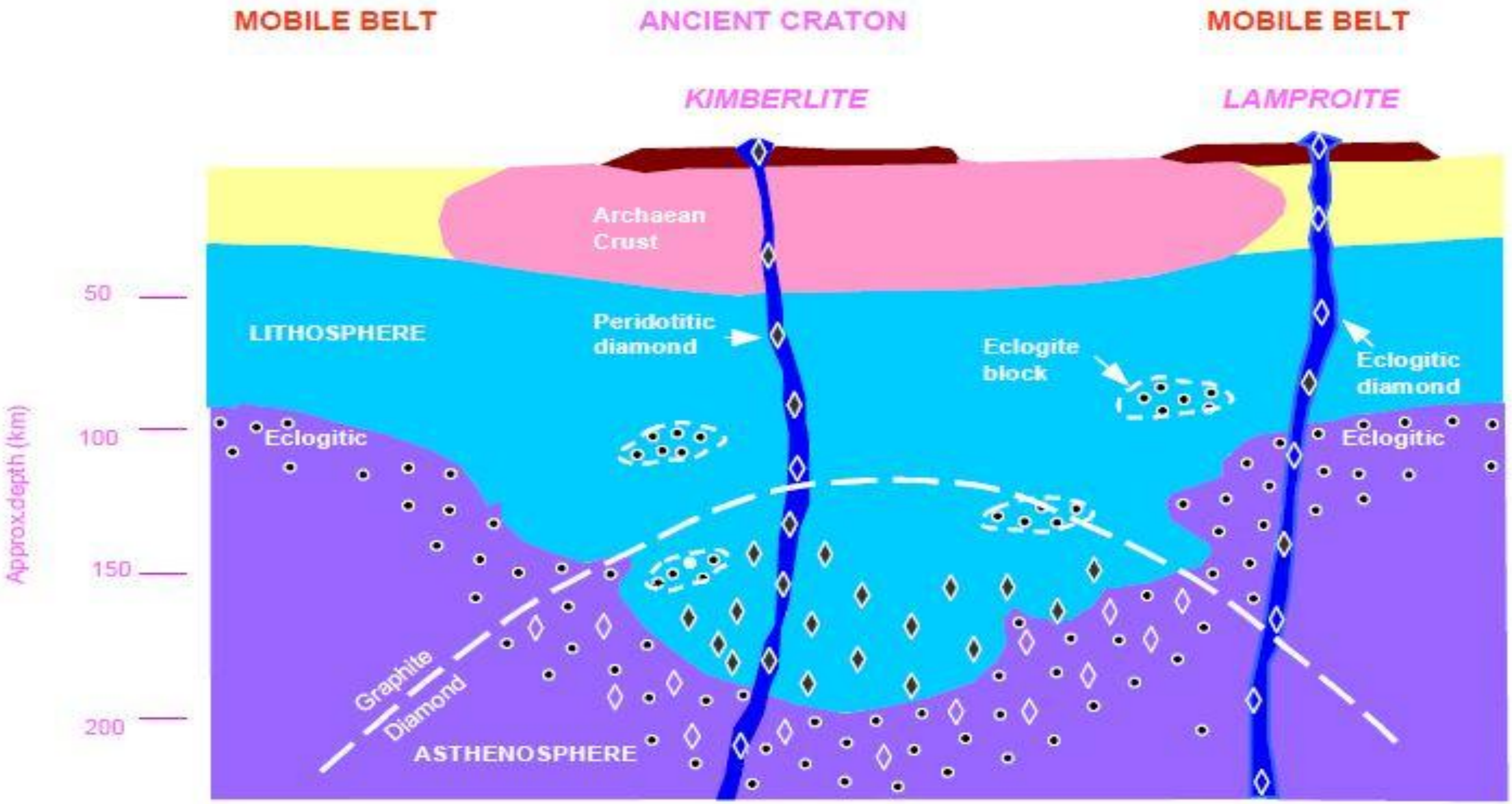
Kimberlite origin and emplacement - Kimberlite and alluvial diamond exploration in Southern Africa.

