



Discovery and Mining



The Diamond Course



Diamond Council of America © 2012

Discovery and Mining

In This Lesson:

- Creating Value
- Finding Diamonds
- Mining Methods
- Recovery
- Investment and Labor

CREATING VALUE

When customers walk in your door, they already know that diamonds are very valuable. Many also understand that the value is largely based on natural rarity, enduring beauty, and emotional meaning. Very few customers, however, have any idea of just how much enterprise and effort a diamond represents.

In this course, you've already seen that one of the 4Cs – cut – is a human addition to diamond value. However, by the time a diamond touches the cutter's wheel, a tremendous amount of expertise, labor, and money have already been invested in it. In fact, the investment begins long before the diamond ever comes out of the ground, and it builds at every step along the market path to your store. From an economic standpoint, this accumulated outlay creates much of a diamond's monetary value. If you total it all up, diamonds are truly a bargain!



The accumulated outlay of money, labor and expertise creates much of diamond's value.

Photo courtesy Argyle.

In the last lesson, you learned about the deposits and countries in which diamonds are found. This lesson and the next two will follow diamonds from those sources to your own sales counter. During the journey you'll examine the process of creating value. It begins with mining companies locating deposits and extracting the diamonds from the earth.



From far-away sources to your own sales counter, diamonds travel a journey that creates value.

Photo courtesy Argyle.

Lesson Objectives

When you have successfully completed this lesson you will be able to:

- Explain the process of discovering and developing diamond deposits.
- Describe how diamonds are mined and recovered.
- Illustrate the impact of investment and labor on diamond value.

FINDING DIAMONDS

You might say that history's most important diamond discovery was an accident. It happened in the Cape Colony (part of modern South Africa) around 1870. According to one version of the story, a teenager picked up a shiny pebble while he was cutting firewood. The pebble turned out to be a 21-carat diamond, and it was the first in a series of finds that alerted the world to Africa's fabulous diamond wealth.

Early diamond lore is full of similar anecdotes. Within the last century, however, the hunt for diamonds has become a full-fledged science. Today's methods are amazingly thorough and sophisticated. Yet success can still take years of work.



A month of following a creek bed led to the Argyle pipe, one of the richest diamond deposits ever found.

Photo courtesy Argyle.

Exploration

As you've learned, diamonds occur in two main types of deposits – primary and secondary. **Primary deposits** are where diamonds were brought to Earth's surface. The most important of these are pipes. **Secondary deposits** are where diamonds were carried by erosion, and there are several kinds:

- **Alluvial deposits** – Concentrations of diamonds in streams and rivers.
- **Marine deposits** – Places where rivers transported diamonds to the ocean.
- **Beach deposits** – Marine deposits that were left on land when the sea level fell.

In most parts of the world, the focus of diamond exploration is on pipes. That's because they have relatively long producing lives. They're also suited for large-scale industrial mining.

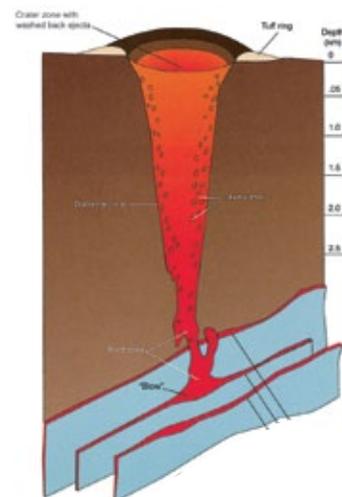
The search usually begins with identifying areas that have the right geology. (These are situated on ancient continental cores.) The next step is locating any pipes in a specific target area. Airplanes, helicopters, and even satellites often aid this effort. The high-tech instruments they carry can detect subtle differences in magnetism, radiation, vegetation, and other features. These provide clues to the whereabouts of Earth's hidden treasures.

A more traditional approach is land-based surveying. Geologists sample stream and river sediments over hundreds or even thousands of square miles. They watch for diamonds or indicator minerals such as garnet, spinel, and zircon, which occur with diamonds. If they find any of these, they carefully trace the watercourse upstream looking for the primary source.

