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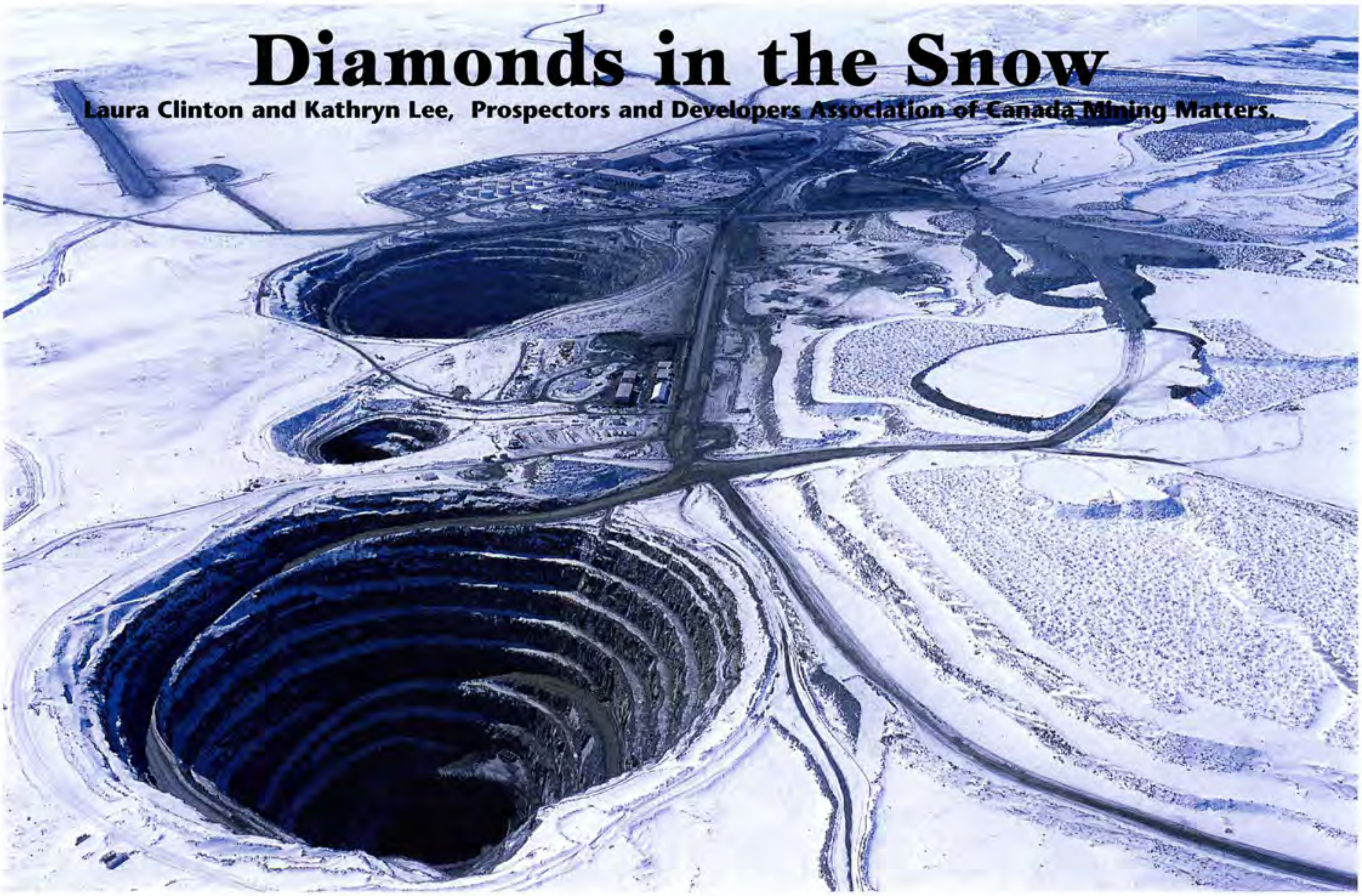
Diamonds in the Snow

Laura Clinton and Kathryn Lee, Prospectors and Developers Association of Canada Mining Matters.



Diamond is a mineral, a natural crystalline substance and is the transparent form of pure carbon. Diamonds found today were formed billions of years ago deep in the Earth's mantle, approximately 150 kilometres below the surface. Carbon in the mantle was squeezed together under tremendous heat and pressure, transforming it into hard, clear diamond crystals. Millions of years after the diamonds were formed, ancient explosive volcanoes acted like elevators, bringing diamonds from deep inside the Earth up through rocky carrot-shaped pipes to the surface. The pipes filled with volcanic rock, mantle fragments and some embedded diamonds. The rocks formed in the pipe and by the explosion are called kimberlites. Kimberlite pipes vary in size and shape, but are generally between 50 metres to several hundred metres across.

Diamond exploration begins with a search for the telltale kimberlite pipes – evidence of the long-ago eruptions. Diamond-bearing kimberlite pipes are only found in ancient areas of the continents. But diamonds have also been found far from the pipes. This is because volcanic rock erodes and is washed away over time. Rivers, streams and glaciers can carry diamonds far from the original volcanoes.

With much of Canada underlain by ancient bedrock, the existence of diamond-bearing kimberlite makes Canada a prime target for exploration. The first Canadian diamond was found in 1920 near Peterborough, Ontario by a worker digging a railroad cut. This diamond, and perhaps others, originated in kimberlite pipes located in the far north. Erosion released the precious mineral from a pipe and ancient glaciers pushed the diamond south. The first Canadian diamond mine was just recently opened in 1998 after exciting kimberlite discoveries in the Northwest Territories. This mine now produces 6 % of the world's diamond production, and diamond exploration in Canada is rapidly expanding.

Where to find Diamonds in Canada:

- ♦ Northwest Territories
- ♦ Wawa, Ontario
- ♦ Chapleau, Ontario
- ♦ James Bay Lowlands
- ♦ Even more prospective sites in Alberta, Manitoba, and Quebec!

Diamond Mining and Processing

There are two main types of diamond mining:

1. Pipe Mining: Extracting diamonds from kimberlite pipes

Initially kimberlite is dug from the surface of the pipes. Once the surface deposits have been exhausted, shafts are sunk into the ground at the edge of the pipes, and tunnels are driven into the deeper parts of the pipes. After the diamond-bearing rock is brought to the surface, it is transported to a sorting plant.

2. Alluvial Mining: Extracting diamonds from riverbeds or ocean beaches

Millions of years ago some diamonds were eroded out of the pipes and carried great distances along rivers and even into oceans. In order to extract diamonds from beaches, a wall is built to hold back the surf. Up to 25 metres of sand is bulldozed aside to reach the diamond-bearing level. Once reached, the diamond-bearing soil is removed and transported to a sorting plant. Mining of these deposits depends upon sufficient concentration and quality of diamonds.

The Sorting Plant

Diamond has a very high density, which means it can be sorted out from the waste rock by density suspension. In this process the diamond bearing rock is mixed with a muddy water suspension and stirred by rotating blades. The heavier materials, including the diamonds, settle to the bottom while the lighter waste rises to the top. The diamonds are sorted out from the ore concentrate usually by one of two methods:

1. Grease table

Diamonds repel water but are attracted to grease. So an easy way to pick out the diamonds is to flush the concentrate with water over a surface covered with grease, called a "grease table." The diamonds stick to the grease while the waste debris is washed away.

2. X-ray sorter

Some diamonds are fluorescent. This means that when diamonds are exposed to ultraviolet light, the diamond can absorb the high-energy radiation and re-emit it as visible light. An x-ray sorter takes advantage of this property. Diamonds fluoresce when exposed to x-rays and a sorter detects the fluorescence and triggers a jet of air, which knocks the diamond into a collection box.

Earth's Hardest Gems are on the Cutting-edge of Technology!

Diamonds are beautiful, rare and durable, but they are used for much more than gemstones. Since diamond is the hardest substance on Earth it has many uses. Diamonds' hard edges are used in dentists' tools to drill through tooth enamel and doctors perform surgery with diamond-edged scalpels. The precious mineral is used in protective eyewear, computer chips, and construction tools. Natural diamonds were even used to make a tiny window in the Pioneer spacecraft that went to Venus in 1978.

Sparkling Diamonds

- ♦ Most diamonds are 3 billion years old
- ♦ On the Mohs scale of hardness diamonds are the hardest at 10.
- ♦ Diamonds are better heat conductors than copper.
- ♦ Diamonds are the birthstone for April.
- ♦ Diamonds are measured by their weight in carats. One carat is equal to 1/100th of an ounce. The average diamond in an engagement ring weighs less than 1 carat.

Experience Diamond Exploration with your Students!

Unearth the history of diamond exploration in Canada and view an animation that illustrates the formation of diamonds at www.nrcan.gc.ca/mms/diam/index_e.htm. This fascinating Web site entitled Canada: A diamond Producing Nation from Natural Resources Canada contains a wealth of information and describes how diamond mining is adding a new lustre to the Canadian economy and dazzle to that of the Northwest Territories.

Visit http://sciencenorth.ca/learn/groundwork/ to explore for diamonds. Using maps, photographs and encouraging text, this interactive Web site takes your students through four exploration activities - geological mapping, geochemical surveys, geophysical surveys, and diamond drilling. After successfully locating a diamond-bearing kimberlite pipe, your students can continue their detective work as they explore for gold and copper!

Visit http://ekati.bhpbilliton.com/default.asp to download a poster and colouring book illustrating the story of this fascinating diamond mine.

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EDITORIAL

Well this has been an eventful year for both Peter and me. Part of the function of getting older is that things should slow down. I don't think that this has been the case for either of us! First I should say a big "Congratulations" to Peter for winning the 2004 GAC's Neale Medal. The competition for this medal is very stiff and I know that a number of excellent candidates will have to wait a year more for their award. I will let the internal expose for Peter speak for itself.

