A BEAD TIMELINE

VOLUME I: PREHISTORY to 1200CE

A Resource for Identification, Classification and Dating.

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stone beads and pendant making techniques

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The large number and great variety of stone beads on the Bead Timeline make their origins and manufacture of special interest. Two factors define the process: the characteristics of the raw material being used, and the effort that a beadmaker wishes to expend. Soft stones, such as talc or soapstone, can easily be carved, drilled and polished to produce a bead or pendant. Harder stones require different techniques, worked out over many thousands of years. In addition, the surface of the stone can be painted, incised or glazed to modify its natural appearance. The nature of the raw material and the processes of manufacture often contribute to the longevity of a bead and its overall cultural or economic value.

FIGURE 1: RAW MATERIALS FOR BEADS AND BEADS ILLUSTRATING MATERIALS, in order of their numbers: limestone, fossiliferous limestone, orbicular jasper, carnelian, banded agate, dyed agate, onyx, chalcedony, sardonyx, moss agate, grey steatite, talc, bloodstone, malachite, lapis lazuli, sodalite, aventurine, serpentine, amethyst, rock crystal, smoky and rose quartz, ruby, jade, basalt, basalt with quartz bands, coral and turquoise. *Photographs: J. Mark Kenoyer.*

Raw Material Origins

Each region of the world has distinct types of natural raw materials which could be used to create objects of value for local as well as external trade. Human communities have experimented with all varieties of rock to make beads or to use as tools in the processing of stone beads. Grinding and polishing stones, as well as drills, are made from specific types of rock that are hard enough to modify the surface of other rocks. The Mohs' hardness scale can be used to give an idea of the relative hardness of various rocks, with values ranging from 1(talc) to 10(diamond). A variety of raw materials commonly used for stone beadmaking is shown in Figure 1.

Selecting an appropriate raw material for making a bead is the first of many stages where decisions are made by a beadmaker. Many stone beads are made from rocks that have natural features that make them attractive, including specific colors, distinctive patterns, or the ease with which the stone can be modified and perforated. From the very earliest times, human communities have shown a preference for materials that are rare and exotic. Generally speaking, rare materials have more value than objects made from commonly available stones, except in situations where the common materials have been modified through complex technologies.

Each species of rock is formed through very specific geological processes that occur in distinct areas of the landscape or the earth's mantle. Plate tectonics create zones of tremendous pressure and heat, transforming the surrounding sedimentary and igneous rocks into their metamorphic counterparts. Rugged mountains form as these same forces push up layers of sediments and rock from the lowest levels of the earth's crust. Over the years, these mountain rocks erode to expose a wide variety of exotic raw materials, many of which have been sought after for making beads.

Rocks themselves, which are composed of a number of constituent minerals, have been used to make beads; examples include basalt, a dark igneous rock; marble, the metamorphic form of limestone; and lapis lazuli, a rock composed of calcite, pyrite, and the blue mineral lazurite. More commonly, beadmakers have sought rocks with concentrations of minerals, such as steatite, serpentine, chlorite, calcite, nephrite, and jadeite, in order of increasing hardness. In order to obtain some crystalline gemstones, such as emerald, ruby, and sapphire, miners must blast through tons of the surrounding matrix to find crystal veins or inclusions. Volcanic eruptions produce obsidian, a natural glass which comes in several colors and has often been used for making beads. Among the most popular beadmaking materials are the various forms of crystalline quartz, ranging from rock crystal through the microcrystalline varieties of chalcedony and banded agate, which form in hollow pockets of massive volcanic lava flows. After millions of years these agate nodules or geodes erode and collect in stream beds as massive gravel deposits. Colored jaspers and chert are formed in limestone or other alluvial deposits that also eventually erode, exposing these very hard rocks for use as beads, or as will be discussed below, to make drills. Each variety of rock has specific features that a beadmaker must take into account as the bead is being processed.

Collecting and Mining

The collection of raw materials depends entirely on the type of rock being sought and the geological processes that have affected the landscape. In many regions of the world, the earliest beadmakers simply collected partially rounded pebbles from streams or beaches and then perforated them to produce a bead. Other rocks can be collected from eroding cliffs or from exposures where they can be broken from the parent rock. One of the early methods for obtaining lapis lazuli and other rocks from massive formations was to build a fire against the rock and throw water on the heated surface to make it crack apart. Through experimentation with fire, people gradually came to understand how to modify rock in other ways. When the surface rocks were depleted, mining was developed to follow a vein of desired rock deep into the earth. Today mining is the major method for obtaining materials such as carnelian, serpentine, talc, chert, jade, turquoise and fine gemstones.