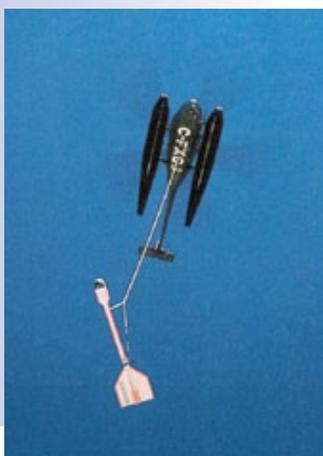
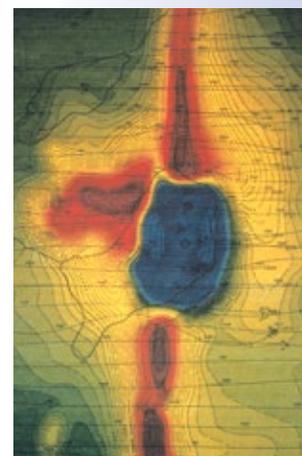
Finding a commercially viable diamond deposit can take decades of exploration and evaluation.

High tech instruments can detect subtle differences in magnetism, radiation, vegetation and geographic features - all of which provide clues to the whereabouts of hidden diamonds.

Photo courtesy BHP Diamonds.



In most parts of the world, the focus of diamond exploration is on pipes.



An airborne magnetic survey identified kimberlites for target testing at the Ekati site in Canada.

Photo courtesy BHP Diamonds.

The process is painstaking and sometimes grueling, especially in regions with extreme climate and rough terrain. The rewards, however, can be phenomenal. In 1979 a prospecting team recovered a couple of small diamonds from a creek in Western Australia. A month of following the creekbed led to the Argyle pipe, one of the richest ever found.

Even with the best know-how and equipment, a little extra help can be crucial. The huge pipe that became Botswana's Jwaneng Mine was buried under 150 feet of sand in the Kalahari Desert. Geologists discovered it after spotting indicator minerals that termites had carried to the surface and scattered around their mounds.

Evaluation

Finding a pipe is good news, but it's no guarantee of success. There are thousands of pipes and related formations around the world. Only a small percentage contain diamonds, and only a few of those are commercially viable. So initial discovery is followed by a series of tests:

- **Surface sampling** – This first step analyzes the pipe's chemistry. Diamonds might not appear in the samples, but geologists can at least determine whether the magma came from the right depth to contain diamonds.
- **Test drilling** – Usually done on a grid pattern, this systematic probing helps to establish the pipe's size and shape. It also provides more samples for testing.

Finding a pipe is no guarantee of success.



Collecting ground data can more accurately define the shape and position of a pipe before drilling.

Photo courtesy BHP Diamonds..

Subsequent development frequently requires heavy capital investment.

- **Small-scale mining** – If early results are positive, equipment is brought in to remove and process up to several hundred thousand tons of ore. Any diamonds recovered are carefully evaluated for size, quantity, and quality.

The purpose of all this testing is to obtain an estimate of the amount of ore in the deposit, the number of carats per ton of ore (known as the grade), and the per-carat value of the diamonds. Multiplied together, these numbers indicate the deposit's total worth. That information is essential for making decisions about further development. It provides only half of the picture, however.

The other half involves a long list of questions: How much will the buildings and equipment cost? Is there an infrastructure of roads, electrical power, and communications, or must they be created? Are there adequate supplies of natural resources such as water? Will the location or climate pose special challenges? Where will the workers come from? Are political and economic conditions favorable? What will the social and environmental impacts be? The answers to these questions often decide whether mining is truly feasible.



In evaluating the potential of a mine, companies have to consider the cost of infrastructure - like roads, airfields, housing, electrical power, environmental impact and facilities.

Photo courtesy BHP Diamonds.

Development

Exploration and evaluation take most of the time in the diamond-finding process. Development, however, takes most of the money and work. One reason is that all of today's leading mines are located in remote and inhospitable parts of the world. They're found in the deserts of southern Africa, the outback of Australia, and the tundra of northern Canada and Russia. In these places everything must be brought in and built from the ground up.

The Ekati Diamond Mine in Canada's Northwest Territories provides a good example of the whole process:

- Geologists found indicator minerals in 1981. However, identifying their source took 10 years of detective work. During the last Ice Age, glaciers had carried the indicators more than 350 miles from their point of origin.