Next, another set of congratulations to Jane Lang also of the Earth Sciences department at Waterloo on her distinguished teaching award. And while I am in a congratulatory mode, another to Shoufa Lin, a colleague in the Department who picked up the Hutchinson Medal from GAC for distinguished scientific work.

Peter and I were both involved in the Brock EdGEO for teachers, associated with the GAC/MAC annual meeting and organized by Astride Silis, Rachal Fretz and Gregg Finn. This went very successfully with an afternoon session for teachers hooked into a one-day workshop, expounding on basic elements of geology, and followed by a one day field trip to various exposures in the Niagara Region.

The rest of the summer (to date) has gone as a bit of a blur, with various committee meetings, completion of a couple of book chapters, a presentation on the Grand River Geoscape at the Canadian Heritage River Conference at Guelph, preparation of the first part of my introductory geology course as a web course for Distance Education and planning for a field trip to Italian volcanoes (more in the Fall issue of What On Earth) and the International Geological Congress. I know that Peter has been equally busy with participation in a book on the Geology of Manitoulin Island and this issue of What On Earth.

In this copy we have included an expose of minerals that can be found in the Middle Silurian quarries at Dundas, Ontario. Two large items are on Geological Time (centrefold) and Diamonds in the Snow, the latter by Laura Clinton and Katheryn Lee, both of the Prospectors and Developer's Association of Canada.

(An interesting segway is that Stewart Blusson, one of the original discoverer's of Canada's first diamond mine, received GAC's prestigous Logan Medal at the same ceremony that honoured Peter and Shoufa).

Additional articles by Paul Karrow, Melissa Battler, Nancy Collins, and Jennifer Nafziger round out the current copy. Peter and I both hope that you enjoy it and find it useful. We look forward to contributions from any of our readers. ***Alan V. Morgan***

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INSIDE THIS ISSUE

Junior student sparkles at BHP Billiton Diamonds Inc.

Nancy Collins, 4B English Communications Associate, on her work term with UW Co-operative Education and Career Services.

As one of the world's most sought-after natural resources, diamonds symbolize many things, including love, engagement and success. Here at CECS, we are proud of our own precious resource – our junior co-op students. Full of enthusiasm and motivation, they are always up for a challenge. Kyle Murray, a 1A Environmental Engineering student, is no exception. When a job was offered to him at BHP Billiton Diamonds Inc. Kyle said goodbye to his cozy Waterloo life and ventured nearly 5000 km northward to BHP Billiton's EKATI diamond mine, located 300 km northeast of Yellowknife in the Northwest Territories.

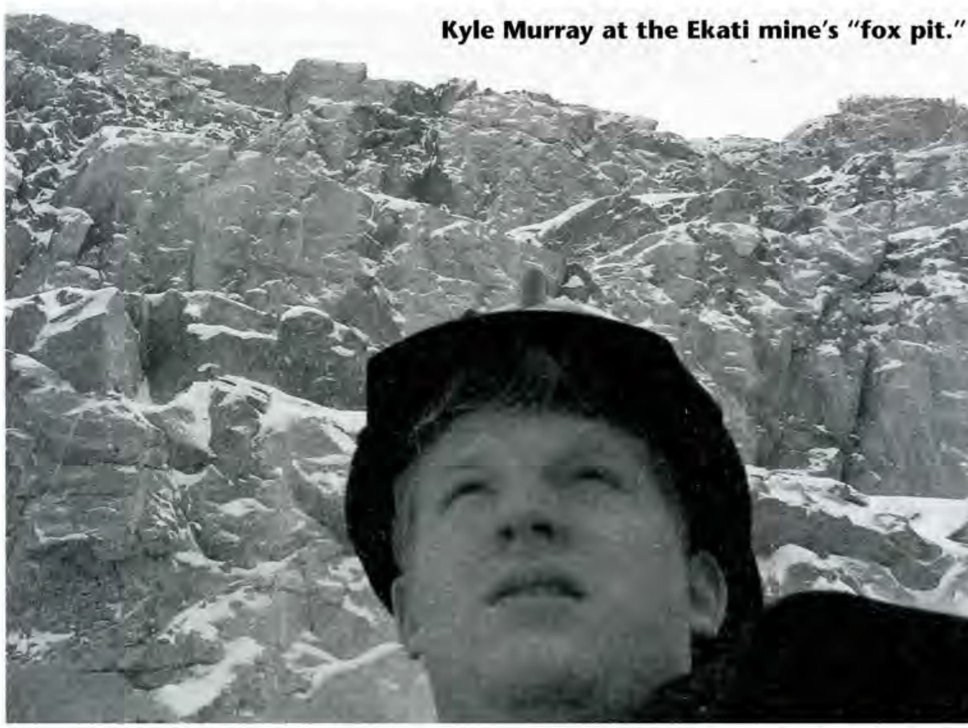
BHP Billiton Diamonds Inc. is part of the world's largest diversified resource company, BHP Billiton Group. Its EKATI mine is North America's largest operational diamond mine, yielding 4% of the world's diamonds by weight and 6% by value. An estimated $1.7 million dollars worth of diamonds are extracted daily at this massive operation.

In EKATI's isolated tundra environment, where winter temperatures can reach minus 40°C plus windchill, Kyle spent his winter in the Environment Department where he worked on a 4/3 rotation, with 4 days working and living at the mine site and 3 days off in Yellowknife. As a member of the environment team, he assisted with a variety of field, lab and office activities, such as extracting water samples and documenting spills. While this type of work may sound routine enough, as Kyle pointed out, life in a tundra environment can turn even ordinary activities into new challenges.

"The clothing required to venture outside in minus 40°C weather is very bulky. Goose down filled parkas, large snow pants, as well as multiple pairs of mitts. Trooping up and down a few flights of stairs wearing this type of equipment can tire you out quite quickly."

The cold created another interesting challenge for Kyle, in the form of a special project. Working independently, he researched the effects of cold weather on the accuracy of field instrumentation, an effort which allowed him to mesh the practical aspects of his job into a unique research study. Project opportunities like this one are something that BHP Billiton's Environment Department always offers its students, as a means of supporting their development in the area of environmental studies. Jim Millard, an Environmental Specialist at the EKATI mine, emphasizes that the company is dedicated to providing students with enriching work experience. "What I see from BHP Billiton, especially from the Environmental Department, is 100% support of students," he said. "We really believe in supporting students to give them the experience they require to become good environmental scientists or engineers."

This support extends to students at all levels. As a first work term student, Kyle was the most junior UW student to have filled the Environment position at BHP Billiton. Regardless, his positive attitude and motivation allowed him to excel and, according to Millard, attitude is what counts the most in a student. "If somebody has a really good attitude, it doesn't matter if they're first year, or second year, or third year," he said.



Kyle Murray at the Ekati mine's "fox pit."

Diamonds

Amy Sittler, Co-op Student,
Elmira District Secondary School.

The Diamond

The diamond is a crystalline form of carbon, and natural diamond is the hardest known mineral there is. The most common form is the octahedron, but other forms are cubes and irregular masses.

The Carat

Diamonds are measured in carats. A carat is 0.2 grams. The word comes from the Arabic kirat. One carat is divided into 100 "points" so that a diamond of 75 points weighs 0.75 carats. The carat weight is the most obvious factor in determining the value of a diamond. Although, the quality of the diamond is also very important.

Kimberite Pipes

These pipes of volcanic rock are where diamonds are found. The way to find diamonds in these pipes is to search for indicators of diamonds, not the diamonds themselves. Certain garnets, in particular red garnets may indicate the presence of diamonds.

Cutting and Polishing of Gems

A rough diamond looks like a piece of frosted broken glass. In order to become a piece of desirable jewelry the raw diamond has to be cut and polished. To cleave a diamond properly a small groove must be made in the diamond surface. Only diamond itself can cut another diamond since it is so hard. The process begins by placing a stationary diamond in contact with a diamond revolving on a lathe, or using a diamond saw while cutting against the grain of the diamond. The diamond saw is made of a paper thin disk of phosphor bronze spinning at more than 4000 revolutions per minute. The cutting edge is made of diamond powder mixed with olive oil. Then, after a groove is created in the rough diamond, a metal wedge is inserted into the groove and hammered once with a mallet to split the diamond. Facets are then cut at precise angles, to make the diamond refract all the colours of the rainbow. Diamonds can be cut into round, pear, or square shapes. The most popular cut is the brilliant cut with 58 facets. The final stage is to polish and clean the diamond. Only about 50% of the rough diamond is actually used in the gem quality diamonds.

Courtney Keenan, Aurora College, Yellowknife, cuts a diamond at the Prospectors and Developer's Conference in March 2004. Aurora College has programs on diamond mining,cutting and polishing. www.auroracollege.nt.ca/

This emerald-cut stone, cut by Courtney is 0.75 carats

http://talc.geo.umn.edu/courses/1081/notes/page4.html

Uses for Diamonds

Diamond use can be split into two categories, gem and industrial diamonds.

Gem Diamonds are prized for their:

- Brilliance – which is the ability to reflect light back to the eye
- Fire – the ability to refract or bend light rays, and to disperse light into the separate colours of the spectrum
- Scintillation – the ability to "twinkle" when the diamond is moved

The way a diamond is cut will determine the degree to which it will exhibit these characteristics.