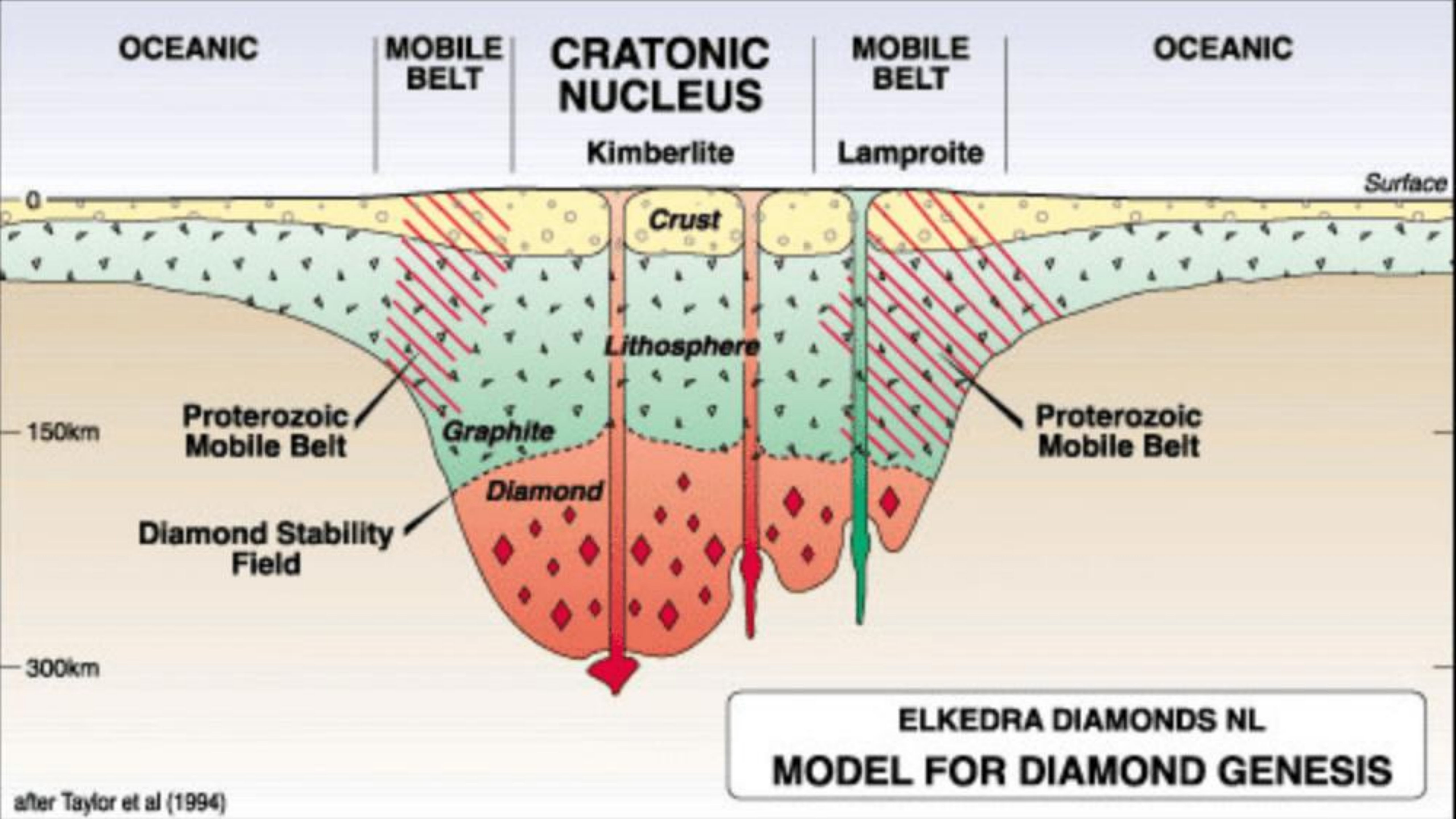
CLASSIFICATION AND GENETIC MODELS

- DIAMOND DEPOSITS ARE CLASSIFIED INTO 2 CLASSES, PRIMARY (KIMBERLITE AND LAMPROITE) AND SECONDARY (ALLUVIAL AND MARINE)
- THE MAJORITY OF DIAMONDS COME FROM KIMBERLITES
- THERE ARE TYPE I AND TYPE II KIMBERLITES
- THE QUANTITY AND QUALITY OF DIAMONDS VARY FROM ONE DEPOSIT TO ANOTHER
- DIAMONDS OCCUR IN DIFFERENT ROCK TRYPES
- CLIFFORD'S RULE

