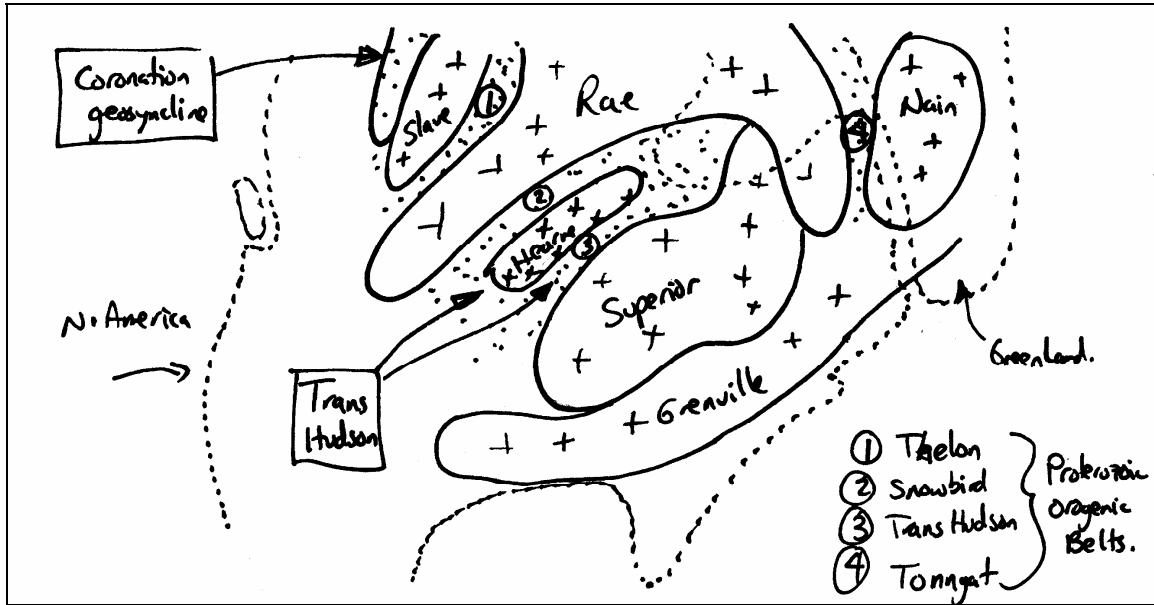


GY 112 Lecture Notes More Proterozoic Tectonics

Lecture Goals:

- A) The Trans Hudson Orogenic Belt
- B) The Grenville Orogeny
- C) Diamonds

Textbook reference: Levin 7th edition (2003) Chapter 7; Levin 8th edition (2006), Chapter 9