Industrial diamonds are the most important industrial abrasive. They are hard enough to cut superhard materials with speed, precision, and economy. Many of the industrial diamonds are synthetically produced, but at very high costs. The uses of diamonds industrially are:

- Lapidary for polishing or grinding optics, gems and glass

- ♦ Drill bits
- ♦ Saws for cutting resistant materials
- ♦ Shaping very fine wires or to cover turning, boring, and milling tools
- ♦ Surgical equipment

Diamonds in Industry

Diamond studded rotary bits are used to drill oil wells, and for mining minerals and building tunnels, for things like subways and highways, etc. Low-grade diamonds are crushed to dust in different grain sizes; this is used as an abrasive powder. The powder is also used to polish and cut gems, including diamonds. There are also diamond-tipped glasscutters, and glass etching pencils. Diamonds can also cut thick wire into thin wire. Synthesized diamonds are also used for industrial purposes. In the late 1980s the technology was developed to use diamond coatings on surfaces. These coatings can be used to cool integrated circuits as a whole instead of cooling each part individually. Another use for the coating may be in prosthetic devices and biosensors.

Man-Made Diamonds

There are man-made substitutes that resemble diamonds in their appearance, like cubic zirconia, but cost much less. These laboratory-created gemstones and man-made diamonds are sometimes hard to distinguish from natural ones. Imitation diamonds have more fire (flashes of colour) but sparkle slightly less than real diamonds, and have become popular as an alternative to real diamonds.

LifeGem

A LifeGem is a certified, high quality diamond created from the carbon out of cremated remains. This is a unique and timeless way to remember your loved ones, and the life they lived. The process involves capturing the carbon from cremated remains, which is then heated to extremely high temperatures under special conditions. The carbon is removed at this point, and is converted into graphite. Then the graphite is placed into a diamond press which imitates the forces of nature that create a diamond- heat and pressure. The final step is the cutting, and this entire process takes about 18 weeks, a far cry from the millions of years it takes to make a real diamond. "Like the memory of a loved one, a diamond lasts forever."

http://www.lifegem.com/index.asp

Famous Large Diamonds

The largest rough diamond ever found was the Cullinan diamond. It was found in South Africa in 1905 and it weighed 3,106 carats. There have been many other large diamond finds, including the Excelsior in 1893. It weighed 995.2 carats and was also found in South Africa. The Star of Sierra Leone came from Sierra Leone in 1972 and weighed 969.8 carats.

Blood Diamonds

Blood Diamonds, or conflict diamonds are defined as, "diamonds that originate from areas under control of forces that are in opposition to elected and internationally recognized governments". The presence of terrorist groups in diamond-rich countries is funded by sale of "blood" diamonds. Sierra Leone is suffering from conflict caused by the availability of diamonds. Other minerals also fund similar conflict, such as Coltan (Columbium-Tantalum) in the Congo.

http://archive.salon.com/business/feature/2000/09/27/diamonds/print.html

The Four C's of Diamonds

CARAT-WEIGHT: The weight/size of a diamond is measured in Carats. One carat is divided into one hundred segments called "points". As in the decimal system, one hundred and twenty five points equals one and a quarter carats.

CLARITY: This is the degree to which a diamond is free of inclusions. Where the inclusions lay, their size, their type, all are factors which determine the value of the stone.

COLOUR: This is another aspect where scarcity determines value. Colourless diamonds are extremely scarce in nature and they are representative of the peak of colour grades.

CUT: Today the art of diamond cutting has been refined to precise mathematical formulae. Most diamonds today are cut with 58 facets. A good cut is determined by its light-reflecting properties and its light dispersion.

http://www.indianchild.com/man_made_diamonds.htm

Diamond Cartels

The problem with diamonds isn't their scarcity, but actually their controlled availability in the marketplace. What cartels do is puts a hold on production to keep the prices of diamonds high and to maintain a strong monopoly. This is something the De Beers diamond cartel knows well. The cartel has stifled the flow of gem quality diamonds from sources that are not under its ownership or control, using a variety of methods.

Famous Diamonds

♦ **The Blue Hope Diamond:** 45.52 carats- This is a dark, steely blue stone from India. It is named the Hope Diamond after one of its owners, Henry Philip Hope. This diamond is famous for its bad luck. It is a feature at the Smithsonian museum.
http://www.nmnh.si.edu/minsci/hope.htm

♦ **The Koh-I-Noor (Mountain of Light)**: 105.60 carats, originally 186 carats- This oval cut diamond dates back through legend before the time of Christ. It was said that whoever owned this diamond ruled the world.

♦ **The Cullinan Diamonds:** 3,106 carats (original rough)- This is the largest gem quality diamond that was ever found, discovered on January 26, 1905 in South Africa. It was noted for its exquisite colour and exceptional purity. It is thought that since the stone had a surprisingly smooth surface on one side it was only part of a larger diamond that was broken off in a weathering process. The Cullinan I is known as the Great Star of Africa weighing 530.20 carats, and the Cullinan II is the Lesser Star of Africa at 317.40 carats.

♦ **The Regent:** 140.50 carats- A stunning gem with a light blue tinge, that is considered the most perfectly cut of all the celebrated old diamonds.

♦ **The Centenary:** 273.85 carats- On the 100-year anniversary of De Beers in 1988, they chanced upon finding a 599 carat diamond, in the rough. After three years of cutting, it was known as the largest modern-cut, flawless diamond.

♦ **The Orlov:** 300 carats (original rough)- The shape of this gem has been likened to the half of a pigeon's egg. It has about 180 facets, and is mounted in the Imperial Sceptre.

♦ **The Idol's Eye:** 79.20 carats- A flattened, pear-shaped stone about the size of a bantam's egg that was once set in the eye of an idol, but was stolen.

♦ **The Taylor-Burton:** 69.42 carats- A spectacular pear-shaped diamond bought by Richard Burton for his fifth wife, Elizabeth Taylor, as a gift.

♦ **The Sancy:** 55 carats- This is a pear-shaped diamond that was named after its owner Seigneur de Sancy.

♦ **The Dresden Green:** 41 carats- This almond shaped stone is the largest apple-green diamond known. The green colour is attributed to the stone's close contact to a radioactive source at some point in its lifetime. Other than its colour it is famous for its elongated shape.

♦ **The Jubilee:** 245.33 carats- A magnificent, colourless cushion-cut diamond that once ranked the sixth largest in the world. Many gemologists considered the Jubilee to be the most perfectly cut of all large diamonds. The facets are so exact that the diamond can be balanced on the culet point, which measures less than 2 millimetres across.

Web Resources

http://www.diamondinfo.org/

http://interactive.usask.ca/ski/mining/search/mineral_types/industrial/diamond.html

http://www.indianchild.com/man_made_diamonds.htm

http://ist-socrates.berkeley.edu/~eps2/wisc/diamondcom.html

http://archive.salon.com/business/feature/2000/09/27/diamonds/print.html

http://www.ncpa.org/pi/internat/pd080300b.html

http://www.maths.tcd.ie/local/JUNK/econrev/ser/html/try.html

http://www.shaneco.com/jewelry/famous_diamonds.asp

http://talc.geo.umn.edu/courses/1081/notes/page4.html

Greg Stott of the Ontario Geological Survey points out the diamond occurences in Ontario. The Ontario kimberlites erupted during early Jurassic times along the trend of dikes of diabase which were intruded during the Precambrian.More details available at www.mndm.gov.on.ca/mndm/mines/ogs/posters/Stott_opa_2003_panel1.pdf

The Rise and Fall of the Great Lakes Revisited (Part 3)

Quaternary Sciences Institute Paul F. Karrow PFK-15

Glaciers make great dams. Ice is impermeable. Yes, it may crack, or dissolve in water, but if it's thick enough (more than about 50m) it flows under its own weight and tends to fill cavities (we might say "self-healing" or "self-sealing).

The last ice sheet, like its predecessors (there were many) in melting away as climate warmed about 20,000 years ago, released huge quantities of meltwater. As the southern limits reached by the ice sheet were along the Ohio River valley in the U.S.A., it was free draining, and remained so as long as the margin was south of the drainage divide between the Ohio River and the Great Lakes basin. However, once the ice edge melted back north of the divide, glacial lakes began to form in the low ground between the divide and the ice sheet (Fig. 1). In reality, such depressional areas were filled by meltwater to overflowing at the lowest available point around the edge. In the Great Lakes area, each of the present lake basins was occupied by a succession of glacial lakes. In general, the oldest lakes were the highest and successively lower lakes formed as the ice melted back to expose lower outlets. If the ice thickened and readvanced, lower outlets were sometimes blocked, raising water levels higher again (only temporarily).

A network of meltwater escape routes has been recognized in the Great Lakes area (Fig. 2), occupied at different times as the ice melted back far enough to expose them. These routes, graded by flowing water, have been used for human transportation routes – e.g. Trent canal between Georgian Bay and Lake Ontario; 11,500 years ago the Trent Valley linked glacial Lake Algonquin in the Huron basin to glacial Lake Iroquois in the Ontario basin, and the route of the never-built Georgian Bay Ship Canal near North Bay (not to mention that of the voyageurs of the fur trade); ten thousand years ago it drained glacial Lake Algonquin of the Huron basin down the Ottawa Valley to the Champlain Sea.