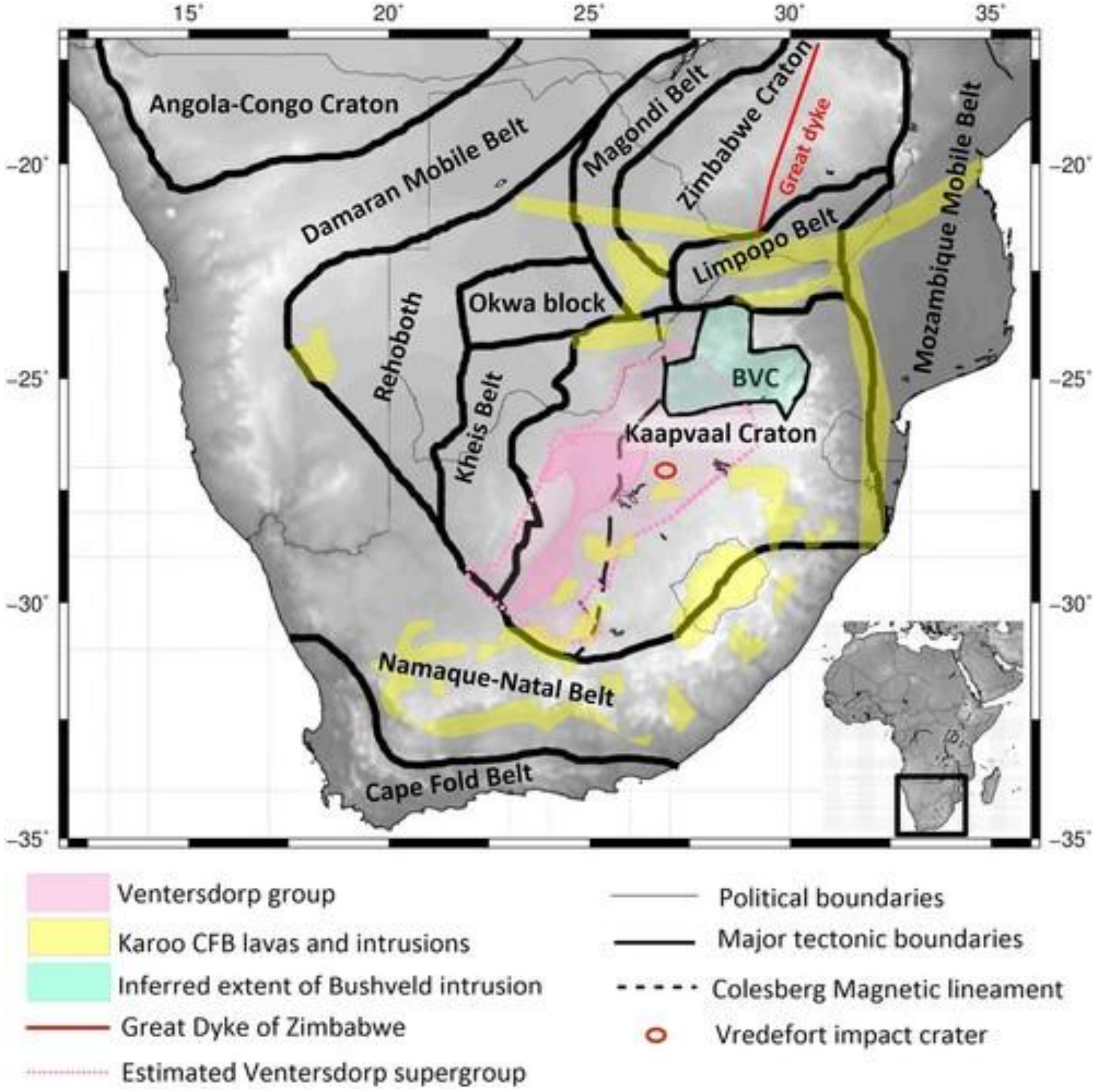
KIMBERLITE ORIGIN

SIGNIFICANCE OF CRATONS

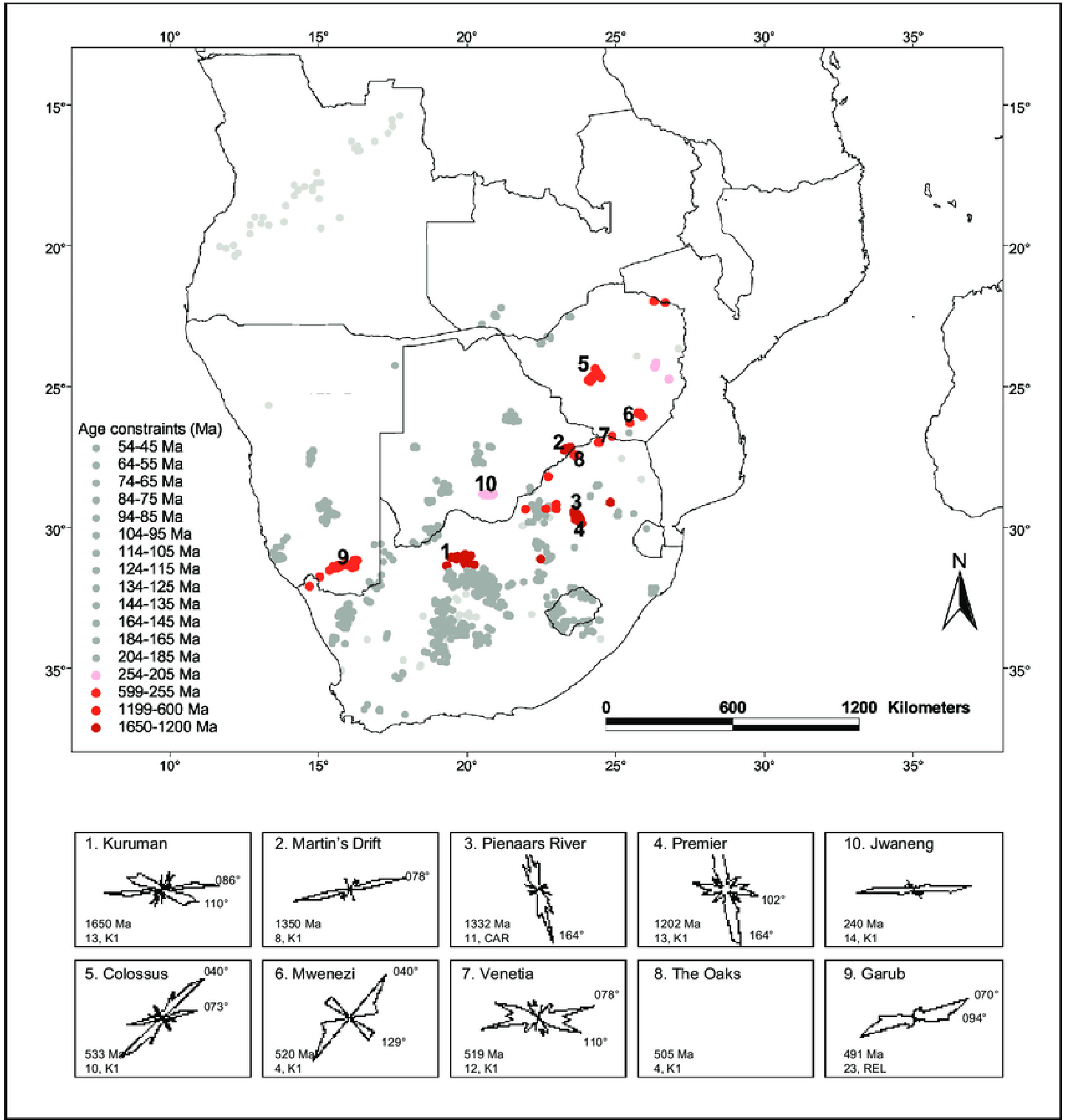



OCEANIC
MOBILE BELT
CRATONIC NUCLEUS
Kimberlite
MOBILE BELT
Lamproite
OCEANIC
Surface
0
Crust
Lithosphere
Proterozoic Mobile Belt
Graphite
150km
Proterozoic Mobile Belt
Diamond
Diamond Stability Field
300km
ELKEDRA DIAMONDS NL
MODEL FOR DIAMOND GENESIS
after Taylor et al (1994)