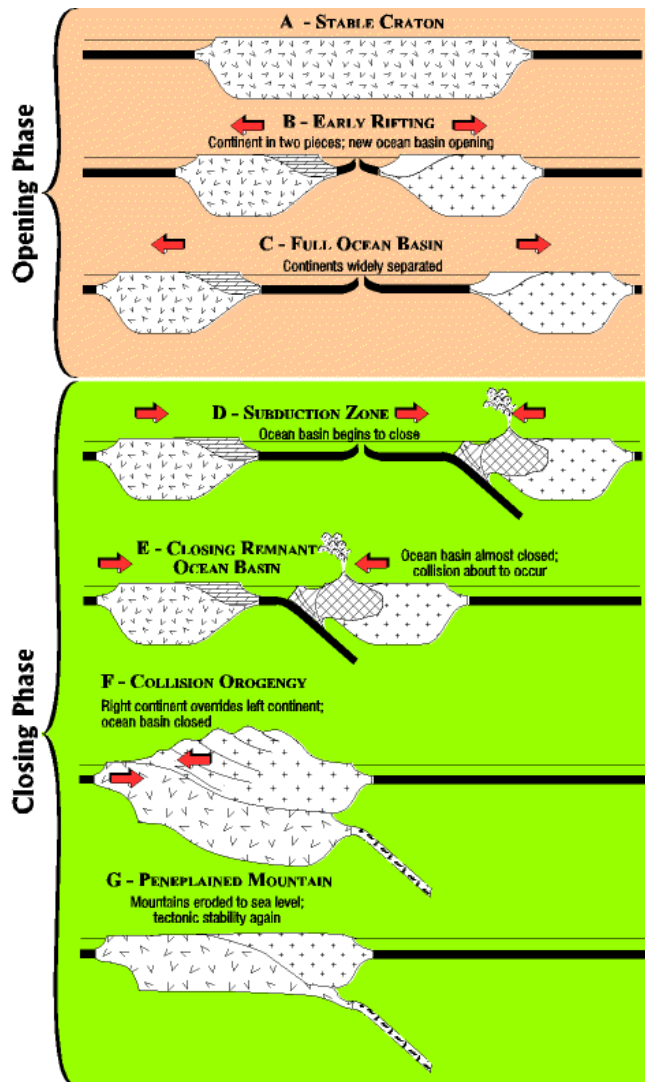
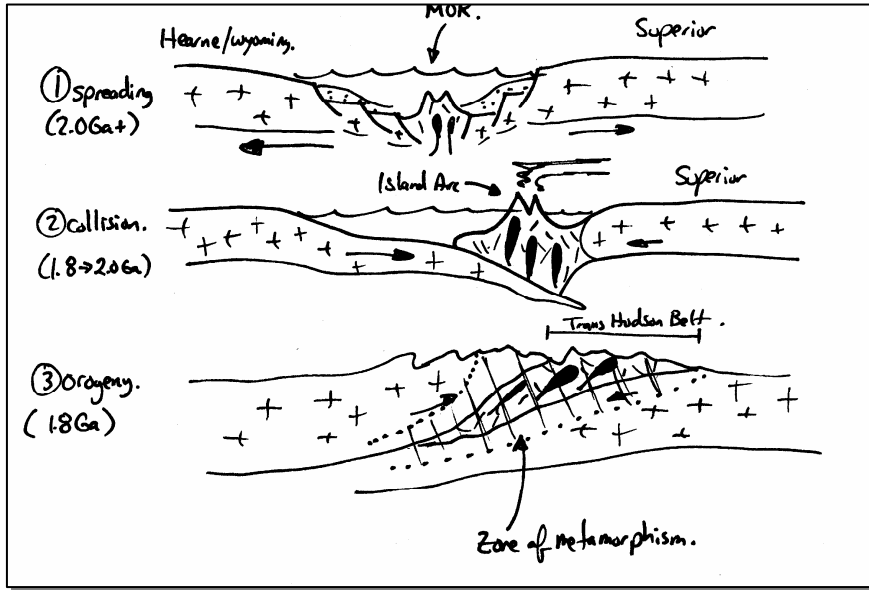


A) The Trans Hudson Orogeny

Last time we discussed Proterozoic paleogeography and the Coronation Geosyncline (Wopmay Orogeny). The main thing to remember from that lecture is that full blown plate tectonics appears to have begun around 2 billion years ago. Plate collisions, the opening of new oceans and the destruction of old ones has been occurring ever since.

One most impressive orogeny took place between 1.8 and 1.9 billion years ago (about the same time as the Wopmay event) and involved two or three large provinces of the Canadian Shield. The event is called the **Trans Hudson Orogeny** because it involved a belt of rocks now exposed from Hudson Bay well down into the United States. The Hearne Province and the Wyoming Provinces (possibly previously docked) appear to have collided with the Superior Province through a collisional tectonic event. Like the Wopmay Orogeny, this event was preceded by initial rifting and the formation of oceanic crust (i.e., divergent plate tectonics) before the collision occurred. It would seem as if the Canadian Shield experienced yet another **Wilson Cycle** (see color diagram from <http://esmres.jmu.edu/geollab/> on the next page). The **Trans Hudson Orogenic Belt** is linear in disposition and comprises mostly mafic and other oceanic crustal rocks. It is best exposed in northern Saskatchewan and Manitoba, in Canada and in the Black Hills of South Dakota.