- The first pipe was located in 1991, and further exploration uncovered about 120 pipes in the area. Evaluation extended over the next three years. Five of the pipes were ultimately selected for development.
- From 1994 to 1997 the project went through reviews and negotiations. The process included an environmental impact study that filled eight volumes and weighed 64 pounds. There were also public hearings and agreements with the national and territorial governments, and local aboriginal groups.



It took years to develop the site and infrastructure of the Ekati Mines - and a colossal investment.

Photo courtesy BHP Diamonds.



A close up look at the Ekati Mines site where several pits are currently being worked.

Photo courtesy BHP Diamonds.

- In January 1997 full-scale development began. The site is 120 miles south of the Arctic Circle. It's in a permafrost region and winter temperatures drop to -65° Fahrenheit. Surface transportation is only possible by ice road from January to April. About 2,000 truckloads of construction materials had to be hauled 190 miles from the nearest town. For year-round access, a landing strip was built to handle Boeing 737 jets and jumbo cargo planes.
- From June 1997 to September 1998 the buildings went up. These included a processing plant for the diamonds. There was also an electrical power plant, worker housing, a medical clinic, and emergency response facilities. The buildings totaled more than 200,000 square feet.
- In October 1998 Ekati went into production. The time from the beginning of exploration to start-up was 17 years. The financial investment totaled about \$700 million before the first full shipment of diamonds went to market.

MINING METHODS

In the last lesson you learned that pipes are the leading mine sources of diamonds. Now you know that they're also the main focus of exploration. Nevertheless, all types of deposits are commercially important, and each location is unique.

The sizes of deposits vary from minute to monstrous. Methods range from primitive to ultramodern. All mining, however, boils down to two steps:

- Digging up tons of soil, gravel, and rock.
- Separating the diamonds from worthless material.

Alluvial Mining

Historically, alluvial deposits were the first to be discovered and the first to be mined. Many are worked about the same way today as they have been for centuries. In places like central Africa, pockets of diamonds are scattered along streams and rivers over vast areas. Many have been reburied in banks and beds, under sand, gravel, and silt.

Individuals or small groups of diggers – adding up to thousands across the region – shovel sand and gravel into buckets. Then they screen the contents through wire-mesh and pick out the diamonds by hand.

In bigger operations, the diggers might use various types of mechanical sifters. They may also construct sluices. These are large troughs with slats along the bottom to trap diamonds as water carries the other material away.

For some particularly rich alluvial deposits, powerful dredges with giant buckets or suction pipes bring up diamond-bearing sediments from the river bottom. For others, engineers dam or divert the water to make mining easier. At highly industrialized sites, bulldozers do much of the digging.



The age-old technique of panning is still used to recover diamonds from some alluvial deposits.

Beach Mining

The world's most important beach deposits lie along the west coasts of Namibia and South Africa. These have been amazingly productive over the years. Since discovery in the 1920s, the Namibian coast alone has yielded more than 65 million carats of high quality diamonds.

Mining methods are similar to those for large-scale alluvial deposits. The extensive area and high concentration of diamonds, however, make the African beach operations truly colossal. The diamonds are typically buried under 20 to 40 feet of sand. At a rate of about 1,800 tons per hour, bulldozers, earthmovers, and trucks push the sand toward the sea, almost 700 feet past the high tide line. In the process they build walls that are 65 feet wide at the top, and they expose the surface down to 60 feet below sea level.



Photos courtesy AlexKor.

Diamonds are typically buried under 20 - 40 feet of sand along the southwest African coast. As the sand is pushed seaward by heavy equipment, huge retaining walls are built to keep the ocean at bay while mining operations sweep the bedrock 60' below sea level.



Photos courtesy De Beers Group.

Once workers reach the diamond-bearing layer, sweepers clean the sand from every nook and cranny where diamonds might hide. They scour potholes in the bedrock. Areas that have solidified are blasted apart. Then the ore is hauled to a processing plant where it goes through a sequence of separating machines.

Meanwhile the battle against the ocean never stops. Heavy surf batters the walls, which have to be repaired constantly. Water seeps in from below, and storms periodically threaten to wreck the whole effort.

