CLASS 3: MINERALS

INTRODUCTION

In the previous class we learned what minerals are and how to identify them using simple physical properties. We illustrated these concepts by examining common rock salt or halite (NaCl). Today we'll consider two minerals that have exactly the same chemical composition but very different properties and origin.

Graphite and diamond are "polymorphs" of the element carbon (C). This means that they both are pure carbon but that the crystal lattices and everything else about the minerals are different.

GRAPHITE

Graphite occurs in flat hexagonal flakes. The flakes in turn are made of strong hexagonal sheets only weakly bonded to each other. This arrangement explains the hexagonal crystal shape, the single perfect cleavage, the low hardness (1-2) and the low specific gravity (2.2). This crystal structure produces a swarm of free electrons that account for graphite's opacity, metallic luster, black streak and excellent conductivity of electricity.

Because of these properties graphite has many important uses. These include use as an additive in steel, as brushes in electric motors, in pencil "leads", as a release agent in sand molds and as a dry lubricant. You can figure what properties are important for each use.

Graphite is primarily a mineral of metamorphic rocks (read about the rock cycle here). The carbon comes from organic matter (plants) as for example in bogs and swamps. With burial come elevated temperatures and greater pressures. Water and oxygen are driven off and the dead vegetation is converted to peat. As these processes become more intense the peat is converted to bituminous coal, a sedimentary rock. At even higher temperature and pressure the coal turns to anthracite, a metamorphic rock. At even more extreme conditions everything is driven off but the carbon and graphite is formed.

DIAMOND

In contrast the carbon atoms in diamond are close together such that each atom is bonded tightly to four others. Diamond crystals grow as cubes, tetrahedrons and octahedrons (like two pyramids attached base to base). There are four "octahedral" cleavages; these correspond to facets formed by shaving off the corners of a cube. The atoms are very small and close together producing a dense (3.5) and hard (10) mineral. Diamond has an "adamantine" (diamond-like) luster and is transparent.

Diamonds are used as abrasives and as jewels. Nowadays many diamonds are man-made. Experiments and attempts to synthesize diamond tell us under what conditions carbon forms graphite or diamond.

ORIGIN OF GRAPHITE AND DIAMOND

These experiments allow us to draw a “phase diagram” showing under what conditions of temperature and pressure the two minerals form (study the diagram here). The phase boundary is such that graphite forms only a depths shallower than about 150 km whereas diamond only forms at greater depths. These lab results lead to several questions. For instance, why is there carbon in the interior of the earth? Is it just left over from formation of the planet or has it been brought back in by plate subduction or some other tectonic process? Another question is how diamond survives its trip from the depths where it forms to the surface where we find it. Two processes appear to explain how diamond travels up to the surface of the earth without changing to graphite as it rises through the graphite stability field.

We have already seen how graphite is formed in metamorphic rocks by deep burial of organic carbon from plants. In a few rare situations (Alps, Kazahkstan, China, Norway) we can find metamorphic rocks that apparently went down so deep that graphite recrystallized as tiny diamonds. In some cases it seems that the rocks returned to the surface so rapidly that the diamonds did not reconvert to graphite. Just how and why this rapid rise occured is not known. Perhaps more commonly, we find highly metamorphosed rocks that returned slowly to the surface. In these we may discover graphite crystals with the external form of diamonds. These “pseudomorphs” indicate that the diamond recrystallized as graphite during the ascent. A key concept is that the phase diagram refers to conditions for formation of a mineral, not necessarily conditions for existence once formed.