So what happened? Rifting began to occur around 2.0 billion years ago and resulted in an ocean of unknown width. It was a real ocean – i.e., flood basalts formed indicating the eruption of large quantities of mafic lava and new oceanic crust. Plate motion reversed itself and

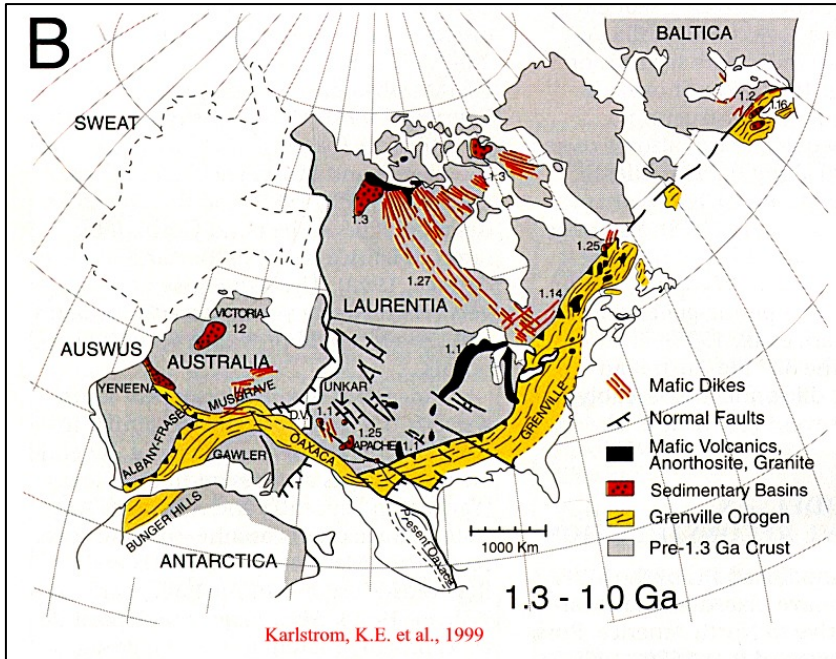


ultimately developed an island arc complex. To the best of my knowledge, the Wopmay Orogeny did not produce an island arc, so there may be some fundamental differences between the two orogenies. In fact, some people regard the Wopmay Orogeny to have been more of an *accretionary* event than the Trans Hudson Orogeny (which was more of a pure *collisional* event). In case you don't already know this, island arcs are linear volcanic islands chains formed through the eruption of intermediate igneous rocks like andesite. They are found along most subduction zones in oceans (e.g., the Aleutian Islands, Japan, etc.) and rocks interpreted to have formed in island arc tectonic settings are common in most Phanerozoic mountain belts like the Appalachians and Rockies. Their presence in the Trans Hudson Orogenic Belt may indicate a relatively wide ocean and a significant amount of subduction prior to the collision. Any way you want to look at it, the collision

between the Superior and Hearne/Wyoming Provinces squeezed the heck out of the intervening oceanic rocks. They are highly folded and faulted, are intensely metamorphosed, and are cut by intrusions (see cartoon below). In other words, the rocks of the Trans Hudson Orogenic belt record a classic **suture** zone. There were many suture zones forming at this time (see first diagram).