Raw Material Preparation

After collection, rocks must be prepared for manufacture through various processes. Some rocks such as agate and chalcedony are dried in the sun for months to remove any moisture prior to heating. The nodules are then slowly heated to around 340° C to drive off the intercrystalline water, making them easier to flake. Heating also changes the color of the raw material. Rocks that are saturated with iron become reddish after heating in an oxidizing atmosphere. If a rock is heated in a smoky or reducing atmosphere it will turn darker and sometimes become black. Intentional coloring of rocks will be discussed below, but the coloring process actually begins right from the first heating. While some rocks become "softer" when heated properly, others can be made harder. Usually this is done after the bead is finished and the most common rock that is hardened by heating is talc or soapstone (steatite), which can change in hardness from Mohs' 3 to Mohs' 5.

Shaping Bead Roughouts

Some stone beads are made from naturally shaped pebbles without any further modification except to drill and sometimes polish the stone. However, most stone beads are made by selecting a large block of stone and breaking or sawing it into smaller pieces, referred to as blocklets or bead roughouts. Rocks such as agate and chert can be flaked relatively easily using a stone hammer or various sizes of metal hammers. In India, beadmakers use the technique of inverse indirect percussion, as shown in Figure 2. An iron stake is set into the ground at an angle and the bead chipper sits on the ground with one knee bracing the stake. In one hand he holds a bead roughout and the other wields a hammer made with water buffalo horn and a flexible bamboo handle. The bead roughout is placed against the stake and the soft hammer is used to strike the bead roughout against the stake to remove a flake without damaging the stone.

Materials such as nephrite and jadeite

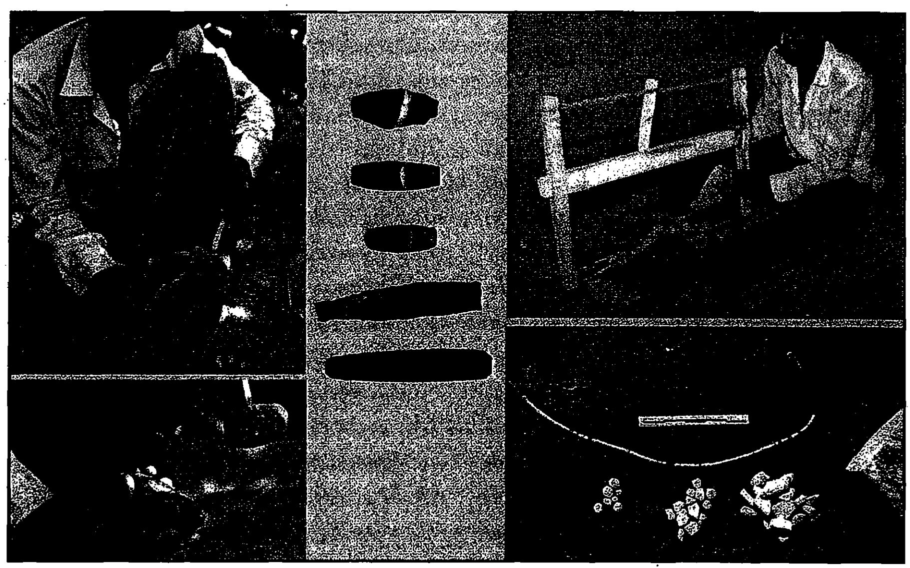


FIGURE 2: Left-hand photographs show inverse indirect percussion technique of preparing bead blanks. Upper right shows sawing of agate with bronze saw and abrasives. Lower right shows preparation of material for microbeads, seen as strand. In middle are respectively from top to bottom: banded agate roughout, bead blank and pierced bead; carnelian roughout and finished bead.

do not break very easily and must be sawn or ground into smaller pieces. Sawing can be done with an abrasive sand and a copper blade, using water as a lubricant and coolant. In cultures that did not have metal tools, sawing was done with a string or even a piece of wood. The grains of hard quartz or emery in the sand become embedded in the soft copper or organic saw and gradually cut through the hard rocks.