CRATONS IN SOUTHERN AFRICA



DISTRIBUTION OF PRE-205 Ma KIMBERLITES IN SOUTHERN AFRICA



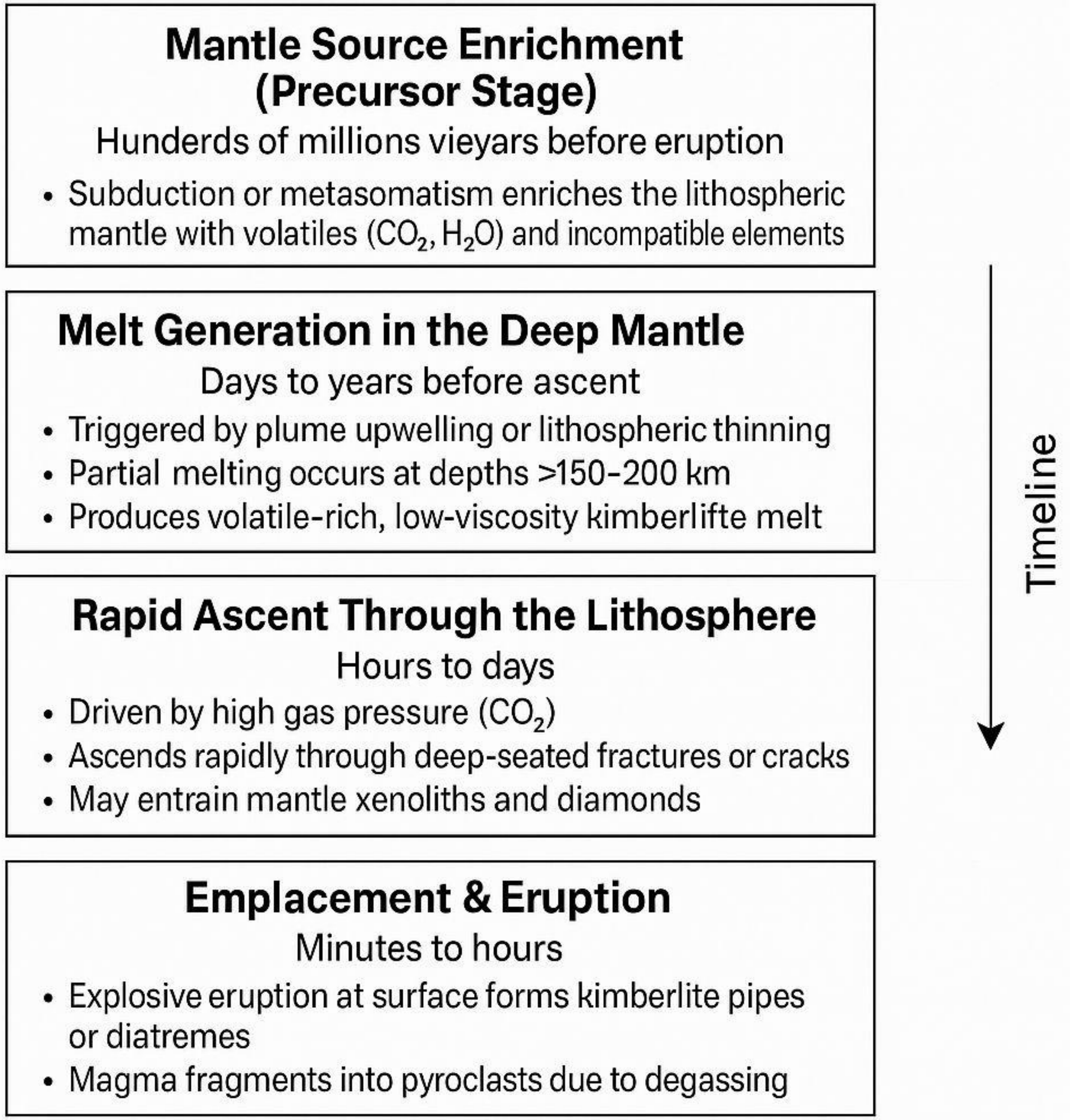
KIMBERLITE MELT ORIGIN

- CLIFFORD'S RULE
- UPPER MANTLE ORIGIN (+150 to -200km) BELOW STABLE CRATONS
- KIMBERLITE MAGMATISM TRIGGER:-

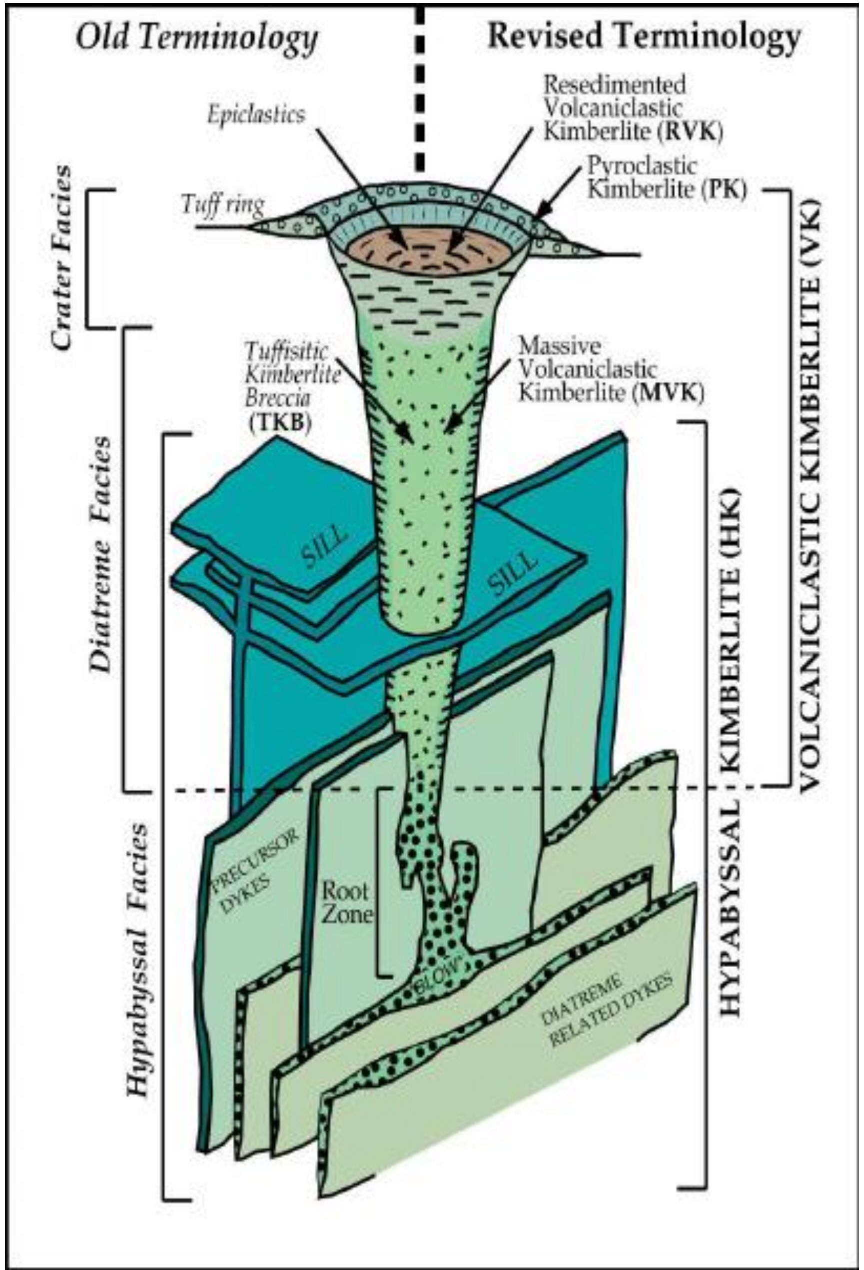
I. PARTIAL MELTING (PRESENCE OF VOLATILES)
II. DEEP MANTLE PLUMES (ORIGINATE FROM MANTLE-CORE BOUNDARY)
III. KIMBERLITE MAGMATISMS IS ASSOCIATED WITH CRATONS AND ANCIENT TECTONIC ACTIVITY
IV. VOLATILE RICH MANTLE