B) The Grenville Orogeny

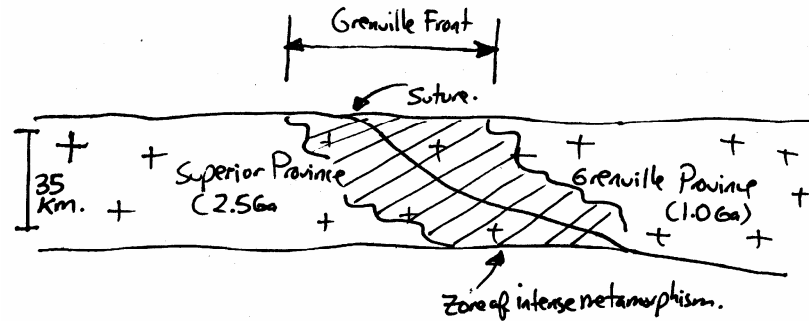
The **Grenville Orogeny** occurred late in the Proterozoic (mostly during the Neoproterozoic) between 1.3 and 0.9 Ga. This event was huge and resulted in a mountain



range that was at least the equal of the Himalayas in elevation that stretched from Sweden, through Labrador, Canada all the way to Mexico (maybe further; see adjacent image from <http://instruct.uwo.ca/earth-sci/300b-01/rodkarl2b.jpg>). Grenville-aged rocks have recently been found underlying Alabama. Something really big collided with North America, and only the passage of time has reduced that

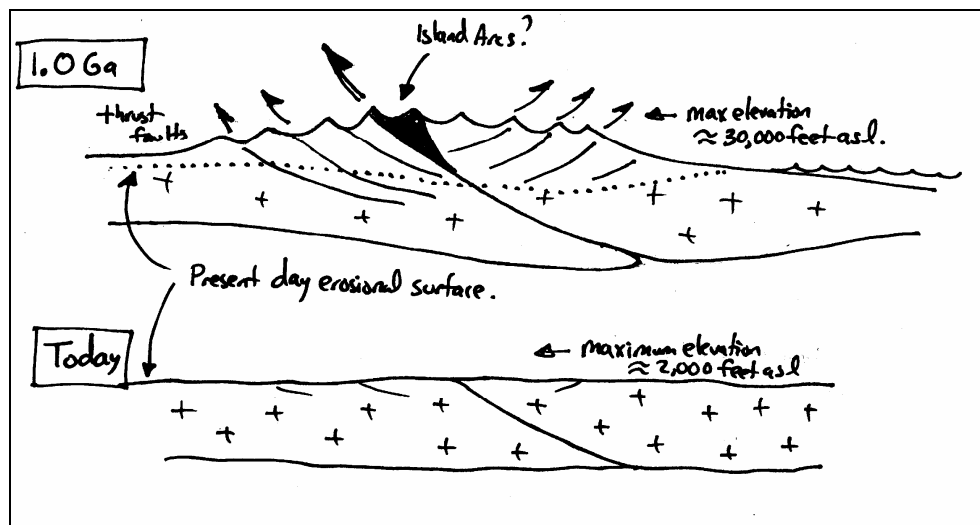
once great mountain chain to its present “flat as a pancake” topography.

Before we discuss what the collisional event might have been, I need to explain a fundamental difference between the Grenville and the Trans Hudson Orogeny. The contact between the Grenville and the Superior Province is remarkably sharp. I have literally straddled the contact, which some call the **Grenville Suture**, in southern Ontario. One foot lay on the Superior Province (2.5 Ga) and the other foot lay on the Grenville Province (1.2 Ga). There is no wide belt of deformed oceanic rocks (i.e., a metamorphosed island arc) between the two provinces that characterizes the Trans Hudson Orogeny. The suture is a planar contact (or pretty close to it). I should point out that while the suture between the two provinces is sharp, the contact is **overprinted** by a relatively wide zone of intense metamorphism presumably induced when the collision occurred. This zone of metamorphism is called the **Grenville Front**.