Bead Blanks

Bead roughouts are often processed again to create various types of final bead shapes which are called bead blanks. Some rocks are initially processed by fine chipping using smaller punches and smaller hammers, but eventually most bead roughouts are ground or carved to achieve the final bead shape. Traditionally, grinding was done by hand using a hard quartzite or sandstone grinding stone. This process is extremely time consuming depending on the size and hardness of the bead material. A long barrel shaped carnelian bead can be hand ground in about four hours of continuous work by an expert, taking great care not to break the blank through excessive heat or pressure. Tiny beads that are too small to hold in the hand are held by a small wooden vise or attached to a wooden rod or dop stick using some form of adhesive. After grinding one side, the tiny bead is taken out of the vise and turned to allow the other portion to be shaped.

Another technique for shaping tiny beads is to cut thin sheets of the rock and break them into small squares or disks that are then drilled in the center. These drilled roughouts are strung on a cord or wire so that many beads can be ground and shaped at the same time. Neolithic microbeads of lapis lazuli and carnelian were prepared in this way, along with as were the shell heishi beads produced in the American Southwest.

Even with modern grinding wheels, the preparation of stone beads requires considerable time and skill. Most beads are individually shaped by hand and only spherical beads can be produced with a minimum of handling.

There are many more techniques of preparing bead roughouts and bead blanks, some of them unique to specific cultures. Many cultures do not necessarily use the most efficient technique since the preparation of beads may be part of a larger social event, and careful hand grinding may be a ritual event undertaken for only a few hours a day.

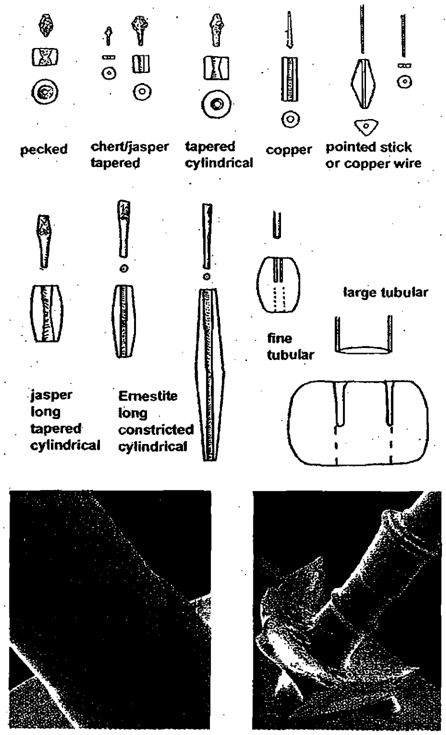
Perforation or Attachment

The point at which a bead blank becomes a bead or pendant is defined by the grooving or drilling of the ornament to facilitate stringing. By taking a pointed object and turning it back and forth it is possible to gouge or drill into a stone and eventually perforate it. While much of the earliest drilling was done by hand, the use of the bow drill was widespread by the 4th millennium BCE, and is still one of the most efficient methods of drilling. Perforations were usually achieved by drilling from both ends, with the hole meeting at the center of the bead. If the drilling is properly centered, it will produce a smooth cylindrical or hourglass shaped perforation.

The actual drilling of the bead blank is one of the most difficult and critical steps in beadmaking, and the specific type of perforation used to make stone beads, whether by pecking or drilling, has turned out to be an informative detail of ancient lapidary that was never fully appreciated by earlier scholars. With the invention of high quality silicone based impression materials, it is now possible to make extremely precise molds of bead perforations that can then be examined under the Scanning Electron Microscope. Experimental studies of perforation and drilling technology, using different types of tools or drill bits have made it possible to differentiate the various perforation techniques and correlate them to specific time periods and to cultural regions, as shown in Figures 3a, b.

Short disk shaped and biconical beads of carnelian and agate reveal the use of a pecking technique that results in a rough hour-glass shaped perforation. Although considerable effort has been made to replicate this process it has not been possible to reproduce the small carnelian beads that were made in the Neolithic of South and

FIGURE 3a: Chart of bead drills and resulting perforations. Lower left and right are respectively Scanning Electron Micrographs of silicon rubber casts of beads drilled by Indus and tubular drills.



West Asia. In fact it was even difficult for ancient beadmakers since we find many beads that were broken in manufacture.

Long and short tapered drills, made by notching and steep retouch on chert microblades are found throughout the world, beginning in the earliest Neolithic period and continuing up through the Iron Age circa 1200 BCE in the Old World and much later in the New World. Some of these drills may have been used to perforate unfired steatite bead blanks, but most of them were probably used on shell, ivory or wood.