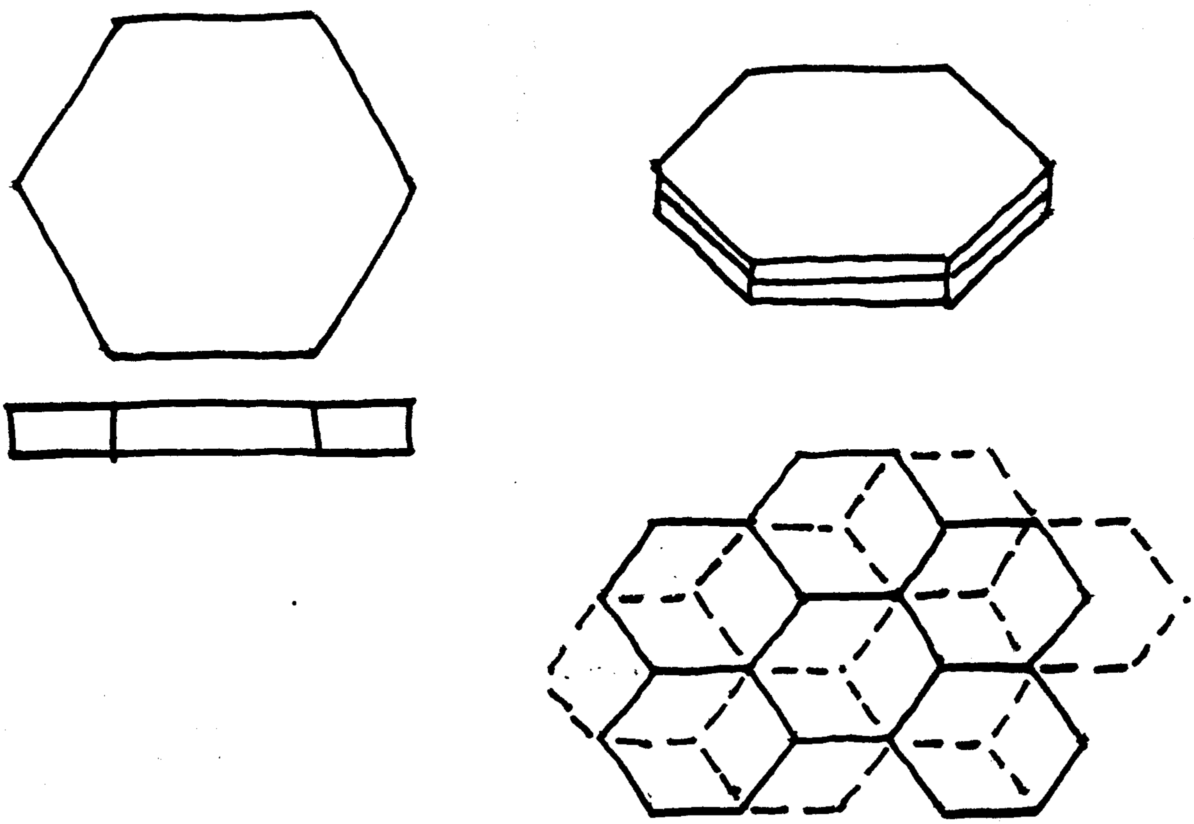
Diamonds also can rapidly rise to the surface via a kind of volcanism. “Kimberlite pipes” are narrow vertical cylinders of fractured rock that form when gas-rich eruptions blast off like a rocket. There’s lots of gas, lots of fractured rock ripped from the walls of the pipe but very little lava or volcanic rock. Such eruptions have never been witnessed by man. Within the volcanic rock diamonds are found. Much of the world’s diamond supply comes from mining these kimberlite pipes. The mines can be profitable with as little as 0.1 carats of diamond per ton of kimberlite (a carat is only one fith of a gram!). It’s probably significant that most kimberlite pipes are found in Archaean “cratons”; that is in continental rocks formed more than 2.5 billion years ago during the first half of earth history.

Given that all kimberlite pipes have been more or less eroded since they were emplaced millions of years ago, we might expect to find diamonds in the streams eroding the pipes. Such “placer” deposits are very common as dense diamond crystals tend to accumulate wherever streams slow down or the stream bed becomes rough and irregular. Placers are also found along beaches, both on land and under the sea. These stream and beach deposits may be those of today or those of the past preserved as sedimentary rocks.

