rod is lowered into the crucible until the seed just touches the melt, and then the rod is slowly withdrawn. The crystal grows as the seed pulls materials from the melt, and the material cools and solidifies. Yet, because of surface tension of the melt, the growing crystal stays in contact with the molten material and continues to grow until the melt is depleted.

Typically, the seed is pulled from the melt at a rate of 1 to 100 millimeters per hour. Crystals grown using this method can be very large, more than 50 millimeters in diameter and 1 meter in length, and of very high purity. Each year producers using this method grow millions of carats of crystals.

Certain gemstones pose unique problems when attempts are made to grow them. The problems arise because certain materials are either so reactive that they cannot be melted even in unreactive platinum and iridium crucibles or they melt at higher temperatures than the crucible materials can endure. Therefore, another melting system must be used, called the skull melting system. Cubic zirconia, because of its high melting point must be grown using the skull melting method.

The "skull" is a hollow-walled copper cup. Water is circulated through the hollow walls to cool the inside wall of the skull. The cup is filled with powdered ingredients and heated by radio frequency induction until the powders melt. Because the water cools the walls of the skull, the powdered materials next to the walls do not melt, and the molten material is contained within a shell of unmelted material. Therefore, the reactive or high-temperature melt is contained within itself. When the heat source is removed and the system is allowed to cool, crystals form by nucleation and grow until the entire melt

solidifies. Crystals grown using this system vary in size, depending on the number of nucleations. In growing cubic zirconia, a single skull yields about 1 kg of material per cycle.

Solution techniques for making synthetic gems include flux methods for emerald, ruby, sapphire, spinel, YAG, GGG, and alexandrite. The other solution method is the hydrothermal method, often used for growing beryl (emerald, aquamarine, and morganite) and quartz.

Quartz crystals are grown in a hydrothermal solution in large pressure vessels known as autoclaves. Careful control of temperature and pressure in the different areas of the autoclave result in the feed material, known as lascas, dissolving in the hotter portion. The material redeposits on seed crystals, located in the cooler portion, forming synthetic quartz crystals. The process usually takes 30 to 60 days for the crystals to reach the desired size. The process can produce rock crystal, amethyst, and citrine, or in some cases blue or green quartz with no natural counterpart The same system is used to grow beryl crystals.

Other techniques involve solid- or liquid-state reactions and phase transformations for jade and lapis lazuli; vapor phase deposition for ruby and sapphire; ceramics for turquoise, lapis lazuli, and coral; and others for opal, or glass and plastics simulants or imitations.

The Verneuil, Czochralski, and skull melting processes are the melt techniques most often used for gem materials.

Tourmaline

Tourmaline seems to have a special place in the hearts of mineral collectors as well as in that of gem and gemstone enthusiasts. Its nearly universal popularity is based on two very important facts: first, it is a bright and beautiful gemstone that can be found in just about any color; and second, materials that are of acceptable quality are affordable to most purchasers.

The word "rainbow" is used figuratively to describe tourmaline. In reality, it is a well recognized fact that tourmaline's diversity in color is not limited to the seven colors of the rainbow. Tourmaline can be colorless to just about any color, hue, or tone known to man. And if range of colors among different tourmalines is not enough, individual crystals can vary in color along their length or in cross-section.

The variations in color along a crystal's length give rise to the bicolor and tricolor tourmalines which have multitudes of color combinations. The variation in color in cross-section can be concentric, as in the case of "watermelon" tourmaline, a pink core

surrounded by a green rind. Or the variation may have a distinct triangular pattern as in the case of liddicoatite.

California.--Tourmaline was, until recently, the single largest contributor to the value of gemstones produced from California. And for the past 5 years, California has ranked as high as second and as low as sixth in the value of natural gemstone produced in the United States. The State's fabulous tourmalines were discovered by the gemstone industry in the late 1870's or early 1880's. The caveat, discovery by the gemstone industry, is used because Native Americans discovered and used these beautiful tourmalines long before that.

Since their discovery, the tourmaline deposits in Riverside and San Diego Counties have had more tourmaline produced and of greater value than any other deposits in the Northern Hemisphere. In fact, it is probable that only the deposits in Brazil have been more productive.

One of the reasons for the productivity of the area is the longevity of the individual mines. Many of them have operated intermittently from the 1890's until the present. The famous Himalaya Mine is quite likely the best example.