Some tapered stone drills made of chert or jasper bladelets were modified into a more specialized form referred to as a "tapered cylindrical drill". These drills were used to decorate and perforate softer stone, such as lapis lazuli, turquoise, or limestone, and to perforate short beads of harder stone such as agate or carnelian. This type of drill is found at sites throughout West Asia and the Indus valley, and has a long history of use that begins in the Copper-Bronze Age around 5500 BCE and continues through to the beginning of the Iron Age.

Constricted cylindrical drills have have only been reported from the Indus Valley during the Harappan period (2600-1900 BCE). They have a long cylndrical shape that is wide at the tip and constricted in the midsection. This shape was developed by the Indus artisans to facilitate the drilling of long slender beads of hard stone such as carnelian, agate and jasper. In contrast to tapered drills, these hard stone drills are made from a specific raw material called "ernestite," in honor of Ernest J.H.Mackay, who excavated the site of Chanhudaro, Pakistan where a carnelian bead workshop with large quantities of drills and drill manufacturing waste was found.

Microscopic examination of drilling striae on experimental and archaeological

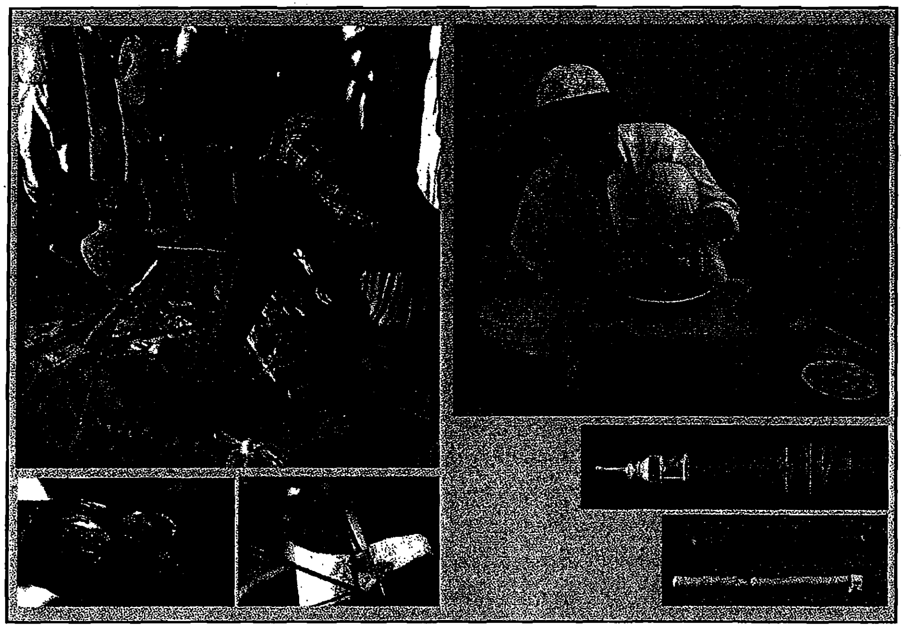


FIGURE 3b: Left-hand images show drilling with single and double diamond drills in Khambhat, India, and closeup of both types of drills. Right-hand images show drilling with single diamond drill in Peshawar, Pakistan. The diamond chip is held in a hyperdermic needle. Carnelian bead perforated with this type of drill and its silicon cast replicates the perforation.

samples of steatite suggest that long perforations were probably made using copper drills rather than with stone drills. The use of solid wood or copper drills with abrasive was the predominant form of drilling in East Asia and many parts of the New World.

Tubular drills made from a reed or bamboo have been documented in many regions of the world and represent a very efficient method of making a big hole with the minimum amount of effort. Instead of drilling out the entire center of a bead the tubular drill cuts a narrow ring and leaves the center of the bead a solid plug that can be removed by a light tap once the tube has been cut through the entire bead. This technique was also used with tubular metal drills beginning in the early Bronze Age, circa 2500 BCE.

The earliest use of hard gemstones for drilling is difficult to determine since much of the early abrasives may have had some particles of garnet or corundum in them. In Africa and the Mediterranean many of the abrasive sands naturally contained the harder minerals. By the late 3rd millennium BCE the intentional use of corundum in western Asia greatly facilitated the perforation of hard stone beads.

The use of tiny diamond chips for drilling dates to around 600 BCE in western India. Although we do not know the precise form of the earliest diamond drills, they appear to have included two different styles. Some drills were made by using a single diamond chip that was crimped to the end of a narrow bronze or iron drill shaft. Anther type of drill was made by crimping two diamond chips at the tip of the drill. The single diamond drilling technique appears to have spread throughout the northern and western parts of Asia, while the double diamond technique appears to have been practiced only in South Asia, primarily in the western bead producing region of Gujarat.