KIMBERLITE EMPLACEMENT

- **PROCESS BY WHICH KIMBERLITE MAGMA RISES FROM THE DEEP MANTLE AND ERUPTS AT THE SURFACE**
  I. **DEEP ORIGIN:** (+150 to -200KM) IN THE SUB-LITHOSPHERIC MANTLE
  II. **RAPID ASCEND:** DRIVEN BY VOLATILES. ENTRAINS XENOLITHS, XENOCRYSTS AND DIAMONDS
  III. **EXPLOSIVE ERUPTION:** DUE TO DEGASSING AT SHALLOW LEVELS. FORMS KIMBERLITE PIPES, OFTEN CARROT SHAPED IN CROSS-SECTION
- **PIPE STRUCTURE**
  I. **ROOT ZONE:** COHERENT KIMBERLITE NEAR SOURCE
  II. **DIATREME ZONE:** FRAGMENTED VOLATILE RICH MATERIAL
  III. **CRATER:** SURFACE EXPRESION, OFTEN ERODED
- **POST EMPLACEMENT**
  - ALTERATION FORMS SERPENTINE, CALCITE ETC


Mantle Source Enrichment (Precursor Stage)
Hunderds of millions vieyars before eruption
• Subduction or metasomatism enriches the lithospheric mantle with volatiles (CO_2, H_2O) and incompatible elements
Melt Generation in the Deep Mantle
Days to years before ascent
• Triggered by plume upwelling or lithospheric thinning
• Partial melting occurs at depths >150–200 km
• Produces volatile-rich, low-viscosity kimberlifte melt
Rapid Ascent Through the Lithosphere
Hours to days
• Driven by high gas pressure (CO_2)
• Ascends rapidly through deep-seated fractures or cracks
• May entrain mantle xenoliths and diamonds
Emplacement & Eruption
Minutes to hours
• Explosive eruption at surface forms kimberlite pipes or diatremes
• Magma fragments into pyroclasts due to degassing
Timeline

KIMBERLITE PIPE STRUCTURE



WHAT IS A KIMBERLITE?

- POTASSIC ULTRABASIC IGNEOUS ROCK CONSISTING MAINLY OF PERIDOTITE (Olivine + pyroxene +carbonate minerals with <45% silica)
- ACCESSORY MINERALS: Magnesian ilmenite, chrome pyrope, almandine-pyrope, chromium diopside, phlogopite, enstatite and titanium poor chromite.
- SOMETIMES CONTAIN DIAMONDS
- MAIN ROCK TYPES: Dunite, Harzburgite, Lherzolite, Websterite, Eclogite, Wherlite, MARID etc

KIMBERLITIC ROCKS

HYPABYSSAL KIMBERLITE

DIATREME FACIES KIMBERLITE

KIMBERLITIC ROCKS CONT'D

EPICLASTIC KIMBERLITE

SLIGHTLY SCHISTOSE KIMBERLITE

ALLUVIAL AND MARINE DIAMOND DEPOSITS

- DIAMOND: RESISTANT TO PHYSICAL AND CHEMICAL WEATHERING
- HIGH SPECIFIC GRAVITY (3.52)
- COMBINATION OF CLIMATE, BASIN DYAMICS AND GEOMORPHIC FACTORS LEAD TO DIAMOND PLACER DEVELOPMENT
- PLACERS OCCUR ON OR ADJACENT TO CRATONS WHERE RIVER FLOW IS DISTURBED
- LITHIFIED ALLUVIAL DEPOSITS ARE KNOWN AS PALEO-PLACERS (CHIYADZWA)
- DIAMONDS INTRODUCED TO CONTINENTAL MARGIN MAYBE CONCENTRATED IF DEPOSITED ON STABLE SURFACE LIKE THE SHALLOW CONTINENTAL SHELF ON THE WEST COAST OF SOUTH AFRICA AND NAMIBIA
- SEA LEVEL REGRESSION AND TRANSGRESSION MAY ENRICH THE DEPOSIT

DIAMOND EXPLORATION

- EXPLORATION IS CONDUCTED IN THE FOLLOWING PHASES:
  I. TARGET SELECTION
  II. RECONNAISSANCE AND FOLLOW-UP
  III. DRILLING
  IV. EVALUATION
- THE EXPLORATION CYCLE IS OFTEN SHORT-CIRCUTED TO ARRIVE AT RISK DECISIONS QUICKLY