Records indicate that from 1898 until 1914, the Himalaya was the world's largest producer of tourmaline. Furthermore, the records indicate that in 1904 production from the mine was at least 5.5 metric tons. In 1989, 84 years later, a single pocket in the mine produced more than 0.5 metric ton of tourmaline.

The history of production from the mine is not one of steady continuous operation. The mine operated continuously from 1898 until 1914, after which it operated sporadically until 1952. At this time, it once again began continuous operations that lasted until 1964 when it returned to intermittent operation until 1977. Since then the mine has been in operation under the direction of Pala International.

California tourmalines come in all colors except certain shades of blue and yellow. They also occur in bicolors, tricolors, and concentrically and laterally zoned combinations. Crystals vary in diameter from about 3 millimeters to as much as 125 millimeters, and vary in length from about 12 millimeters to as much as 250 millimeters.

Because of the large size of the crystals available, some large stones have been cut from California tourmaline. A 400-carat pink-red stone has been cut, as well as a flawless 75 carat green to pink bicolor and flawless 30- to 40 carat green to colorless to pink tricolored stones.

California deposits should continue to produce quantities of faceting, carving, and cabochon grade, as well as specimen-grade tourmalines for some time into the future. In late 1992, a new deposit of tourmaline was discovered in Riverside County that could result in greater production over even a longer period of time.

Maine.--Tourmaline was the first gemstone mined in the United States by miners other than prehistoric man or Native Americans. Tourmaline mining began at Mount Mica, ME, in 1822 and, with starts and stops, has continued to the present. In 1992, operations at Mount Mica produced both gem-quality and mineral specimen tourmaline.

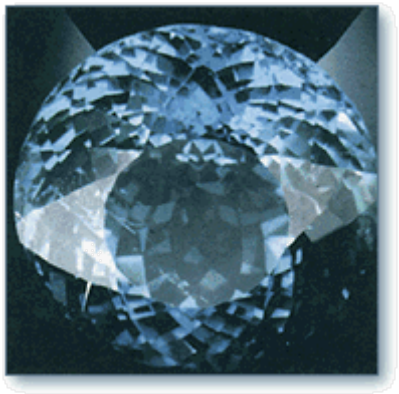

Figure 11.--Tourmaline from Maine.
(Photo is courtesy of Smithsonian.)

Over the years, mining operations on Mount Mica produced hundreds of kilograms of tourmaline. Museums and private collections around the world contain outstanding examples of tourmaline from the deposit. The largest reported crystal from the site apparently is one that is 39.4 centimeters long, 17.8 centimeters wide, and weighs about 14.3 kilograms. Apparently, a flawless, blue-green 256-carat stone is the largest cut stone from Mount Mica.

Mount Mica may have been the first tourmaline producer in Maine, but it is by no means the largest. Newry Hill, a spur off Plumbago Mountain, or more specifically the Dunton Mine on Newry Hill, is the most prolific tourmaline producer in Maine. Since its discovery in 1898, production from the mine has exceeded thousands of kilograms of high-quality tourmaline. The mines ability to yield large quantities of quality tourmaline was clearly demonstrated by Plumbago Mining Corp. The company reported that from October 1972 until the Fall of 1974, it produced more than one metric ton of fine-quality tourmaline.

Other mines and quarries in a three county area produce gem- and specimen-grade tourmalines. The level and type of activities at each mine or quarry vary from year to year. Currently, most of them are open to hobbyist or professional collectors for a fee or with the owners permission.

Maine tourmalines come in a wide variation of colors, deep grass green to light green to yellow-green to blue green. They are also found in all shades of red, from pink to deep red, and blue-green to light blue to deep blue, and as colorless crystals. The State's mines also produce bicolors and watermelon crystals. The colors can be very fine and some believe that Maine tourmalines set the standard for non-chrome green tourmaline.

Turquoise

Figure 12. -- Carved turquoise from Arizona
(Photo is courtesy of the author.)