Perforation of hard stone beads with stone drills or abrasive is extremely time consuming. Experimental studies have shown that chert or jasper drills can perforate agate at a rate of approximately 0.8 mm per hour. Ernestite drills are much more effective at 2.4 mm per hour, and the double diamond drill can perforate at the rate of 536.5 mm per hour. Without calculating the time involved in preparing the beads and the drills, the introduction of the diamond drill made it possible to drill beads at a rate 224 times faster than could be done with the most effective stone or abrasive hand drilling techniques. In fact, the introduction of diamond drilling so changed the value of hard stone beads such as carnelian and jasper, that elite consumers soon turned to beads made from rolled or faceted gemstones such as flawless rock crystal, emerald, ruby and diamond, as these were rare and more difficult to manufacture.

Finishing

Since many beads are broken during the drilling process, ancient beadmakers usually completed the final finishing after the successful drilling of the bead. The finishing includes polishing, heating or dyeing to enhance the color and decoration using various techniques of surface modification.

Polishing a stone bead usually involves repeated grinding with finer and finer abrasives to create a reflective surface. Throughout most of human history the polishing was done by hand, with initial polishing on fine quartzite or siltstone grinders, and final polishing on a wooden or leather surface with extra fine abrasive powder. The abrasive powder can be made from finely ground agate or even brick dust that has been carefully strained to remove all coarse particles.

Once stone beads could be produced in larger quantities using diamond drills the polishing of beads by hand was no longer economically viable and we see the introduction of mass polishing techniques. The earliest process was to place a large number of beads in a watertight leather bag along with water and powdered agate or corundum. The precise mixture of polishing powder was kept secret so that other people would not be able to replicate the process. By rolling or shaking the bag back and forth for around 15 days, the beads would attain a low luster polish. Bag polishing was eventually replaced with mechanized tumbling barrels using different grades of abrasive and this is the technique used for most common shapes of beads today. However, specially produced long bicones, carved beads and faceted stone beads are all still polished by hand.

The color of some stone beads was intentionally enhanced or modified by various processes as early as 5000 BCE. Nodules containing agate and jasper may erode into massive gravel beds that are then covered by other sediments that contain different types of minerals, including iron, in the form of hematite or limonite. As ground water percolates through the sediments it carries these iron minerals through the gravel beds, which become saturated with fine particles of iron. Agate and jasper are made up of multiple layers of silica that may have slightly different porosity due to density of crystal formation, which will affect the final appearance of the stone. Rocks with relatively uniform porosity will turn a uniform color, depending on the amount and type of iron found in the stone, as well as the degree to which it has been heated. High quantities of hematite or limonite will turn the rock a deep reddish orange color which is called "carnelian", while smaller proportions of the mineral leave the agate a pale yellow, called "citrine". Agates with alternating bands of highly porous and non-porous silica result in banded red and white agates that are sometimes referred to as "sardonyx". If the rock is heated in a reducing atmosphere with very little oxygen reaching the iron, it can turn grey or black, resulting in black and white banded agate or onyx. Another way to make a stone blacker is to soak it in a sugar solution or honey and then basically caramelize the sugar which has saturated the porous stone. This process has been documented since the early Roman era and may have been practiced even earlier in South Asia. There are several examples on the Timeline of beautiful agate beads with intentionally enhanced banding, particularly in Chapter 3.

Many modern agate beads are colored with a wide range of chemicals to create blue, green, yellow, reddish orange and black colors. These processes were not used in antiquity, and the modern, dyed stones tend to be more uniform in color, without the luminosity of the ancient examples.

Another technique for coloring stone is to bleach the surface to turn it white. This can be done most efficiently by dipping the stone into an alkali solution or painting designs on the surface and then heating the bead over red hot charcoal. In ancient times the alkali solution or "potash" appears to have been made from a plant ash derived from burning certain desert plants, and then mixed with natural plant resin to improve adhesion. The ash contains potassium and sodium carbonate, and is still produced throughout West and South Asia, where it is used as a flux for melting glass and as well as for producing a form of soap. The whitening appears to be the result of tiny microscopic fractures in the stone surface as well as a bleaching of any natural colors in the stone. After thousands of years the bleached surface often erodes, leaving a shallow etched design that led earlier scholars to refer to these beads as being "etched". The term "etched carnelian" is still used in the literature to describe red carnelian beads that have white designs painted on their surface. Etched carnelian beads from the Indus Valley have been found in Mesopotamia, most notably in the mid-3rd millennium BCE tombs at Ur. Examples on the Timeline in Chapter 7 are typical of beads from the Parthian and Sasanian periods, although decorated carnelian beads have been prodced into modern times. Beads that have a white surface and black lines appear to be the result of improper firing where the overall surface of the bead was whitened from heating; the painted lines became saturated with carbon, since they are more porous than the other surface areas.