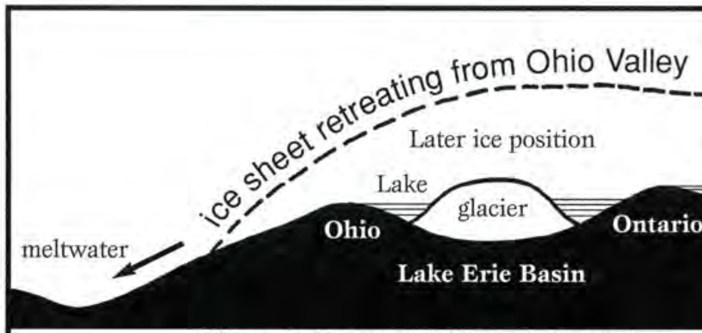


Figure 1. Drainage divide and glacial lakes

Remember that the ice sheet caused the Earth's crust to sink and as the ice melted the crust rose again (see What on Earth Spring 2002), a process so slow it continues today. However, 10,000 to 12,000 years ago, as the ice sheet was melting away from southern Ontario, much of that rebounding had not yet taken place so the land to the northeast was much lower than it is today. With that in mind, picture the ice unblocking the east end of the Erie basin so the contained glacial lakes could flow freely to the northeast, and later the same thing in the Ontario and Huron basins. When these three basins were "uncorked" by the retreating ice front, water levels dropped to way below their present levels (by 50 to 100m or more). That left a lot of former glacial lake bottom dry land, which was soon occupied by plants and animals. Then as the crust tilted up to the northeast, water in the basins was raised to about their present levels over thousands of years. From time to time drowned forest stumps are found in the bottoms of lakes Erie and Huron, giving evidence of the former land areas drowned by uplift of the sills (Fig. 3).

Thus, glacier fluctuations have also caused great effects on Great Lakes water levels.

Figure 2. Spillways of the Great Lakes area

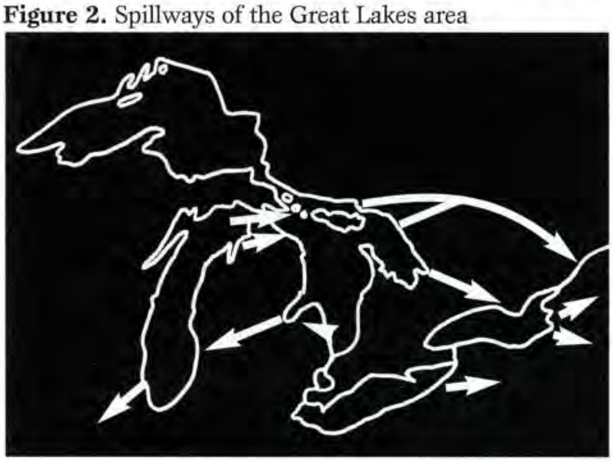
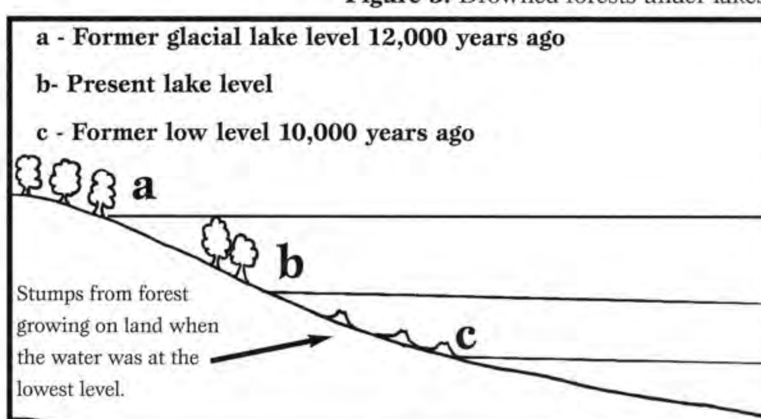


Figure 3. Drowned forests under lakes



Dundas Quarries

Alan V. Morgan

Not so very far from the University of Waterloo are a number of large stone quarries working the dolostones at the top of the Niagara escarpment near Dundas, Ontario. Our older magazine "WAT ON EARTH" described a visit to this quarry a number of years ago (Wat On Earth, volume 14, number 2, 2001).

Background.

The Dundas Quarry is working well-bedded sedimentary rocks of the Lockport Formation of middle Silurian age (about 425 million years). These sequences show some interesting mineralization that we will come to shortly. The principal product being quarried is dolostone, a calcium-magnesium rich sedimentary rock. The end use is for aggregate, building stone (Figure 1), facing blocks and a component that is used in fluxes in the metallurgical industry. The working faces have exposed a number of interesting geological features, two of which are mentioned here.

Faults

Several small faults cut parts of the sequences. One of these can be seen in Figure 2. The student is looking at a curved face that cuts through the well-bedded dolostones. The curved face is the fault plane and the grooves, technically called "slickensides", show that this fault has moved horizontally rather than vertically. High horizontal stresses have been documented from the Hamilton region and these might also be expressed in the phenomenon known as:

Pop-ups

Southwestern Ontario has a large number of features known as "pop-ups". These are breaks in the bedrock sequences (both Ordovician shales and Silurian carbonates) where the flanks of the pop-up dip sharply away from a central crestline. In Figure 3 Peter is standing on such a crestline in the Dundas Quarry. These "heaves" or "bumps" are frequently encountered when mining has relieved some of the confining pressure and the stresses disrupt a quarry floor or mining adit.

Mineralisation at Dundas

Given the nature of the bedrock (Calcium and Magnesium carbonates) it is not surprising that calcite, $CaCO_3$, is

abundant, infilling many fractures in the rock mass. These angular chunks are part of a breccia (a sedimentary rock with angular fragments) that has calcite cementing the blocks together. Elsewhere it is not uncommon to see small voids or "vugs" that are lined with calcite crystals. These whitish masses are "nail-head" calcite crystals in the more massive grey-buff coloured dolostone. The calcite crystals can also form more interesting shapes. We call these well-formed crystals, scalenohedrons. In more easy terminology they are known as "dog-tooth spar".

Sometimes the voids are lined with a greenish or yellowish brown mineral. This is a variety of iron sulphide known as marcasite. Here individual calcite crystals are sitting on marcasite. Iron pyrite (FeS_2) and is commonly found as "films" – rather thin dustings that encrust joint surfaces and fractures in the rock.

Figure 1. Dundas Quarry

Figure 2. "Slickenslides"on the side of a fault

Figure 3. Peter is standing on the crestline of a pop-up in Dundas Quarry

Figure 4. Celestite

Figure 5. Calcite scalenohedra, also known as dog-tooth spar.

Figure 6. Galena on marcasite found in a vein exposed in the 1960's.

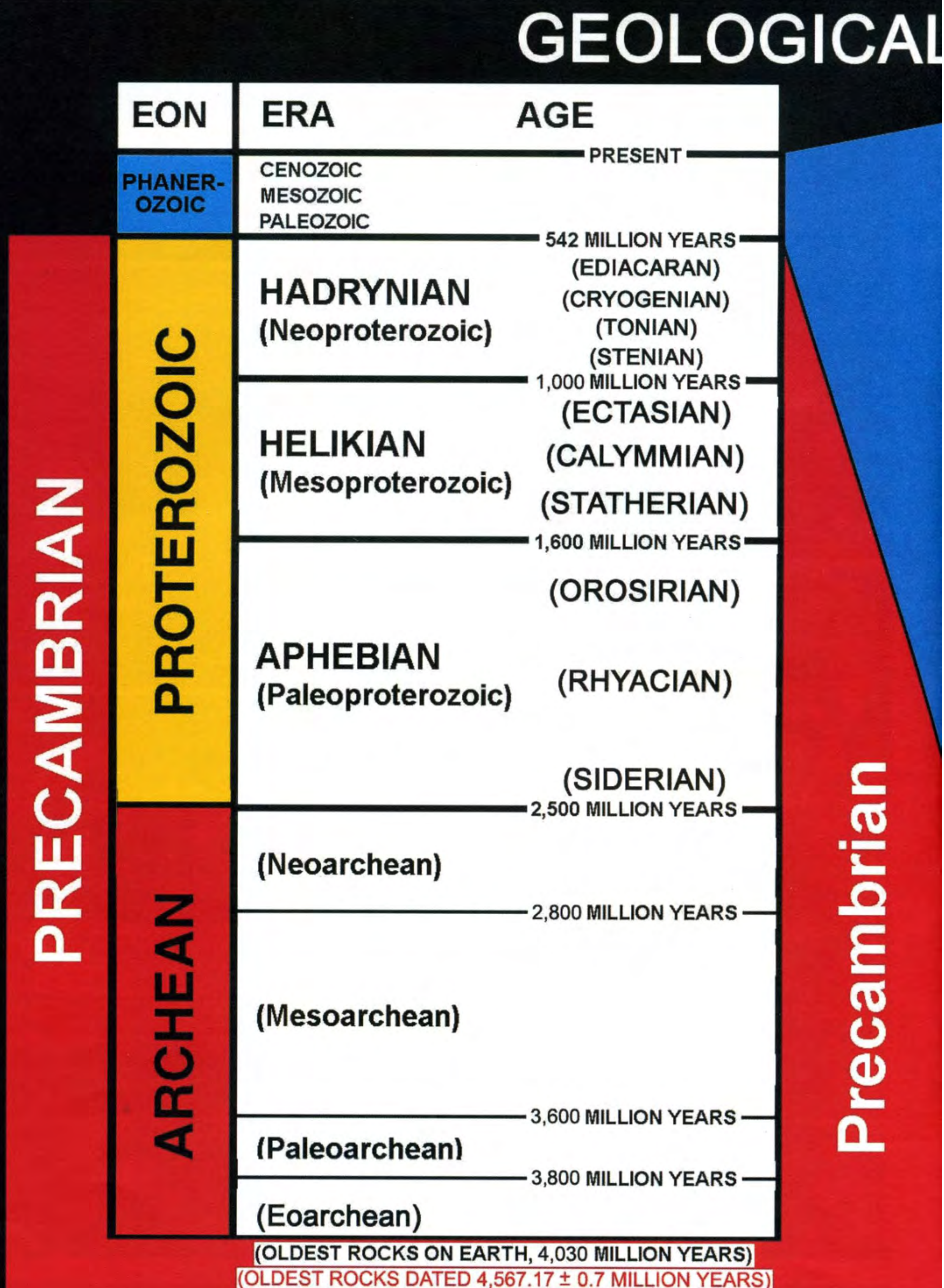
Figure 7. Calcite on marcasite found lining vugs in the dolostone.