Turquoise, the robin's egg blue gemstone worn by Pharaohs and Aztec Kings, is probably one of the oldest gemstones known. Yet, only its prized blue color, a color so distinctive that its name is used to describe any color that resembles it, results in its being used as a gemstone. Turquoise has been, since about 200 B.C., extensively used by both southwestern U.S. Native Americans and by many of the Indian tribes in Mexico. The Native American Jewelry or "Indian style" jewelry with turquoise mounted in or with silver is relatively new. Some believe this style of Jewelry was unknown prior to about 1880, when a white trader persuaded a Navajo craftsman to make turquoise and silver jewelry using coin silver. Prior to this time, the Native Americans had made solid turquoise beads, carvings, and inlaid mosaics. Recently, turquoise has found wide acceptance among people of all walks of life and from many different ethnic groups.

The name turquoise may have come from the word Turquie, French for Turkey, because of the early belief that the mineral came from that country (the turquoise most likely came from Alimersai Mountain in Persia (now Iran) or the Sinai Peninsula in Egypt, two of the world's oldest known turquoise mining areas.) Another possibility could be the name came from the French description of the gemstone, "pierre turquin" meaning dark blue stone.

Chemically, a hydrated phosphate of copper and aluminum, turquoise is formed by the percolation of meteoric or groundwater through aluminous rock in the presence of copper. For this reason, it is often associated with copper deposits as a secondary mineral, most often in copper deposits in arid, semiarid, or desert environments.

For thousands of years the finest intense blue turquoise in the world was found in Persia, and the term "Persian Turquoise" became synonymous with the finest quality. This changed during the late 1800's and early 1900's when modern miners discovered or rediscovered significant deposits of high-quality turquoise in the western and

southwestern United States. Material from many of these deposits was just as fine as the finest "Persian." Today, the term "Persian Turquoise" is more often a definition of quality than a statement of origin, and the majority of the world's finest-quality turquoise comes from the United States, the largest producer of turquoise.

The increased acceptance of turquoise resulted in higher prices, some of the most desirable materials going for as much as $2,200 per kg. The increased demand could not be met through production of acceptable mine run materials. Therefore, an industry emerged--the business of turquoise stabilization, reconstitution, and the manufacture of synthetic and simulated turquoise. In most instances, the stabilization and reconstitution of turquoise involve the use of earthy or highly porous types of turquoise which are pressure-impregnated with hot acrylic resins. The resins improve the color, hardness, and durability of the material to a point that inexpensive porous, poorly colored, or nearly colorless materials become suitable for use in jewelry. As long as the materials are represented as treated, stabilized, or reconstituted, the marketplace can accept or reject the materials based on decisions that are purely business or economic.

Arizona.--In Arizona turquoise ranks first in terms of value of production and is also the best known of its gem materials. As stated earlier, nearly all important deposits of turquoise are located near copper occurrences or in copper deposits in arid desert regions of the world. Thus, the world famous turquoise deposits associated with certain of the large Arizona copper deposits are to be expected. Turquoise is or has been mined from a number of these copper mines as a byproduct, usually by outside contractors.

The financial and operating terms of the collecting contracts vary from mine to mine. Some of the operations are little more than the efforts of individual commercial collectors. Some are essentially full-scale mining operations that are simultaneous with, but separate from, the regular mining operations; and still others operate on an on-call basis as turquoise is uncovered by the regular copper mining operation. Regardless of the size or the sophistication of the initial mining or recovery operation, the actual turquoise is recovered by careful extraction using hand methods.

California.--The production of turquoise from deposits in California can be traced back to pre-Colombian Native Americans. Prehistoric mining tools have been found in some of the old workings of the turquoise mines in San Bernardino County.

Over the years, the State's deposits have produced a substantial amount of turquoise. Deposits are located in San Bernardino, Imperial, and Inyo Counties. The material occurs as nodules and as vein filling. Most of the nodules are small in size, about the size of the end of your thumb, and the vein material is about 4 millimeters thick. In the better grade materials, the color varies from a pale to a dark blue, poorer grade materials are greenish-blue and green in color. Some of the material has yellow-brown limonite spiderwebbing.

In the past, a number of turquoise mines operated in the State, several or more mines in each of the counties. Today, only a single mine, the Apache Canyon Mine, is

commercially producing turquoise. Material from the mine is a fine blue color, hard, and takes a good polish.

Colorado.--Turquoise is produced from several locations in Colorado. Currently the only commercial production is near Manassa, Conejos County. Other production was from Leadville, Lake County; near Colorado Springs, El Paso County; and near Villa Grove, Saguache County.