SOME DIAMOND HISTORY

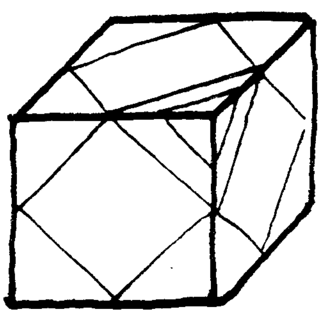
Diamonds were first known in the classic western world (Greece, Rome, Egypt, etc.) about 500 BC. Marco Polo (1254-1325 AD) described the Golconda mines in India. King Louis IX (1215-1270 AD, “Saint Louis”) decreed that only men could wear diamonds. Early in the fifteenth century King Charles II of France allowed his girl friend, Agnes Sorel, to wear diamonds. On August 17, 1477 AD, The Emperor Maximilian of Austria gave the first known diamond engagement ring to Marie of Burgundy. In the 1600's the three musketeers saved the queen of France (Anne of Austria) by recovering her diamond studs, a gift from her husband Louis XIII , that she had given to her boy friend. Mines opened in Brazil in 1725 and in South Africa in 1866. In 1872 General McClellan, the "Little Napoleon", was swindled in a diamond mining scam in Wyoming. Hot new exploration is today occuring in the western USA and Canada. On a darker note we see African wars fueled and financed by diamond discoveries.