TARGET SELECTION

- FOR KIMBERLITES, PROSPECTIVE AREAS CAN BE IDENTIFIED AND PRIORITISED ON BOTH REGIONAL AND LOCAL SCALE

I. Global, regional and local tectonics

II. Lithospheric structure and composition

III. Diamond formation and preservation

IV. Known host rock petrogenesis and emplacement

V. Country rock and source rock geochronology

VI. Local Tectonics

PROSPECTING METHODS

- AFTER TARGET IDENTIFICATION A SUITABLE OR COMBINATION OF PROSPECTING METHODS ARE USED AND THESE INCLUDE:-

  I. Stream sediment sampling

  II. Soil deflation sampling

  III. Geophysics

  IV. Remote sensing

  V. Combination of the above methods

SAMPLE PROCESSING

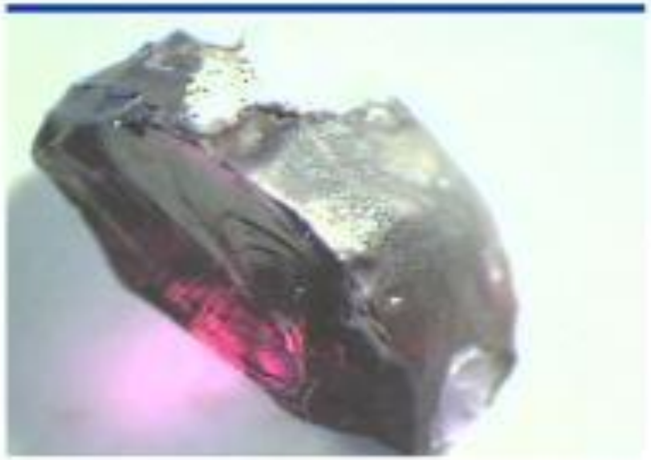
- STREAM SEDIMENT AND SOIL SAMPLES ARE WASHED AND SPLIT INTO 2 SIZE FRACTIONS
- SAMPLES ARE CONCENTRATED USING EITHER JIGS OR MINI DENSE MEDIA SEPARATORS (DMS)
- MANUAL CONCENTRATION USED IN WET AREAS WHERE STREAM SEDIMENT SAMPLES ARE COLLECTED
- CONCENTRATE IS SORTED FOR INDICATOR MINERALS USING BINOCULAR MICROSCOPES
- SURFACE TEXTURE ANALYSIS OF INDICATOR GRAINS IS DONE TO ASSESS PROXIMITY TO SOURCE

KIMBERLITE INDICATOR MINERALS

Garnets Surface Textures

1. **Remnant of Kelyphite**
2. **Sub-kelyphitic**
3. **Sculptured Surface**
4. **Abraded –No Remnant of Original Surface**

ROK



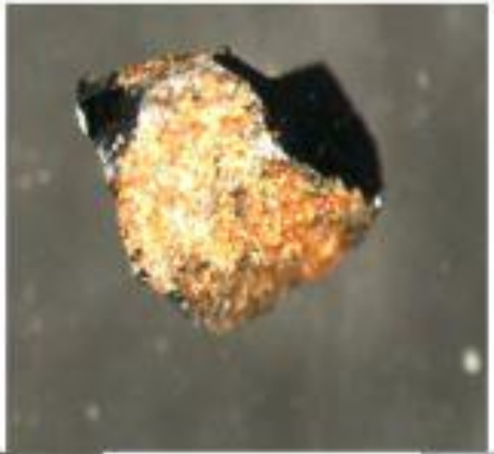
SKS

NROS

Imenites Surface Textures

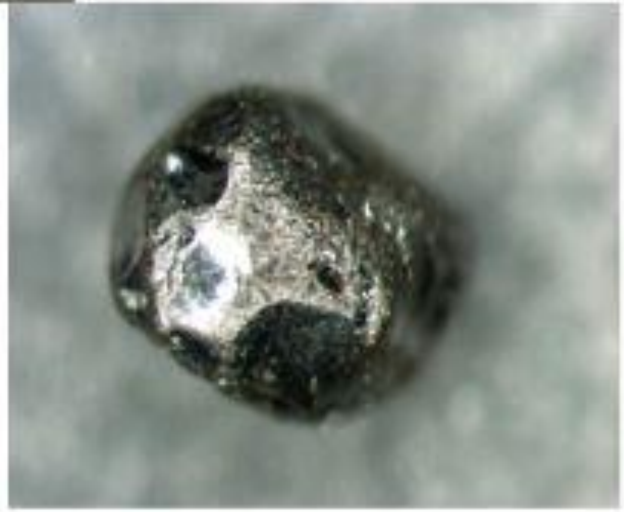
1. Perovskite Mantle –PM
2. Sculptured Surface – SS
3. Abraded – No Remnant of Original Surface Texture