New Mexico.--Until the 1920's, New Mexico was the United States largest producer of turquoise. However, since then Arizona and Nevada has surpassed it in terms of both annual and total production.

Production of turquoise from deposits in the Cerrillos Hills, Santa Fe County; the Burro Mountains and Little Hachita Mountains, Grant County; the Jarilla Hills, Otero County; and the Guadelupe Mountains, Eddy County; can be traced to prehistoric Indians. Several different mines operate or have operated at each of the New Mexico locations mentioned, producing seam and nugget turquoise. Many of the more famous and higher-quality deposits are economically depleted. Turquoise from these deposits was as good as that from any deposit in the world and were the first to displace true Persian turquoise in the U.S. market. Color varied from light to dark green, greenish-blue, bluish-green, paler blue shades, and fine sky-blue. Much of the material was spiderwebbed with thin veinlets of limonite.

Currently, with the exception of byproduct material from copper mines, production of turquoise from deposits in New Mexico, for all practical purposes, has stopped. Turquoise still can be found in New Mexico, but production in any significant quantity is a question of economics and the determination of the individuals involved.

Nevada.--Nevada has been a major producer of turquoise since the 1930's, and until the early 1980's, the State was the largest producer in the United States. It is estimated that over the years, 75 to 100 different mines/prospects produced sizable quantities of turquoise. Production varied from a few thousand dollars worth of material at some of the properties to more than a million dollars at others. To date, total production of rough turquoise is estimated to be in the range of $40 to $50 million.

Turquoise from Nevada comes in various shades of blue, blue-green, green-blue, and green. Some of the turquoise may contain iron, if it does, its color is pale green to yellow-green to yellow. The material can be solid colored or spiderwebbed with either brown or black webbing; the spiderwebbing may occur in any of the different colors or shades. Some of the blue material is represented as the finest pure-blue turquoise produced. It can occur in thin veins or seams or as nodules, with single nodules reported as large as 150 pounds. The quality varies from hard solid material that takes a good polish, to soft porous material that can only be use as feed stock for treatment, enhancement, or stabilization processes.

Associated with some of the turquoise deposits are two other gem materials that can resemble certain colors and shades of turquoise, but are separate mineral species. The first is variscite, and the other is faustite. Both have been mistaken for and marketed as turquoise. Attractive gem stones can be cut from both variscite and faustite and therefore, would be note worthy as gem materials on their own.

Other Sources of Information

U.S. Bureau of Mines Publications

Gemstones -- Online, recent editions of publications listed below
Gemstones ch. of Minerals Yearbook
1980, 1987, 1988, 1989, 1990, 1991, 1992, 1993.
Gemstones ch. of Mineral Commodity Summaries
1987, 1988, 1989, 1990, 1991, 1992,1993,1994,1995.
Gemstones ch. of Mineral Facts and Problems, 1985.
Mineral Industry Surveys "An Overview of Gemstone Production In the United States."
Mineral Industry Surveys "Directory of Principal U.S. Gemstone Producers in 1993."

Other Publications

Color Encyclopedia of Gemstones, by Joel Arem.
Colored Stone Magazine.
Gem & Gemology.
Gemstones of North America, Vol. I & II, by John Sinkankas.
Jewelers' Circular-Keystone.
Jewelry News Asia.
Lapidary Journal.
Modern Jeweler.
National Jeweler.

Links of Interest

- USGS Information on Rock and Mineral Collecting
- USGS Mineral Resource Surveys Program

End Notes

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Ordering Print Versions

Gemstones: An Overview of Production of Specific U.S. Gemstones.
1995, 41 pages, Price (paper) $5.50 (Foreign $6.88), GPO Stock #024-004-02429-1

U.S. Government Printing Office -- Order Form

About This Online Publication

This online version of "Gemstones: An Overview of Production Specific U.S. Gemstones" contains the text of the originally published book in its entirety. Some figures, however, have been changed for purposes of online presentation. This publication was repurposed for online presentation by Andrea Greenwood.

The original "Gemstones: An Overview of Production Specific U.S. Gemstones" was published by the Gemstone Specialist of the former U.S. Bureau of Mines. Continuation of that service is now provided by the Gemstone Specialist within the Minerals Information Team of the U.S. Geological Survey.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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