Figure 8. Sphalerite and calcite.

A rarer blue coloured mineral is celestite ($SrSO_4$) or strontium sulphate. It is the source of strontium used in fireworks and sugar beet refining.

Perhaps the most interesting commonly found mineral is sphalerite (ZnS), the principle ore of zinc. Lead and zinc are frequently found in sedimentary sequences especially those of the American mid-west. These are known as "Mississippi type" ores. A more massive form (with white calcite) is seen below. Typical views of sphalerite show the traditional brownish-yellow (amber) colour on some of the lighter surfaces.

Other minerals that can be found at the quarry are the halide mineral, fluorite (CaF_2), and lead sulphide, galena (PbS), the chief ore of lead.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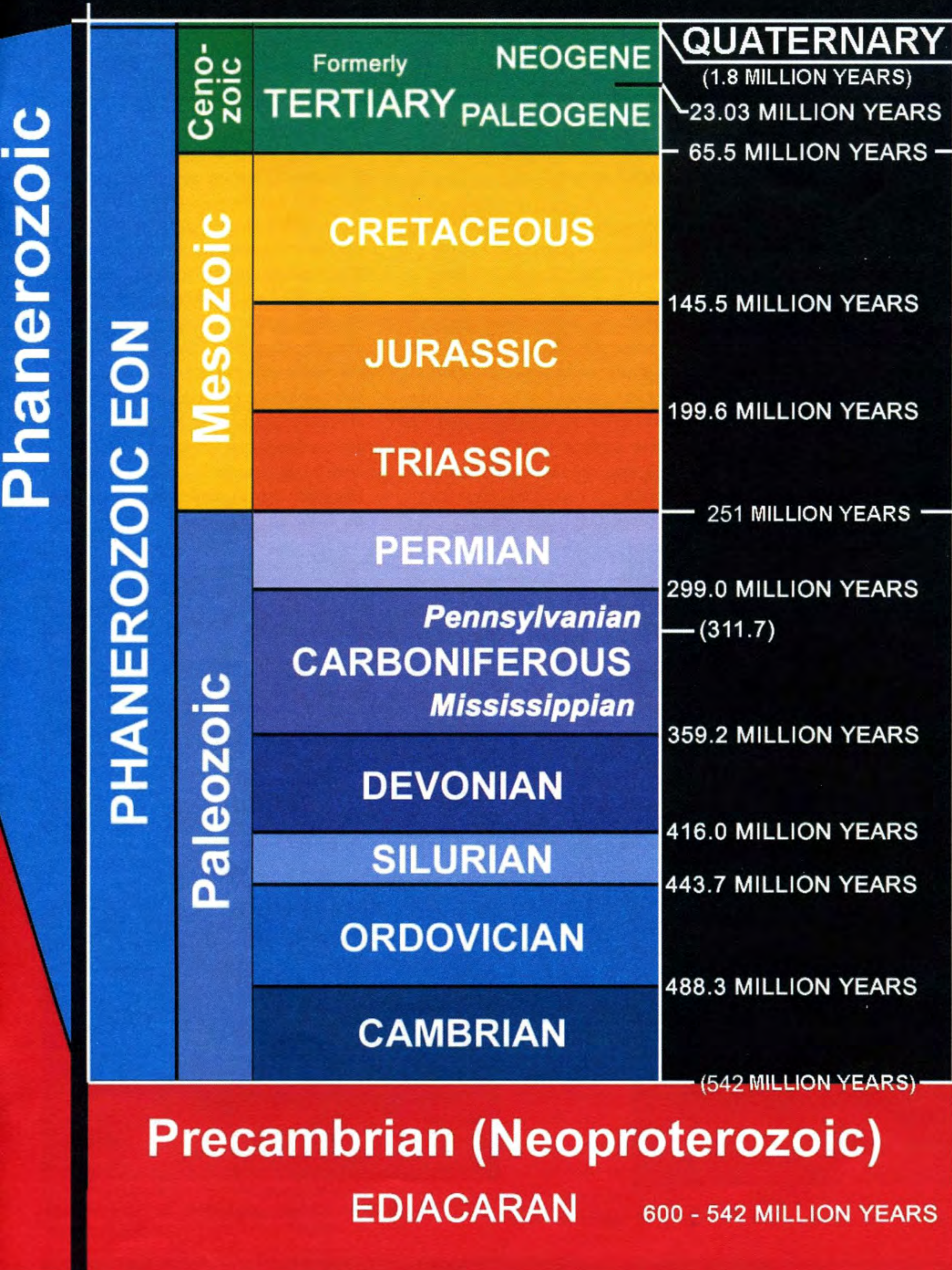
AGE
PRESENT
PHANER-OZOIC
CENOZOIC
MESOZOIC
PALEOZOIC
542 MILLION YEARS
PRECAMBRIAN
PROTEROZOIC
HADRYNIAN
(Neoproterozoic)
(EDIACARAN)
(CRYOGENIAN)
(TONIAN)
(STENIAN)
1,000 MILLION YEARS
HELIKIAN
(Mesoproterozoic)
(ECTASIAN)
(CALYMMIAN)
(STATHERIAN)
1,600 MILLION YEARS
APHEBIAN
(Paleoproterozoic)
(OROSIRIAN)
(RHYACIAN)
(SIDERIAN)
2,500 MILLION YEARS
ARCHEAN
(Neoarchean)
2,800 MILLION YEARS
(Mesoarchean)
3,600 MILLION YEARS
(Paleoarchean)
3,800 MILLION YEARS
(Eoarchean)
(OLDEST ROCKS ON EARTH, 4,030 MILLION YEARS)
(OLDEST ROCKS DATED 4,567.17 ± 0.7 MILLION YEARS)
Precambrian

TIME SCALE


Phanerozoic
PHANEROZOIC EON
Ceno-zoic
Mesozoic
Paleozoic
Formerly TERTIARY
NEOGENE
PALEOGENE
QUATERNARY
(1.8 MILLION YEARS)
23.03 MILLION YEARS
65.5 MILLION YEARS
CRETACEOUS
145.5 MILLION YEARS
JURASSIC
199.6 MILLION YEARS
TRIASSIC
251 MILLION YEARS
PERMIAN
299.0 MILLION YEARS
Pennsylvanian
(311.7)
CARBONIFEROUS
Mississippian
359.2 MILLION YEARS
DEVONIAN
416.0 MILLION YEARS
SILURIAN
443.7 MILLION YEARS
ORDOVICIAN
488.3 MILLION YEARS
CAMBRIAN
(542 MILLION YEARS)
Precambrian (Neoproterozoic)
EDIACARAN
600 - 542 MILLION YEARS

The Geological Time Scale

Alan V. Morgan

One of the "advantages" of living to be a more "senior" person is the hindsight gained in looking back over your lifetime. In the half-century (plus a little) that I have been interested in geology, the geological time scale has been refined time and time again. For example, when I started university, back in 1961, the base of the Cambrian period was 600 million years, then placed at 530 million (1982), back again to 590 million (also in 1982), then to 570 (1990) and now, perhaps finally, placed at 542 $\pm$ 0.2 million years (Ma). Remember that the Cambrian and younger rock sequences only represent a small part of the geological time scale that has been established over 200 years of geologic observations. But perhaps I am getting a little beyond myself.

Certainly at the age of about 10 or 11 I was looking at rock sequences in my hometown of Barry in South Wales. I would like to share a few of these observations since they throw some light on the perplexing problem of sorting out the age of the world. I was really fortunate in living in a part of Britain where the geological structures were only moderately affected by earth movements in the past and so it was very easy to observe the juxtaposition of beds. This brings me to the first aspect of dating termed:

Relative dating

Figure 1 shows a rock sequence exposed in the sea cliffs about one kilometre from my childhood home. The beds here are horizontal and they display three of the fundamental laws that cover stratigraphy. **The Principle of Superposition** first expounded (or at least documented) by Nicolaus Steno over 300 years ago states that the oldest (first deposited) bed is always at the bottom of a given sequence and the youngest (last deposited) bed is always at the top. (The inherent assumption is that the sequence has not been totally inverted). The **Principle of Horizontality** is another assumption that the sediments that form the bed were laid

Figure 1: Horizontal basal Jurassic strata, Old Harbour, Barry, South Wales.

Figure 2: Angular unconformity at Friar's Point, Barry Island, South Wales.

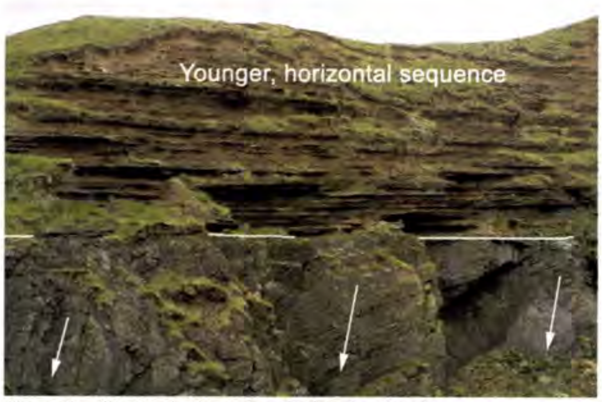


Figure 3.: "Hutton's Unconformity" in Scotland.