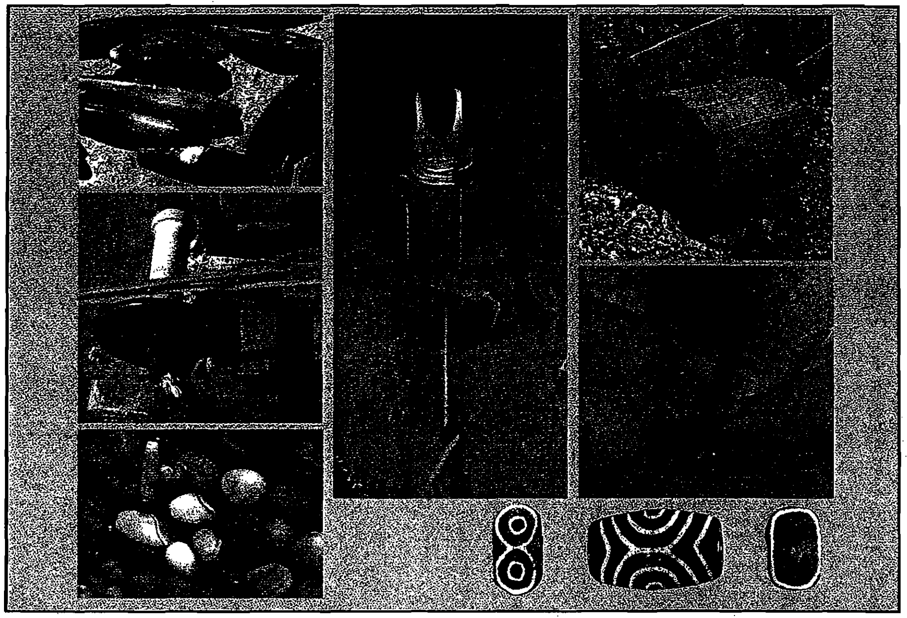


FIGURE 4: Left-hand images show hand polished canelian beads, hand polishing with bow-turned wheel and other polished agate beads. Middle image of two men engaged in leather bag polishing. Upper right is a wooden drum polisher, lower replication of bleached carnelians, with three ancient bleached carnelian beads, often called etched carnelians.

Another technique of coloring was to blacken the bead and decorate it with white lines. Several different techniques may have been used to achieve this effect, but the most common process was probably to blacken the entire bead using the carbonizing process described above and then to use the alkali technique to create the white lines. The famous Tibetan Zi (dZi) beads are made with this technique.

Soft talc or steatite beads were usually heated to around 1000° C to harden the talc by transforming it into another set of minerals called cristobalite and enstatite, and many of the earliest high-quality beads and stamp seals, such as those in Chapter 1, were formed by this technique. At times, the surface of the stone was bleached using some form of alkali solution. Large numbers of small black and white (often called "burnt," but probably including some sort of bleaching technique) steatite beads have been found at ancient sites, and are shown on the Timeline in Chapter 2.

Glazed steatite or quartz beads were made by coating the surface of the beads with finely ground silica colored with copper or azurite, and then heating under controlled conditions. This very early pyrotechnology was particularly well developed in Egypt as early as the last quarter of the 5th millennium BCE, and predates Egyptian faience, glass, and glazed pottery. Some soapstone beads were colored with an iron pigment to turn them red, and red and white beads were made using iron and the bleaching process described previously.

Conclusion

Stone bead making is a fascinating topic that still has many unanswered questions. The creative abilities of early beadmakers and the continued use of stone in manufacturing modern beads have resulted in an almost unlimited combination of techniques and raw materials. With the global trade of beads it is almost impossible to be certain of where a bead comes from. In the markets of Africa, beads made in Europe, Asia and the New World can be found next to locally produced stone beads. The same situation exists in almost every corner of the world. It is only through the careful study of all aspects of stone bead manufacture that archaeologists and bead collectors will be able to associate specific beads to specific world regions and time periods.