Marine Mining

The offshore counterparts of the African beach deposits pose great challenges to mining. Since they may hold millions of carats, however, they offer tremendous incentives.

To find diamonds beneath the sea, research teams start by gathering data about wind and wave patterns, and also the underwater landscape. Next, computers create models of how diamonds might be distributed along the ocean floor. Then mini-submersibles take geologists down for a first-hand look.

The deposits are located up to 60 miles from shore, and in water as much as 500 feet deep. Converted oil exploration vessels serve as operational platforms. In areas where the floor is relatively flat, remote-controlled mining vehicles called crawlers are used. These move back and forth across designated areas, sucking up diamond-bearing sediments. Where the bottom is rocky and uneven, rotary drills that are 20 feet in diameter bore into the seabed. Vacuum hoses then carry the material back up to the ship for processing.



Marine deposits are as far as 60 miles from shore in water as deep as 500 feet. Marine mining technology involves sophisticated vacuum systems for sucking up diamond bearing sediment from the ocean floor.

Photos courtesy De Beers Group.

Off shore
deposits are in
a completely
non-human
environment.

Pipe Mining

Diamond pipes vary greatly in size. That's partly because they were created by eruptions of different sizes, and also because they've undergone differing amounts of erosion. One of the world's largest diamond pipes is called Orapa. It's located in Botswana, and it was found almost intact. At the time of its discovery, Orapa had a surface area of about 260 acres and a diatreme (primary mining section) that was more than a mile deep. At the opposite extreme, some of the smallest pipes cover less than 5 acres. The average is around 30 acres.

Pipe mining can proceed in two ways:

- **Open Pit Mining** – This is the most common method. As a first step, barren rock called overburden is removed. (At Australia’s Argyle Mine there were more than 22 million tons of it!) Once that’s done, blasting loosens the ore from the bedrock. Then giant loaders scoop 900 cubic feet at a time into trucks that hold up to 250 tons apiece.

Excavation is deepest in the middle of the pipe, and it’s carried out in a way that creates a spiral roadway along the mine’s outer walls. As the pit gets deeper, benches are cut into the surrounding rock at vertical intervals of about 45 feet. This prevents the walls from collapsing. However, it also requires removing more than 5 tons of additional rock for every ton of ore. The result is a gigantic hole that keeps growing as the mining continues. Argyle was more than 1½ miles in diameter and 1900 feet deep before it was changed to underground operations.



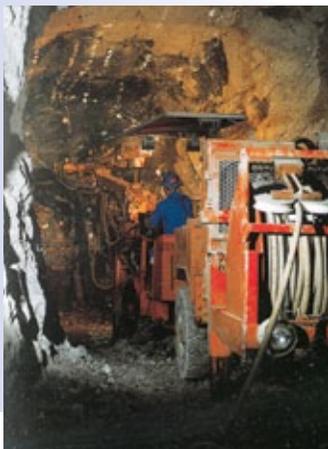
Over 22 million tons of barren overburden had to be removed to expose the Argyle pipe.

Photo courtesy Argyle.



Excavation of a pipe is carried out in a way that creates a spiral roadway along the perimeter of the mine. As the pit gets deeper, benches are cut in the surrounding rock to keep the walls from collapsing.

Photo courtesy BHP Diamonds.



Underground drilling in horizontal shafts of the Finsch Mines in South Africa.

Photos courtesy De Beers Group.

- **Underground Mining** – Because of this method’s complexity and expense, it’s used only for the largest and richest pipes. The transition to underground mining usually begins when a pit is becoming too deep for further excavation. At the Finsch Mine – South Africa’s top producer – the switch started when the pit reached 1,400 feet.

In a standard approach, large vertical shafts are sunk into the hard rock surrounding the pipe. These serve as the main arteries for moving workers and materials. From the shafts, horizontal tunnels, called drifts, are dug around and through the pipe itself. (Finsch has 50 miles

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of these.) The drifts are where the actual mining takes place. Miners blast out and remove diamond-bearing ore, then load it into trucks or onto conveyors that transport it to one of the main shafts. From there it's hoisted to the surface for processing.