Figure 4: Igneous rock near Kingston, ON. The light angular unconformity (grey overlying beds) contains clasts from the lower sequence, and must be younger.

down horizontally. In a sequence that is as well defined and undisturbed it is easy to see the fundamentals of a third principle. This is the **Principle of Lateral Continuity;** where one can follow a bed for hundreds of metres (or even kilometres) until the bed finally either grades into another lithological unit, thins out and vanishes, or is cut off by some other factor. It might drop below beach level, be cut by topsoil at the ground surface or terminate in a rock break such as a fault or a sharp contact with another rock type.

Figure 2 illustrates another outcrop on a nearby headland. Again the geology is relatively simple but it shows a fourth important principle. This is the **Principle of Cross-cutting Relationships.** The Principle of Cross-cutting Relationships states that in a given rock sequence if "something" (and the something might be an igneous intrusion, a mineral vein, a fault or younger strata) cuts through a sequence of beds then the "something" must be younger than the beds through which it cuts. In Figure 2 it is fairly easy to see that the lower beds (originally deposited horizontally) have been subsequently tilted and then cut by a second (horizontal) sequence. Even as a younger person it was not difficult to assume that the tilted sequence was older than the horizontal strata above the dipping beds. More importantly this illustrates the concept of relative ages. Let's put this in order of events, so we start at the bottom (the oldest part).

Stage 8: Formation of topsoil and growth of grass.
Stage 7: Erosion of the upper, horizontal strata (note that the erosion surface is more irregular)
Stage 6: Accumulation of the upper beds as horizontal strata on the flat erosion surface
Stage 5: Erosion of the lower unit (note that the erosion surface is horizontal)
Stage 4: Uplift of the lower unit
Stage 3: Tilting of the lower unit.
Stage 2: Compaction and lithification of the sediments.
Stage 1: Deposition of material as horizontal sediment.
(Start here and work upward).

By working your way from one local outcrop to the next "up" or "down" through each sequence, it is possible to find additional regionally younger and older units and to determine how beds might grade laterally from one lithology into another. This provides a "relative" way of assessing the oldest and youngest beds in the area being studied. Perhaps one of the most famous examples in the world is "Hutton's unconformity" at Siccar Point in Berwickshire, Scotland (Figure 3). It was at this locality that James Hutton recognized the true immensity of geological time and helped the natural historians of the day to break away from the religious dogma that supposedly (according to the Irish Bishop Ussher) dictated that the world was created in 4004 BC.

If you are dealing with metamorphic or igneous terranes that have no fossils then you can probably at least determine which are the oldest and youngest rocks and the age progression of each by using cross-cutting relationships. An example is illustrated in Figure 4.

In sedimentary units your observations will not only include the lithology of the beds that you are mapping (which allows a determination of the type of environment that existed when the sediments were deposited), but also the fossil content of the beds concerned. Fossils may be blatantly obvious, or they may be totally absent. Most sedimentary rocks do contain macroscopic or microscopic fossils and a careful determination of the families, genera and species might also allow the "age" of the beds to be determined.

Certain fossil groups are "generalists" existing for huge blocks of geologic time with little or no apparent change. The small intertidal brachiopod *Lingula,* looks the same today is it did in rocks as old as 500 million years. On the other hand, more rapidly-evolving organisms such as certain graptolites or ammonites, changed morphologically over "short" periods of geologic time (perhaps 500,000 years). We use the fossilised remains of such rapidly-evolving animals or plants as **zonal fossils.**

Zonal fossils have certain requirements. In a rather simplistic way, these are: **rapid evolution** (they exist for short time frames); **easily recognised** (usually a function of **hard parts** that are easily preserved); **wide geographic distribution** (found in many different parts of the world), and **presence in rocks of different lithologies** (many depositional environments). Many excellent zonal fossils were "drifters" in marine sequences of the past.

Because zonal fossils existed for short widows of geologic time one can use their presence to correlate one outcrop with another. This is true in regional contexts but might also be true for world-wide correlation. *Lingula*, for example, would make a most unsuitable zonal fossil because finding specimens in a rock sequence would not provide much information about age (only that the rock sequence falls somewhere in the last 542 million years of geologic time)! On the other hand finding *Psiloceras planorbis* (an ammonite) would be extremely useful over much of western Europe since it only exists in the lowest zone of the Jurassic (199.6 +/- 0.6 Ma). Putting a geological age such as this on a fossil takes us out of the realm of relative dating and into:

Absolute dating.

"Absolute dating" implies "absolute dates" and this is not quite correct. To a geologist it illustrates that a certain radiometric decay series has been used (sometimes more than one) to determine the rock age. It does not imply precise calendar years, but it does

Table 1: Main radiometric dating techniques

Elements and isotopes involved	Half-life	Age range provided	Dates obtained from
Uranium – Lead Series			
238U - 206Pb	4.6 Billion years	Age of Earth	Zircon
235U - 207Pb	713 Million years	Age of Earth	Zircon
Potassium - Argon			
40K - 40Ar	1.3 Billion years	Age of the Earth	Micas (volcanic rocks)
Radiocarbon dating			
C14 - N14	5,730 years	-150 to ~ 50,000	Organic materials

provide a framework which, with limitations, provides an approximation of the ages of rocks. For example the age determinations on the junction between Cretaceous and Paleogene (Tertiary) rocks are 65.5 +/- 0.3 Ma. Multiple determinations using different dating techniques on this boundary from many different areas of our planet average at this age. Rocks older than this (Cretaceous) contain dinosaur remains. Rocks younger than this (Paleogene in age) do not contain dinosaur remains, unless odd bones have been weathered out and are incorporated in younger sediments. If you wander the badlands of Alberta you will find dinosaur bones (sometimes lots of them; - see What On Earth, Fall issue 2003), but this is not an indication that dinosaurs are alive today. Dinosaur bones can therefore be incorporated into sediments that are being laid down today in the Red Deer River valley, but to a future (insectoid?) geologist it should not be an indication that dinosaurs were alive in the Quaternary Period (the time frame that we live in today). On the other hand, bones of humans cannot be found in sediments of Cretaceous age because humans simply were not alive on Earth at that time.

Painstaking analyses of different rock sequences all over the world by generations of geologists have provided observations that allow us to state, with a fair degree of confidence, what types of fossils should occur when and where. Of course Mother Nature throws us an occasional odd curve ball, such as the discovery of living coelacanths in the Indian Ocean, when the last fossil specimens found in rock sequences date back to about 70 Ma!

I have implied above that we use different types of dating methods to provide ages on rock sequences. A discussion of each of them is beyond the scope of this article, but I would like to mention the main techniques and the ages most suited to that determination. These are summarised in Table 1.

A detailed discussion of each of these methods is inappropriate. Suffice to say that the parent product will decay to a daughter product (often through a whole series of subsidiary decay series). The measurement of the remaining "parent" isotope to the abundance of "daughter" isotope provides a measurable difference that allows a calculation of the "age" of the rock under examination. If you are really interested in following this topic I refer you to the webpage of the International Stratigraphic Commission (www.stratigraphy.org).

I have provided a simplified example using radiocarbon-14 as an example. This is also known as Carbon-14 or radiocarbon dating. Radiocarbon dating is extremely useful to Quaternary geologists looking at the younger events of the last ice age and to archeologists, studying the past 40,000 to 50,000 years since practically all organic materials — shells, bones, teeth, skin and hair, peat, wood, (and structures made from wood), or charcoal — can be dated. There are some problems with the technique. Human use of fossil fuels (coal and oil particularly) has added vast quantities of "infinitely old" carbon to our atmosphere over the past 200 years. Furthermore, above-ground testing of large nuclear bombs, especially in the 1960's, added radioactive contaminants that complicate analyses of natural decay rates. For these reasons dates prior to about 1800 are considered reliable and dates following 1800 are not usually attempted. At the more distant end of the methodology dates beyond about 50,000 are also considered unreliable.

How does this technique work? Cosmic rays from our Sun, enter the upper atmosphere forcing the conversion of $Nitrogen^{14}$ to $Carbon^{14}$. Most $Carbon^{14}$ is oxidized to form Carbon Dioxide (CO_2). The CO_2 is then absorbed by plants, which are then eaten by other organisms. However, some of the original $Carbon^{14}$ is not altered and the ratio of original $Carbon^{14}$ (the unstable form) to CO_2 (the stable form) is about 1 atom to one trillion atoms. When the plant or animal dies it stops taking in

CO_2 and the decay of Carbon14 begins. Since the dead plant or animal cannot take in any more CO_2 or $Carbon^{14}$ the "radiometric clock" within the organism begins to count down. We know the precise decay rate of $Carbon^{14}$ since it has been measured against annual rings taken from long-living organisms, sections of giant Sequoia trees, for example that are $>2,000$ years old or Bristlecone Pine ($>4,000$ years). The $Carbon^{14}$ in the sample decays to $Nitrogen^{14}$ in a constant manner, with 50% changing (or "one-half life" changing) every 5,730 years. Put in another way, 5,730 years after the organism dies only 50% of the $Carbon^{14}$ contained within the organism remains. After another 5,730 years (or at 11,460 years after the organism died) only 25% remains. Unfortunately by 7 half-lives (age 40,110 years) less than 1% of daughter isotope is left. This explains why dates greater than 50,000 years before present are considered unreliable, since the amount of measurable activity is exceedingly small. Incidentally, "before present", is by convention before 1950. Conversion scales for "carbon-14 years" to real "calendar years" are also available in the very youngest part of time.