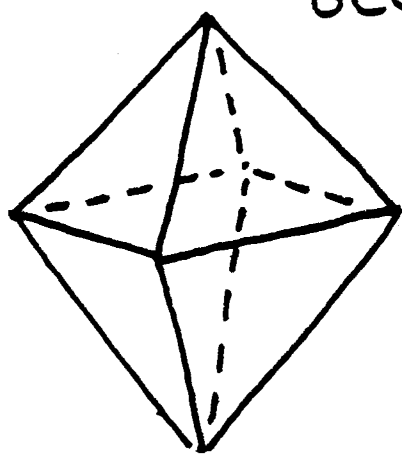
Graphite C

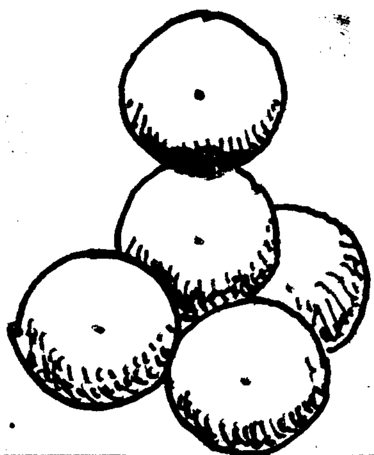


Diamond C

octahedron

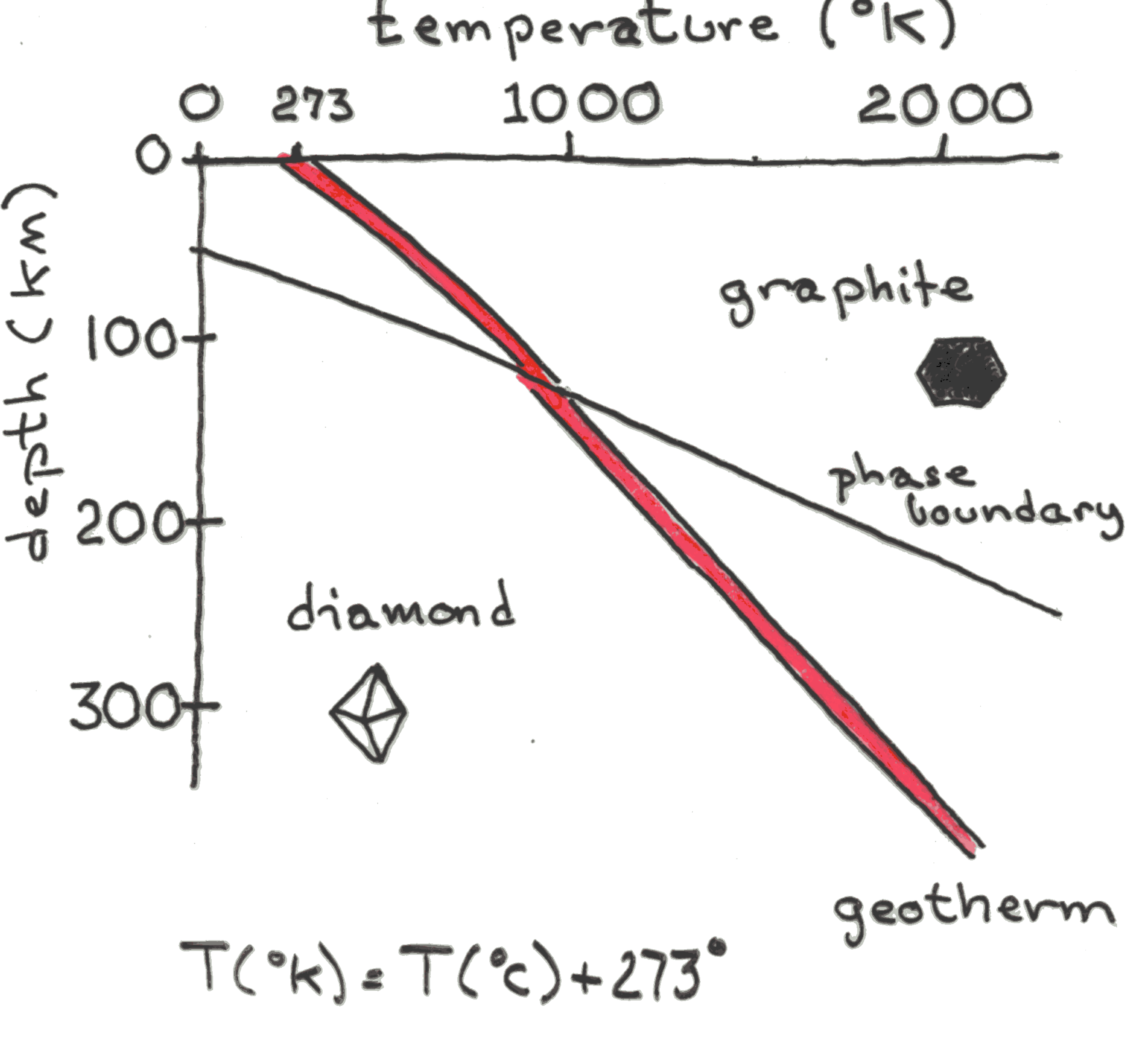






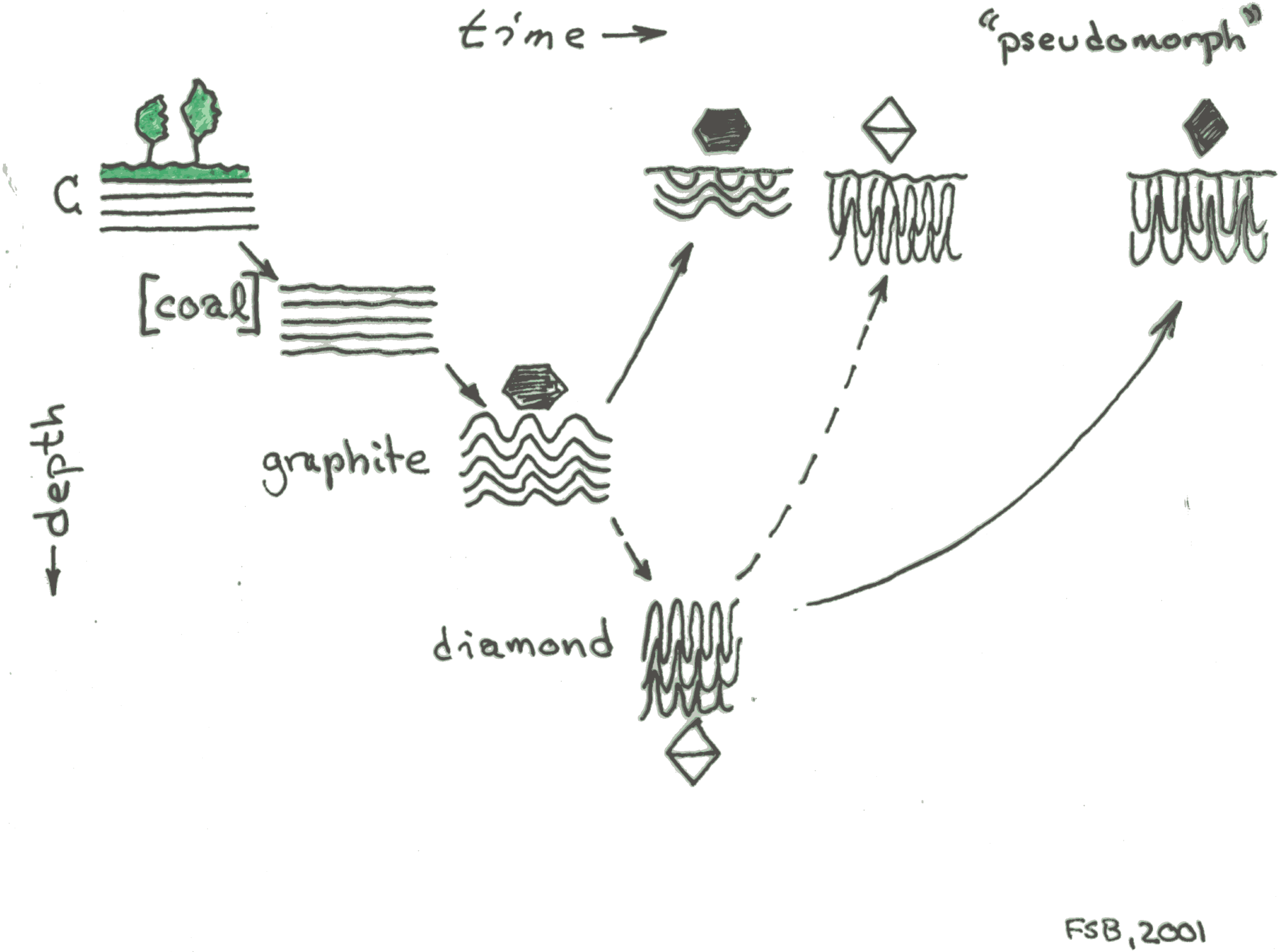