In the last lesson you learned that most diamond pipes are gradually tapering cones. As operations go deeper, the pipe narrows and yield decreases until the mine is no longer profitable. The life span of a pipe mine averages about 30 years. Some, however, have lasted much longer. South Africa's Cullinan Mine opened in 1902. Now more than 2,500 feet deep, it's expected to remain viable for several more decades. Some experts believe Botswana's Orapa Mine may still be producing diamonds 200 years from now.



South Africa's Cullinan Mine opened in 1902 but is expected to remain viable for several more decades.

Photos courtesy De Beers Group.

RECOVERY

Ore processing – or recovery – is a separate phase of mining in all but the smallest alluvial digs. Specific methods depend on the type and quantity of ore, as well as the capital resources of the company. In many of today's big pipe mines, the processing plants cover several acres. They're so completely automated that most workers never even see a diamond.

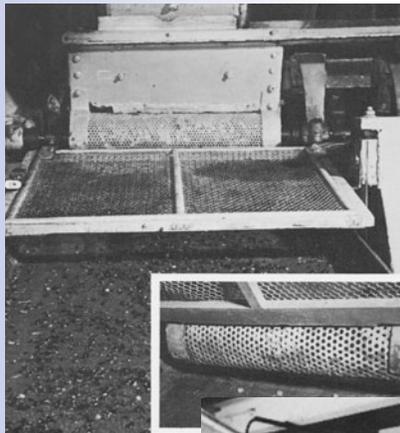
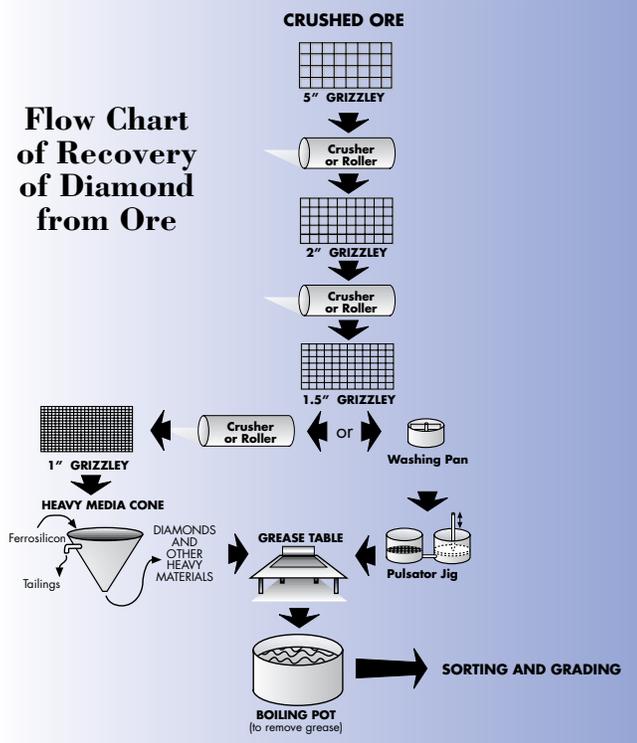
In a typical processing sequence, the ore first passes through a series of crushers and screens that reduce boulder-size chunks to pieces less than an inch in diameter. Although this might seem like a brutal way to handle diamonds, the machinery is designed to minimize the possibility of damage.



In many of today's big pipe mining operations, the processing plants cover several acres.

Photos courtesy De Beers Group.

After crushing, the ore goes into a scrubber – a large rotating drum in which water dissolves and washes away dirt – then on to a heavy media separator. The separator contains a mixture of water, iron, and silicon with a specific gravity between 2.5 and 3.0. (As you learned in Lesson 9, specific gravity is the weight of a material compared to an equal volume of water.) Lighter rocks and minerals float to the top of the mixture and are drawn off. Gem quality diamonds have a specific gravity of about 3.52 so they sink to the bottom, forming a concentrate with other heavy minerals such as garnet and zircon.



The grease belt is a traditional way of capturing diamonds. Diamonds stick to the grease while other materials are washed away.

Photos courtesy De Beers Group.



In modern treatment plants, an x-ray separator is used. As diamonds pass through the x-ray beam, they trigger an airjet, which blows them into a container.

Typically, ore passes through a series of crushers and screens, then into a washing pan or heavy media separator, then to a grease belt or x-ray separator.