Radiometric dating, therefore, depends on when the "parent" material was formed and the rate of decay of that parent material to the daughter product. In the case of igneous rocks it depends on the time of crystallization of the parent mineral in the rock that is being dated. Let's take the case of a granite, an igneous intrusion that is, in reality, two billion years old. The atomic clock starts counting down when the magma cools. Unfortunately the rock sequence is involved in a later reheating (perhaps another mountain-building episode) at one billion years. The atomic clock within the granite is "reset" by this later reheating and partial melting episode, and acquires the "new" later age. Geologists must be aware that they are dating this later episode of mountain building and not the original age of the granite. Careful mapping and dating elsewhere in the region can usually resolve such conflicts.

When the granite disintegrates a geologist might date grains of feldspars (using Potassium40 dating) that are trapped in sedimentary rocks. The sedimentary rocks are, perhaps, 600 million years old. However, the geologist would have to be careful to realize that they might be dating grains that come from the original granite that cooled 2 billion years ago, or from the "reset" feldspar ages that were derived from the altered granites one billion years ago. Neither of these ages would reflect the "true" age of the sedimentary sequence that is 600 million years old.

The net result is that with reliable dating methods that have been developed largely over the past three or four decades, coupled with meticulous geological mapping over the past 200 years, the geoscience community has been able to unlock the history of our world. We know how old it is, when life forms began to inhabit the Earth; when major catastrophes and calamities have overwhelmed our planet; when new species have appeared or evolved, in many cases, provide the rates of evolution. Finally we have been able to say when certain mineral deposits (including all the energy minerals, so necessary for our survival) were created and also how our world has physically evolved. Much remains for future generations of geologists! The current geological timescale is featured in the centrefold of this issue.

Some comments on the Timescale and Teminologies use.

The timescale illustrated in the centrefold is the latest version of many. This is the currently accepted scale with the latest refinements using absolute time. The meeting of the 32nd International Congress, to be held in August of 2004 in Florence, Italy, will ratify a number of the latest amendments.

Please note that I have not used the correct colours for the various divisions of geological time (there are indeed designated colours) and I have introduced a few of my own views. For example, in the left side of the diagram in the Proterozoic I have kept the "Aphebian" "Hadrinian" and "Helikian", rather than just absorbing the newer terms (Siderian to Ediacaran); although the latter are included. The Edicaran (latest period of the latest Precambrian) is now known to have many fossils in various parts of the world. My suspicion is that sometime in the future this might be absorbed into the Phanerozoic Eon, although I am unaware of any suggestions for this to take place. At the very bottom of the timescale I have included the oldest radiometrically dated rocks (extra-terrestrial and on Earth). Note that some terrestrial minerals (zircons) are dated to between 4.3 and 4.4 billion years.

In the Paleozoic (Carboniferous Period) I have indicated the current time break between the "lower" (Mississippian) and "upper" (Pennsylvanian) subdivisions used extensively in North America.

In the Cenozoic, one of the most important changes will be to delete the long-familiar "Tertiary Period" and replace it with the Paleogene and the Neogene, divided at 23.03 million years. There is also a proposal to delete the Quaternary and replace it with the "Pleistogene". I have not included this in the chart.

Melissa Battler's Mission to Mars

Melissa Battler


Melissa collecting a sample of the Dakota Sandstone.


Ready for fieldwork.

Earth and Space is part of the new Ontario Curriculum through grade 12. Melissa got the Earth Sciences bug while she was at high school in Cambridge. Her Earth sciences teacher, Stan Jones created the spark of interest and she has found her career interest. Melissa wishes to work on Mars exploration projects. When she graduated from the University of Waterloo in Spring 2004 she will continue an interest which has given her opportunities even as an undergraduate.

Melissa was keen on organizing a field trip to the Southwestern U.S.A. for the Earth Sciences Students Society and was one of the student organizers who planned the trip with Peter Russell over the Christmas vacation 2002-03. The trip included a daylong hike of the Grand Canyon and a visit to the Berringer Meteorite Crater.

A month after that trip Melissa took part in a project at the Mars Desert Research Station. This was a joint project of the Mars Society of Canada and the Mars Society of Australia, these groups formed the Mars Expedition Research Council. Melissa flew to Salt Lake City and drove to Hanksville, in southeastern Utah. The Mars Desert Research Station is a Mars analog Research Station at a designated Mars Society Analog site. While at the Mars Desert Research Station, Melissa participated in Expedition One. Expedition One is the first in a series of science-driven Mars simulations. During the two weeks of the project Melissa lived and worked in the Mars Habitat a building housing labs and living quarters. Attached to the Mars Habitat is a greenhab where the water is recycled using plants etc. An observatory is also on site. Food for the mission was army rations and dried food. Participants were also limited to one shower per week.

Melissa was one of the three mission geologists on Expedition One. There were nine geological and biological goals for the mission. 14 people were involved in the four phases of the mission. Most participants on the mission were geologists, biologists, engineers and psychologists. They came from NASA, universities and government. All the work from the mission has been published. Melissa studied the Dakota Sandstone as if it occurred on Mars. The sandstone was studied for evidence of water. This research was used for Melissa's fourth year thesis, part of her final year of courses at the University of Waterloo.

Starting in June 2004 Melissa will spend ten weeks at the NASA Aimes Astrobiology Academy as the Canadian representative. She will attend courses, participate in research and visit NASA facilities in California. Part of the research will be the design of a drill to be used on a Mars project in five years time.

Melissa will then travel to Memorial University, Newfoundland where she will start a Masters degree with Guigné International. Melissa will study ice berg scours on Earth, and features that appear to be ice berg scours on Mars (caused by ice floating in rivers or oceans and scraping the bottom sediment). Guigné International specializes in geophysics applied to space activities.


Mars Habitat with greenhab and observatory.

David Forget Essay Award Winner

Jennifer Nafziger 2B Geological Engineering

The great waves of the Pacific crash only a few meters below me as I write. I am sitting on the Bolsa Chica State beach in southern California, somehow escaping the great white Canadian winter. I watch the black dots marking sandpipers and surfers with a sense of disbelief: how in the world did I end up here? I hope this essay will help answer that question, both for the reader and for myself.

I spent the best days of my childhood on the shores of Lake Huron. I taught myself to swim in the chilly waters and spent countless hours collecting shells and driftwood. But my favourite was the stones. For hours I would search for the prettiest stones; the prize was a piece of smooth rose quartz or pink granite. I was always disappointed that they never looked as pretty when dry as they did when I first saw them underwater. I remember expressing my disappointment to my grandfather (a rock hound in his own right). He took a few of my stones and when I came back to visit the next weekend he had tumbled them smooth, revealing the beauty I saw through the waves. Even though my grandfather has been dead for years I still have those polished stones, I almost wish I had them with me now.

My interests also expanded inland. I had an independent exploratory sprit: roaming the woodlots all day, seeing how the sun glinted off the rocks, climbing to observe how moss clung to high-up branches and watching the herons angle in the river. I would spend summer evenings with my feet in swamp-water-soaked rubber boots, trying to catch frogs and turtles. I know exactly how I looked when I came home for bed: mud from head to toe and one giant smile. My mother would just shake her head and chuckle. She would just put me into a warm bath where I would express another geological obsession through dinosaur-shaped soap, dinosaur-shaped sponges and little plastic dinosaur figures.

Jennifer Nafziger visiting the Giant Sequoia National Park in March 2004, includes two of her favorite things: rocks and trees!

Time, as it tends to do, marches on. Those precious summer months gave way to years, and we can't play in the woods forever. Or can we? I spent my first full time summer job as a stewardship ranger with the Ontario Ministry of Natural Resources. I was in heaven. I was paid to get muddy, work in the woods and learn absolutely everything I could about plants, water and soil. I left that summer knowing one thing: I have to be able to work out of doors.

Eventually I had to decide what to do with myself after high school. I knew that I wanted a job that was scientific; I wanted to explore new ideas. But I also wanted a job that would allow for field work. Strangely, it was an interest in inorganic chemistry that led me to geological engineering. I had applied to geochemistry, geology, and chemical engineering at various Ontario universities. Then, two days before the final deadline for making changes to your OUAC application, I was flipping through the Waterloo application guide and discovered geological engineering. That March, my final choice was easy after I was shown around Waterloo's Engineering and Earth Science labs by a very enthusiastic Geo Eng grad. I have not looked back.

Today I can only look forward to the next four months with Komex's geoscience team in California, to graduation, and then to wherever the winds will carry me next.

What on Earth co-editor receives top national award.

WATERLOO, Ont. -- Peter Russell, curator at the University of Waterloo's Department of Earth Sciences, has been chosen as the 2004 recipient of the prestigious E.R.W. Neale Medal.

The esteemed medal is awarded by the Geological Association of Canada (GAC) to an individual for sustained outstanding efforts in sharing earth science with Canadians. The medal has been awarded annually since 1995.

Russell, who curates UW's Earth Sciences Museum, has been one of the most active promoters of earth science education in Canada by working at the grass-roots level with several hundred thousand children and thousands of teachers and members of the public over more than 30 years. His energy has been phenomenal, the GAC says.

He has judged at the Waterloo-Wellington Science and Engineering Fairs since 1971. From the late 1970s he organized and distributed the "Geoscience Slide Library" kits and notes and boxes of minerals, fossils and rocks, to assist teachers in the curriculum for Grades 4 to 6 throughout Waterloo Region.

The Waterloo "Junior Naturalists' Program" was set up and guided by him from 1979 to 1990, expanding into the "Science and Engineering Quest." Innumerable public and student field trips and EdGEO teacher training workshops have been run for over three decades.

In the late 1980s, he helped initiate and continues to co-edit What on Earth, an earth sciences newsletter. Also, he was the illustrator for Mineralogical Association of Canada's Encyclopedia of Mineral Names and has designed an interpretive logo for every issue of GAC's flagship journal, Geoscience Canada, since its launch 31 years ago.

Travelling exhibits designed by Peter have appeared at gem shows throughout Ontario and the United States.