FSB, 2001

Carbon Phase Diagram

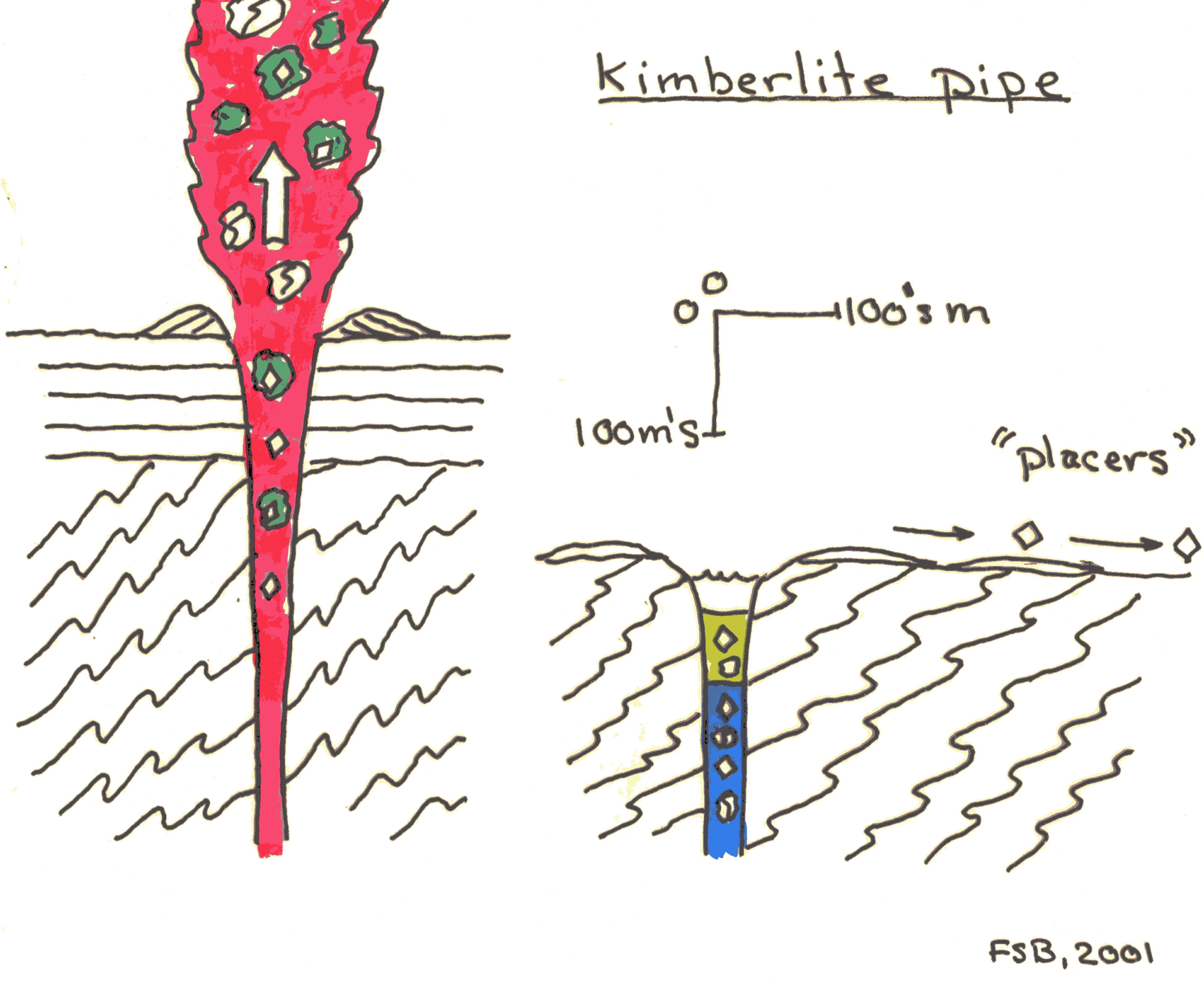


$$T(°k) = T(°c) + 273°$$

FSB, 2001



time →
"pseudomorph"
C
[coal]
graphite
diamond
← depth