A traditional way of separating diamonds from the concentrate is the grease belt. The principles of this technique were applied centuries ago in India, and the modern version is a standard method for recovering small diamonds. A stream of water washes the concentrate across a conveyor belt that's covered with a thick coat of grease. Diamonds aren't wettable – in other words, water doesn't adhere to them. As a result, they stick to the grease while other minerals are washed away.

Another separation technique relies on the fact that most diamonds fluoresce when they're exposed to x-rays. The concentrate is fed onto a conveyor belt running under an x-ray machine. As each diamond passes through the beam it emits a flash of light. A photocell detects this flash and triggers an air jet that ejects the diamond out of the feed stream and into a container. Each photocell-jet combination can produce up to 500 blasts per second, and the process is more than 99% effective.

Despite the high degree of mechanization, hand sorting still has a place in recovery. For security reasons, though, sorters never actually touch the diamonds. They work through gloves that are attached to transparent boxes containing only a pair of tweezers and the gems.

Once the diamonds have been separated, they're cleaned in acid to remove any grease, oil, or other residue. After a final rinse in water, they're ready to enter the market channel heading toward retail stores.

1. Crushing, scrubbing and screening.

Run-of-mine ore is delivered by haul trucks to the primary crusher at the plant site. Material discharged from the crusher is conveyed either directly to the process plant or to a crushed ore stockpile. Coarse ore from the stockpile or the crusher is conveyed to a secondary crushing section inside the plant building which further reduces the size of the primary crushed material. The material is then sent to the primary scrubber to loosen the ore particles and dispense any clay that is present. The scrubber then discharges ore onto a horizontal vibrating screen, which removes water and sizes the material.



2. High pressure grinding rolls (HPGR).

The crushed and washed material is now subjected to high pressure grinding to further reduce the size of individual particles before being sent for secondary scrubbing. Following that, the product is degritted and desanded, removing any fine waste material.



5. Tailings disposal.

Fine and coarse tailings will be handled separately. The coarse sand will be trucked to a waste dump. Fine tailings, will be thickened within the plant before being pumped to Long Lake. The tailings system is designed to discharge only water that meets permitted standards.

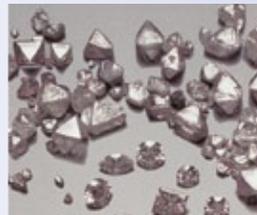


Modern diamond processing.

Graphics courtesy BHP Diamonds.

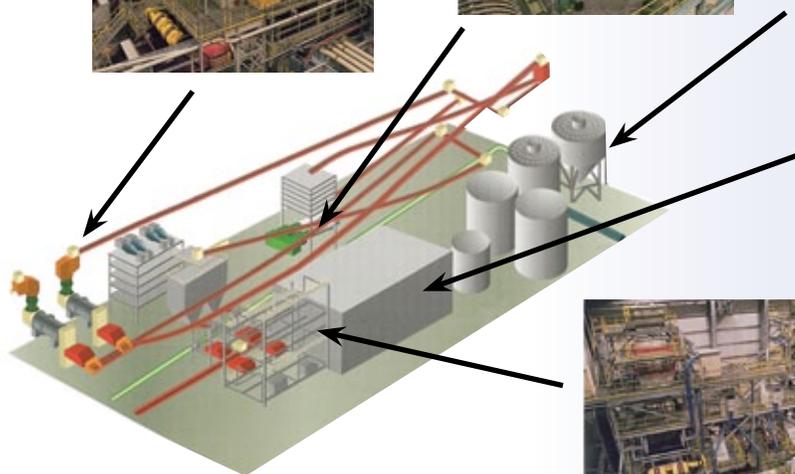
4. Recovery section.

Diamond recovery is based on X-ray sorting. Diamonds luminesce when exposed to x-rays. An ejector separates the luminescent, mostly diamond material from non-luminescent, non-diamond material. The x-ray sorters are fed by vibrating tube feeders discharging into motorized distributors. Grease tables are used to audit the x-ray sorting tailings. The diamonds are then cleaned, mechanically sieved, weighed and packaged by size for inventory control.



3. Heavy medium separation (HMS).

Heavy medium separation is a process that uses gravity to separate high density particles, including diamonds, from lower density, non-diamond material. This is done in a conventional separating cyclone. Product which floats in the cyclone is disposed of as either coarse and fine tailings (waste). Product that sinks (heavy minerals), is collected and transported to a feed storage bin for the diamond recovery section.