I am not bothered by the lack of intervening rocks between the two provinces involved in the collision. We see similar suture zones in other areas where continental rocks have collided (e.g., India and Asia). Since continental rocks do not like to be subducted, they tend to ramp over one another as the diagram below suggests. The great amount of erosion that has taken place since the orogeny may also have simply removed a lot of the squished up intervening rocks. I certainly believe that there was a collision because of the regional metamorphism that occurs around the suture

The origin of the Grenville Continental mass prior to collision has been the subject of some debate. Large parts of the Grenville are composed of metamorphosed siliciclastic sedimentary rocks that were probably originally deposited along stable shoreline and shallow marine environments. Some geologists have even suggested that these rocks were deposited along the edge of the Superior Province and were simply metamorphosed in place rather than being added to the edge of the craton through a plate collision. Some text books discuss this as possible origin of the Grenville Province, but I'm not sure if this idea is all that popular now. Most of the recent material I have perused about the Grenville Orogeny endorses the collision model and there is little discussion about in place sedimentation/metamorphism. You may be interested to know that expert geologists who study plate tectonics are convinced that the Grenville Orogeny was simply the first of three major Wilson Cycles to affect the "Atlantic Ocean" and eastern



North America. It was also the largest (some geologists have concluded that the Grenville Orogeny was the largest mountain building event *ever* on this planet). I have tried to illustrate this series of events in the cartoons on the next page Note that the present Atlantic Ocean was superceded by the **Iapetus Ocean** (Early Phanerozoic) and the **Uranus Ocean** (Mesoproterozoic). I once heard geologist Hank Williams (Memorial University in Newfoundland, Canada) refer to this as the “**accordion effect**”.



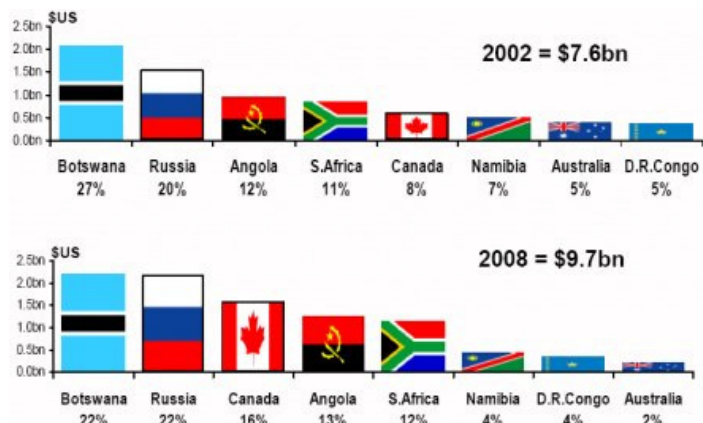
C) Diamonds

The only reason that I am discussing diamonds now is that I have some extra time (this is a short lecture to this point) and I would not be able to fit this material in at any other time in this course. So we do it now or never.