FSB, 2001


Kimberlite pipe
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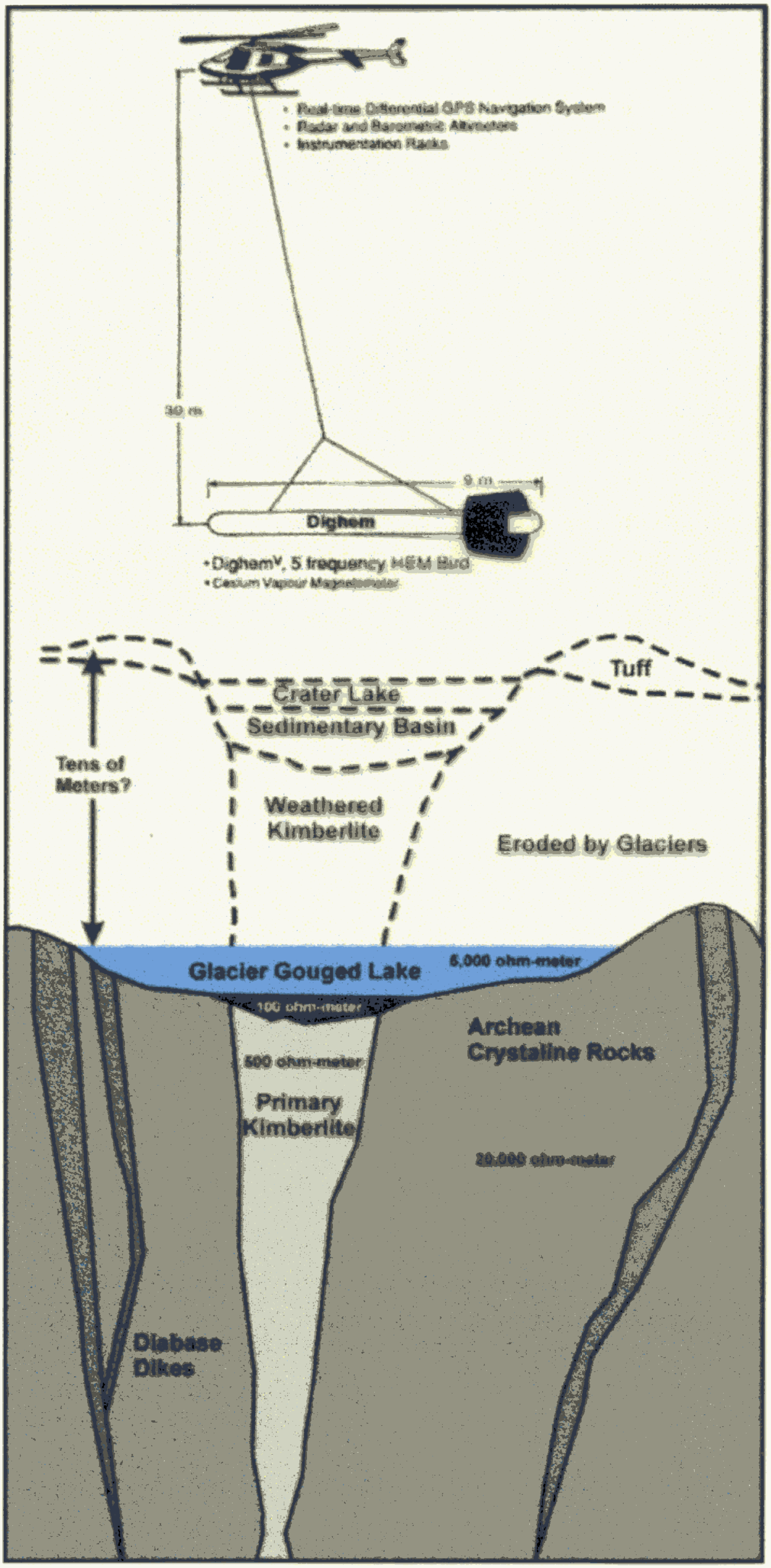
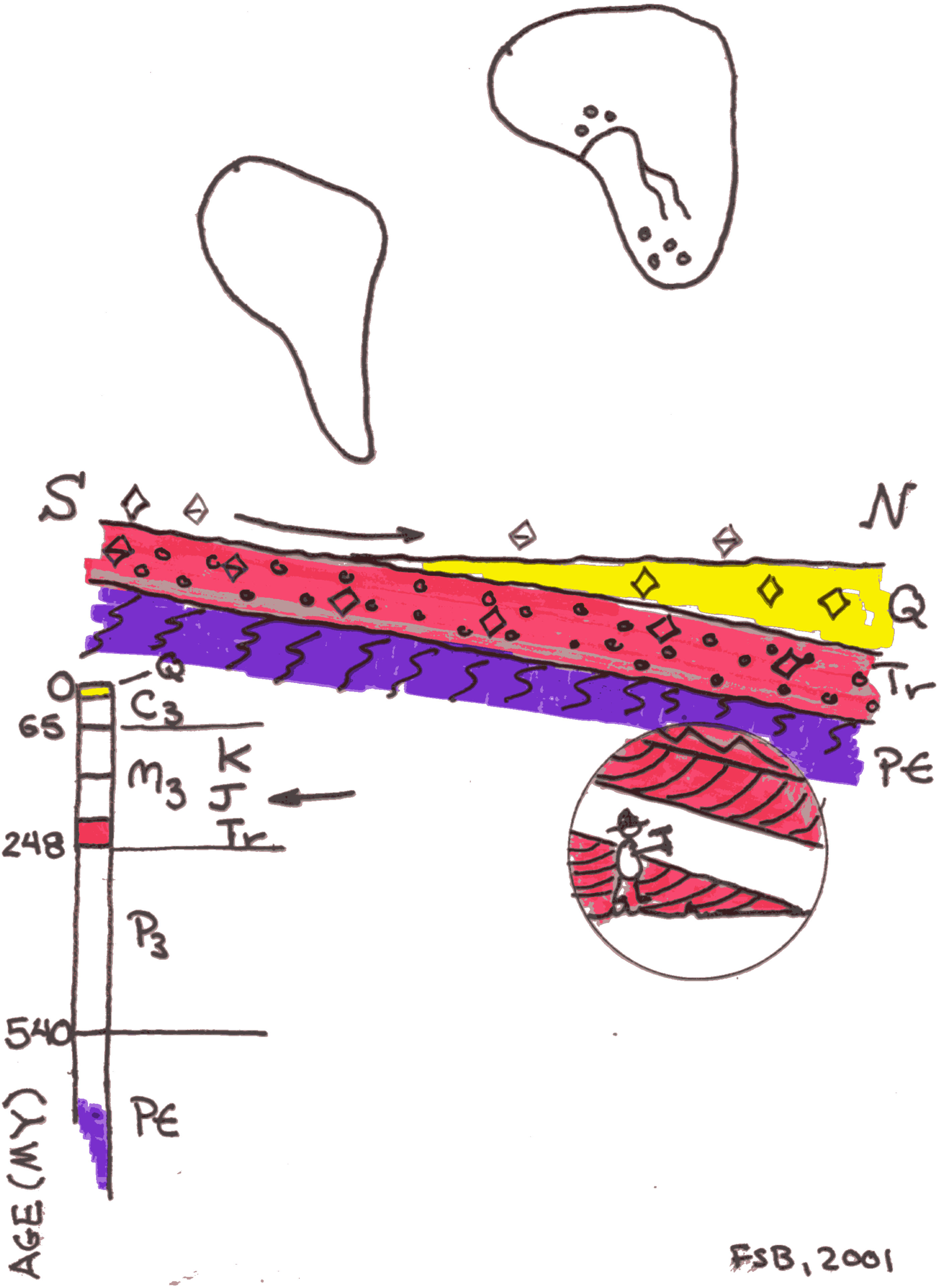
100m's
"placers"
FSB, 2001



kimberlite exploration



FSB, 2001

PROPERTY	GRAPHITE	DIAMOND
habit	hexagons	cubes, octagons
cleavage	1	4 @ 70°
specific gravity	2.2	3.5
hardness	1–2	10
color	gray	variable
luster	metallic	adamantine
light transmission	opaque	transparent
conductivity	very high	moderate
uses	dry lubricant etc.	abrasive
occurence	metamorphic rocks	kimberlites, placers

FSB, 2003