INVESTMENT AND LABOR

One reason diamonds are so valuable is the tremendous investment and labor that's required to obtain relatively small quantities of the end product. There are a couple of ways you could put this into perspective for customers:

- **Financial** – Nowadays many people manage their own investment portfolios so you might provide a little Wall Street-type analysis. As you've seen, the start-up costs for a diamond mine can be hundreds of millions of dollars. A number of the larger pipes process 5 million tons of ore per year. With exceptional efficiency, operating costs work out to about \$25 per ton. A pipe mine has an average lifespan of 30 years. Thus, the total overhead can easily exceed \$4 billion. Of course there's a return on this investment. In most cases, however, it's relatively modest. For example, over the next 15 to 20 years the Ekati Mine is projected to generate approximately \$6 billion in revenue.



For a pipe mine with an average lifespan of 30 years, the total overhead cost can easily exceed \$4 billion.

Photo courtesy Argyle.

For every point of finished diamond weight at least 1,200 pounds of rock and ore must be excavated.

- **Physical** – If customers aren't interested in the dollars and cents of diamond mining, they might be impressed with the points and pounds. Mine grades typically range from 10 to 100 carats per hundred tons of ore. Only 20% of the overall output is gem quality, however. Even in the top mines it may take moving 5 tons of ore, plus 25 tons of additional rock, to produce 1 carat of gem diamonds. About half that weight is lost in cutting. So the final yield is approximately 1/2 carat. This means that for each point of finished diamond weight, workers and machines somewhere in the world excavate at least 1,200 pounds of ore and rock!

RECAP OF KEY POINTS

- From the perspective of market economics, human activities like exploration and mining create much of a diamond's value.
- Finding a commercially viable diamond deposit can take decades of exploration and evaluation. Further development often requires heavy capital investment.
- Mining methods are dictated by the type and size of the deposit as well as the financial resources of the individuals or companies involved in the enterprise. The most industrialized operations are pipe mines.
- In the recovery phase of mining, ore first goes through crushers and washing machines that reduce the particle size and remove dirt. Then properties such as specific gravity and x-ray fluorescence are used to separate the diamonds.
- Explaining investment and labor can help some customers understand why diamonds are so valuable. Total development and operating costs over the life a diamond mine can surpass \$4 billion. For every point of finished diamond weight, at least 1,200 pounds of rock and ore must be excavated.

LESSON 11 FOLLOW-UP CHECKLIST

- _____ Develop a brief description of diamond mining (30 seconds or less). Then, with a coworker, role-play using that description to underscore the human effort represented by each diamond.
- _____ Scan through the lesson and highlight or underline key facts you can best use in your sales presentations. Look for points that make easy sense to you and that seem to flow with your personality and style of selling.
- _____ Select a diamond from your inventory and calculate the minimum pounds of rock and ore that had to be excavated to produce it. (Multiply the weight in points by 1,200.) Practice using that fact in a presentation.

Lesson 11 Self-Test

This lesson also includes a Self-Test that's designed to help you gauge your comprehension of the lesson material. The test is an important part of the learning process, so be sure to complete it.

When you're ready to take the test, go to the Course Materials page (the one that lists all the lessons and click on "Take Self-Test." Make certain you select the test for this lesson.

All questions in the test are based on Lesson 11. More than one answer for a question might seem correct, but you should select the one **best** answer based on the lesson discussion.

As you take the test, you may refer to the lesson. To do this, you'll need to have the lesson loaded in a separate window of your browser.

If you feel certain about a question, try answering it without looking at the lesson. But if you're not sure, check the lesson before answering.

After you answer a question, you'll receive immediate results and feedback. You'll find out whether you answered correctly, what the correct answer was (in case you missed it), and also the page number in the lesson where the information can be found. Take time to review any material you're not completely clear on.

At the end of the test, you'll receive your overall results. Then you'll be able to continue to the next step in your coursework.

If you have questions or need help, please contact us. You can use this website – just click on Help. You can also email studenthelp@diamondcouncil.org or phone 615-385-5301 / toll free 877-283-5669.