Teaching exhibits on groundwater are used for Groundwater Festivals and Clean Water Fairs in six Ontario counties and are distributed as far away as Quebec. The "Wally and Deanna" cartoon booklets have been wildly successful with children and more than 28,000 copies have been produced in three languages.

Three years after his formal retirement in 1996, Russell received the designation "Honorary Member of the University" at UW's convocation in recognition of his work on building public awareness of science. As well, the rock garden on campus was named "Peter Russell Rock Garden."

Subsequently, under his imaginative guidance, the Centre for Environment Innovation and Technology (CEIT) was transformed, with Russell persuading the architects to build the five-storey building around a huge (nine-metre-tall) monolithic block of stone that is now ensconced through three floors in the central hallway.

The Earth Sciences Museum now is located in a much more visible location in the new March Networks Exhibit Atrium in the CEIT.

Over the past three decades, Russell has excelled in interactions with the general public, with teachers and particularly with children. It is estimated that he has talked to a minimum of 250,000 children and teachers during that time period, an equivalent of several "Skydomes" packed to capacity.

Jennifer Bates. chair of the GAC's Public Awareness Committee presented the award to Russell during the GAC awards luncheon held Wednesday, May 12 at the annual GAC-MAC conference at Brock University in St. Catharines.

University of Waterloo opens new CEIT Building.

Following a two-year plus period of building, the Department of Earth Sciences (or most of it) moved into the CEIT (Centre for Environment, Innovation and Technology) Building in September of 2003. However, a number of changes took place over the following six months, including a multitude of wall placements and the installation of museum specimens, and the building was formally opened on February 27, 2004.

Since this is the "home" for What On Earth, and since Peter was a key figure in the "geodesign" we thought we would illustrate the lower floor and the one million dollar The March Atrium of CEIT. This is the principal area that displays some of the geological features and houses the small Museum area.

The opening ceremony was marked in true Waterloo style with a machine ribbon-cutting ceremony. Everyone waited with anticipation, and, as the cameras rolled, flashed and beeped, the robotic arm snipped the black ribbon, to formally open CEIT.

I was able to persuade President Johnson and Bob Harding, Chair of the Board of Governors, to pose with Peter beside the "Great Lakes Fountain" that runs along one side of the new Atrium. Some of the walking tours explored the building and one of the features that was admired was the huge gneiss monolith. The CEIT building was built around the monolith. This was installed very early in the construction phase and featured in the Fall 2001 issue of WAT ON EARTH. Beside the many cases of mineral specimens a ceiling area illustrates a series of drill bits that were donated by various companies in western Canada and gathered by a former student, Jerry Pilny.

Opening CEIT: The robotic arm marks the precise opening of the CEIT building as the ribbon flutters down. Peter is on the extreme left of the photograph with George Dixon, Dean of Science to the right. President David Johnson is on the extreme right. Other dignitaries include, from the left of President Johnson, proceeding left; David Caplan, Minister of Public Infrastructure Renewal, Ted Arnott, MPP for Waterloo-Wellington, and Bob Harding, Chair of the Board of Governors.

The Great Lakes Fountain: Bob Harding, Peter (centre) and David Johnson on the US side of the Great Lakes. David is pointing out his home town of Sault Ste. Marie. Each of the Lake basins portrays the bottom topography in three-dimensional relief and is cut into a red granite. Water flows from Superior to the St. Lawrence, and is recirculated in a closed loop.

The drill-bit ceiling area: Poking through the ceiling are various diameter drill bits that are used for drilling, water, oil and gas wells. These bits were donated by Security DBS, Calgary, Christiensen Mining Products and Walker McDonald Bits. They are mounted to show how they would look from below as they make their way through rock strata deep underground.

Towards a Grand Sense of Place (ISBN: 1-894072-55-3)

For those interested in the Grand River basin these "writings on changing environments, land uses, landscapes, lifestyles and planning of a Canadian Heritage River" provide an interesting and comprehensive overview.

The book is available in paperback only. It consists of some 300 pages contained within 20 Chapters and costs $32.00 including GST. It is part of the series of the Environments Publication associated with the University of Waterloo Geography Publication Series, and it can be ordered from the Heritage Resources Centre at the University of Waterloo, Waterloo, Ontario, N2L 3G1. The book was organized by Gordon Nelson and prepared and designed by Beth Dempster. The release in June, 2004, coincided with the 10th Anniversary of the Grand as a Canadian Heritage River, and the 20th anniversary of the Canadian Heritage River System.

The chapters are grouped, and for the audience reading What On Earth, the first section on Natural and Cultural Heritage probably would be of most interest. Here the Bedrock and Quaternary geology is covered in two chapters by Alan Morgan and Paul Karrow. These are followed by Climate variability (Marie Saunderson and Brian Mills), Water Regime and Hydrology (Dwight Boyd, Sam Bellamy, Dave Schultz and Gordon Nelson); the Grand River vegetation and wildlife (Virgil Martin) and early Aboriginal Occupation (Gary Warrick). Later sections of the book cover European Arrival and Settlement; Thinking about the Grand, Past, Present and Future, and Linking Nature, Culture and Planning in the Watershed.

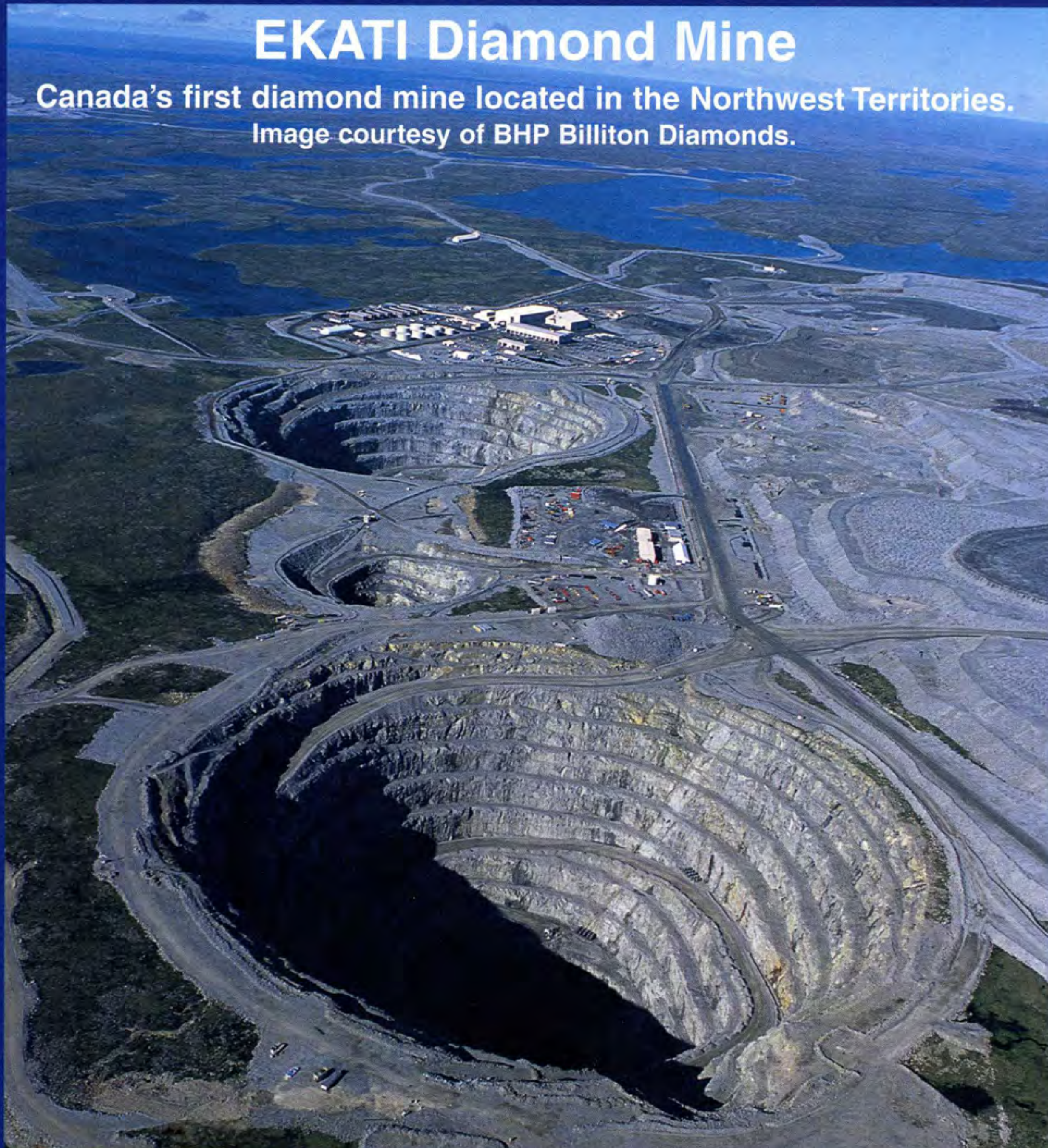
This book does pull together the various disparate elements that make up the natural and cultural history and the exploitation of this important watershed in the Lake Erie catchment. The authors hope that it will serve as a model for others. **Alan V. Morgan.**

The monolith: The large gneiss monolith rises through three floors inside CEIT. Originally lowered to the basement level on December 1st, 2001. The first view shows a group of admirers at the bottom of the basement stairway looking upward. Paul Karrow, an emeritus professor is over 2m tall and stands at the foreground right.

This view illustrates part of the monolith from above. The new chair of Earth Sciences, Mario Coniglio (top centre) stands at the base. Most of the participants in the group have single page copies of the WAT ON EARTH article that describes the installation of the monolith.

bhpbilliton

EKATI Diamond Mine



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