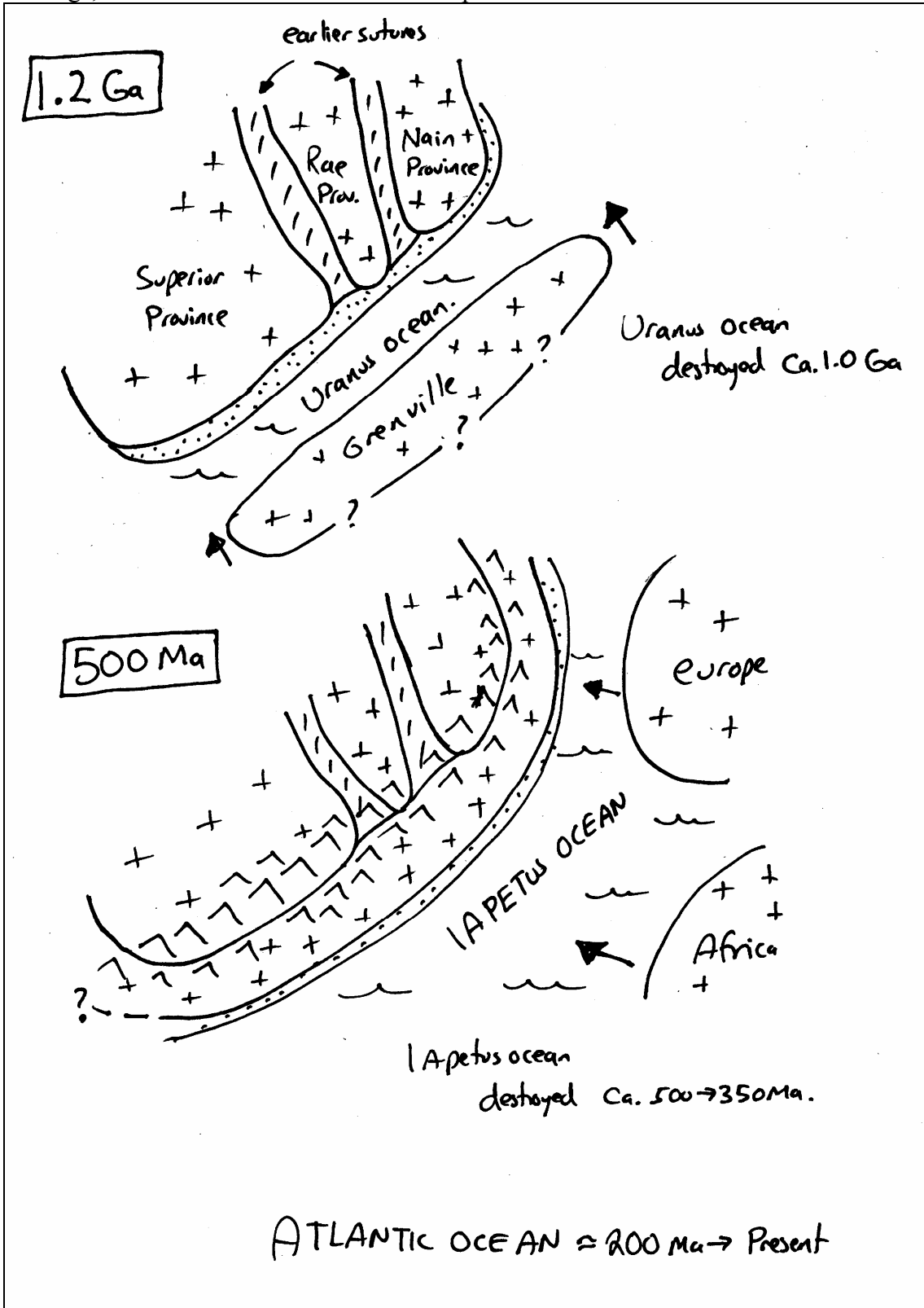
As you all know, diamonds *are a girl's best friend* and are a curse to us poor males who have to buy them for them. The demand for diamonds is the best example that I am aware that illustrates the power of advertising and merchandising (thank you very much De Beers). Diamonds have been mined for thousands of years, but with the exception of a few small deposits (e.g., Arkansas), they were uncommon in North America. Well that's not entirely true. Raw diamonds were occasionally found in

some river sands in central Canada (minerals that are reworked into river sediments are called **placer deposits**), so it was known that there were diamonds somewhere in the Great White North. The problem was that the source of the river sands were glacial deposits and since glaciers bulldozed much of the country during the height of the last glacial period, no one knew where those diamonds were. That is, until 1985.

In 1985, two geologists (Charles Fipke and Stewart Blusson) found **kimberlite** rocks in Canada's Northwest Territories. In other parts of the world, kimberlites are diamond-



bearings, so Fipke and Blusson



began to study them. They followed the trail of kimberlites to their source, a **kimberlite pipe** north of Yellowknife in the Slave Province of the Canadian Shield (refer to the Coronation Geosyncline lecture). After a few exploratory cores, they found diamonds. Since that time, one mine has been established by BHP, a large Australian mining company (it is now producing diamonds) and others are planned. De Beers is the other large player in this area and in 2001, they began to develop their first diamond mine outside of Africa. Literally over night, diamonds became a billion dollar industry in North America, and a couple of insightful geologists became fabulously wealthy.