SS- Ilmenite



PM **Ilmenite**

NROS - Abraded



Chrome-diopside

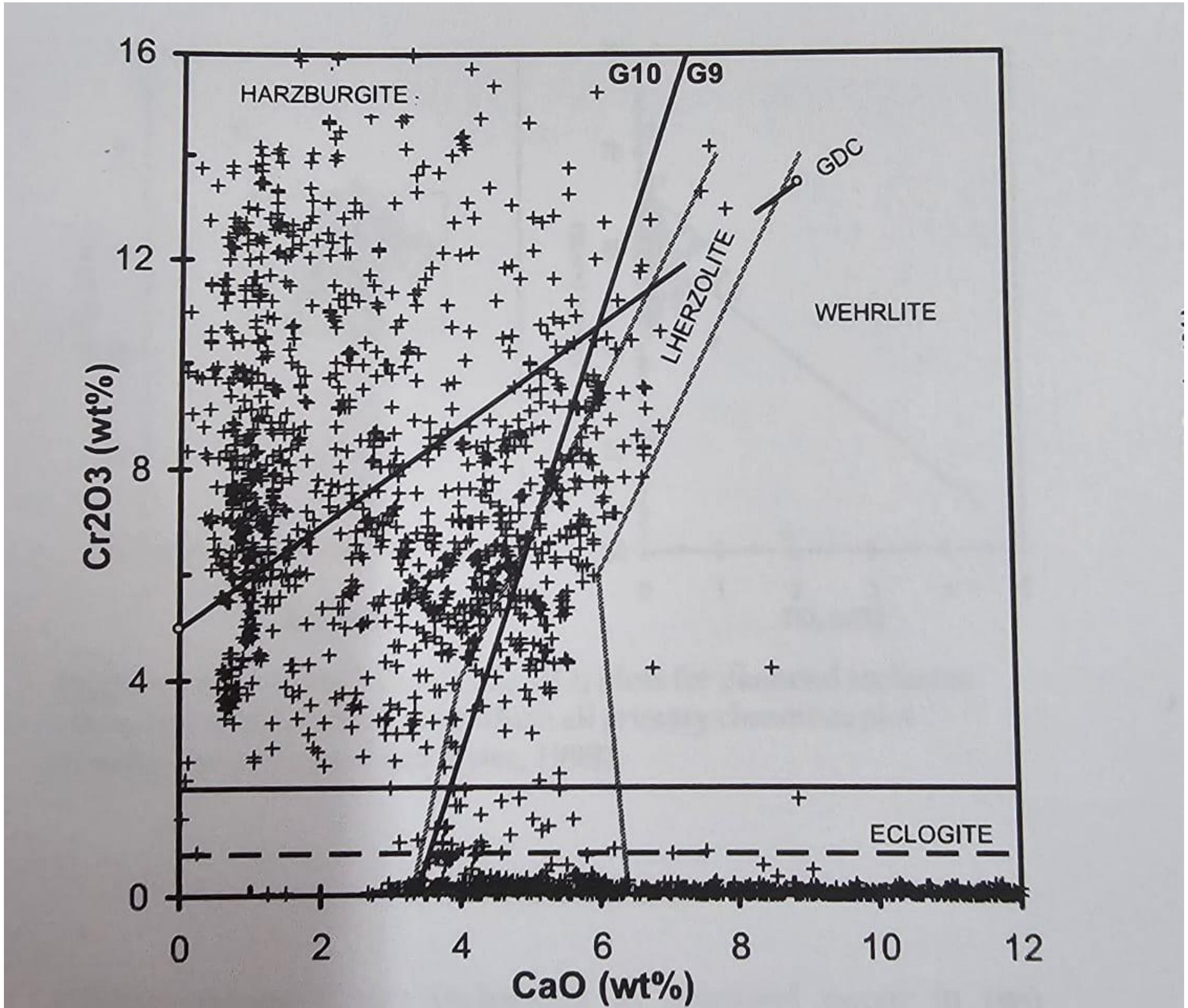
MAIN INDICATOR MINERAL CHEMISTRY

- **Garnet (especially G10 & G9)**. G10, Pyrope garnet. Hi Cr, low Ca. Associated with diamond stability field. G9 garnets: Slightly higher Ca. From Lherzolite, not as diamondiferous.
- **Chromite (Cr-Spinel)**: High Cr#(Cr/Cr+Al) 0.6-0.9. Survives transport and indicate mantle origin.
- **Ilmenite ($FeTiO_3$)**: Common in kimberlites, can be Mg or Cr rich. Can be used to infer mantle oxygen fugacity and magma evolution.
- **Clinopyroxene (Cr-diopside)**: Rich in Cr_2O_3, often green. Indicates mantle xenoliths and proximity to diamond stability field.
- **Orthopyroxene**: Occurs as xenocrysts or in xenoliths. High Mg#(Mg/Mg+Fe) >0.9. Low CaO and Al_2O_3 suggesting residual mantle origin. May show metasomatic enrichment in Al, Cr or Ti if altered by kimberlitic magma or associated fluids

GARNET MINERAL CHEMISTRY

- **Garnets ($Mg_3Al_2Si_3O_{12}$)**
- **Eclogitic Garnets:** Variable composition but low Cr_2O_3 and high CaO.
  I. **Highly sodic**: NaO content >0.06 wt might be diamondiferous
  II. **Derivation**: Highly fractionated oceanic crust (Suduction origin)
- **G10 Garnets (Pyrope garnets)**
  I. **Composition**: High Cr_2O_3, low CaO
  II. **Harzburgitic**: Found in diamond stability field (Cr_2O_3 1-14 wt%, CaO <~2 wt%)
- **G9 Garnets (Pyrope Garnets)**
  I. **Composition**: High CaO >5 wt%, Moderate Cr_2O_3 1-5 wt%
  II. **Lherzolitic**: May not indicate diamonds. Still mantle derived.

Cr2O3 vs CaO SCATTER PLOT FOR GARNETS



Cr2O3 vs MgO & Cr2O3 vs TiO2 SCATTER PLOTS FOR CHROMITES