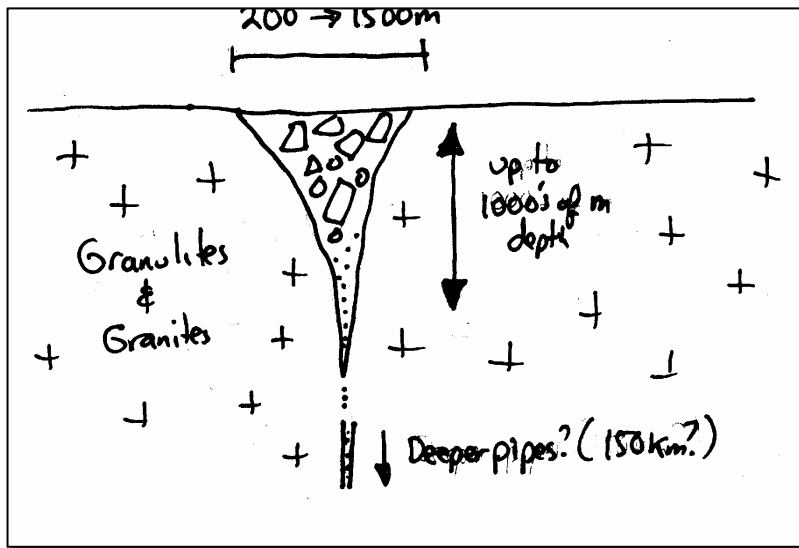
Now, what about those kimberlites? Kimberlites are grey-green colored igneous rocks that contain many minerals including, sometimes, diamond like that in the image to the left (from <http://www.geopolis-fr.com/mineraux/>). They are thought to originate from deep in the Earth, perhaps even the mantle some 150 km or more down. The most diagnostic minerals are olivine and strange pyroxenes and garnets. Kimberlite pipes are the conduits through which these rocks passed from the Earth's interior, to its surface. The neat thing about kimberlite pipes is that the magma seems to have passed through them quickly (I read somewhere 30 km/hour – but I find this hard to believe), and explosively. Kimberlites are usually **brecciated** and contain exotic clasts due to their rapid passage through the pipes. They also frequently contain a lot of carbonate minerals suggesting that CO₂ gas may have been also involved in the eruption. It would have been a hell of a bang at the surface of the

Earth when one of these volcanoes exploded.

Kimberlite pipes usually occur in swarms. Some may be diamond-bearing, others may not. Most experts feel that kimberlites did not form diamonds but are simply the means by which diamonds made it to the surface of the Earth. Isotopic studies of gases trapped within diamonds suggest that most diamonds probably formed a long time ago (Archean?), at depth in the mantle from carbon sublimation. Moreover, the carbon was probably derived from methane gas. You cannot form gem quality diamonds from coal regardless of what you might see in re-runs of the Superman television show. The pressures and temperatures needed are extreme (about 800,000 psi of pressure and temperatures between 1100°C and 1500°C). It is remarkable that they were ever able to make it to the surface of the Earth because they formed well below the lithosphere.

The Canadian diamonds were extracted from the mantle via kimberlite pipes around 50-55 million years ago. I was surprised by this, because I was expecting them to be much older (Proterozoic). This was during the Cenozoic! Apparently some of the kimberlites

contain ripped up pieces of trees. Makes you wonder about what the impact on local life forms was doesn't it? It also makes you wonder what might happen to us if future kimberlite eruptions were to occur.



Important terms/concepts from today's lecture
(Google any terms that you are not familiar with)

Trans Hudson Orogeny
 Trans Hudson Orogenic Belt
 Suture
 Island Arc
 Grenville Orogeny
 Grenville Province
 Grenville Suture
 Grenville Front
 Iapetus Ocean
 Uranus Ocean
 Overprinting
 Accordion effect
 Placer deposits
 brecciation
 Kimberlite
 Kimberlite pipe