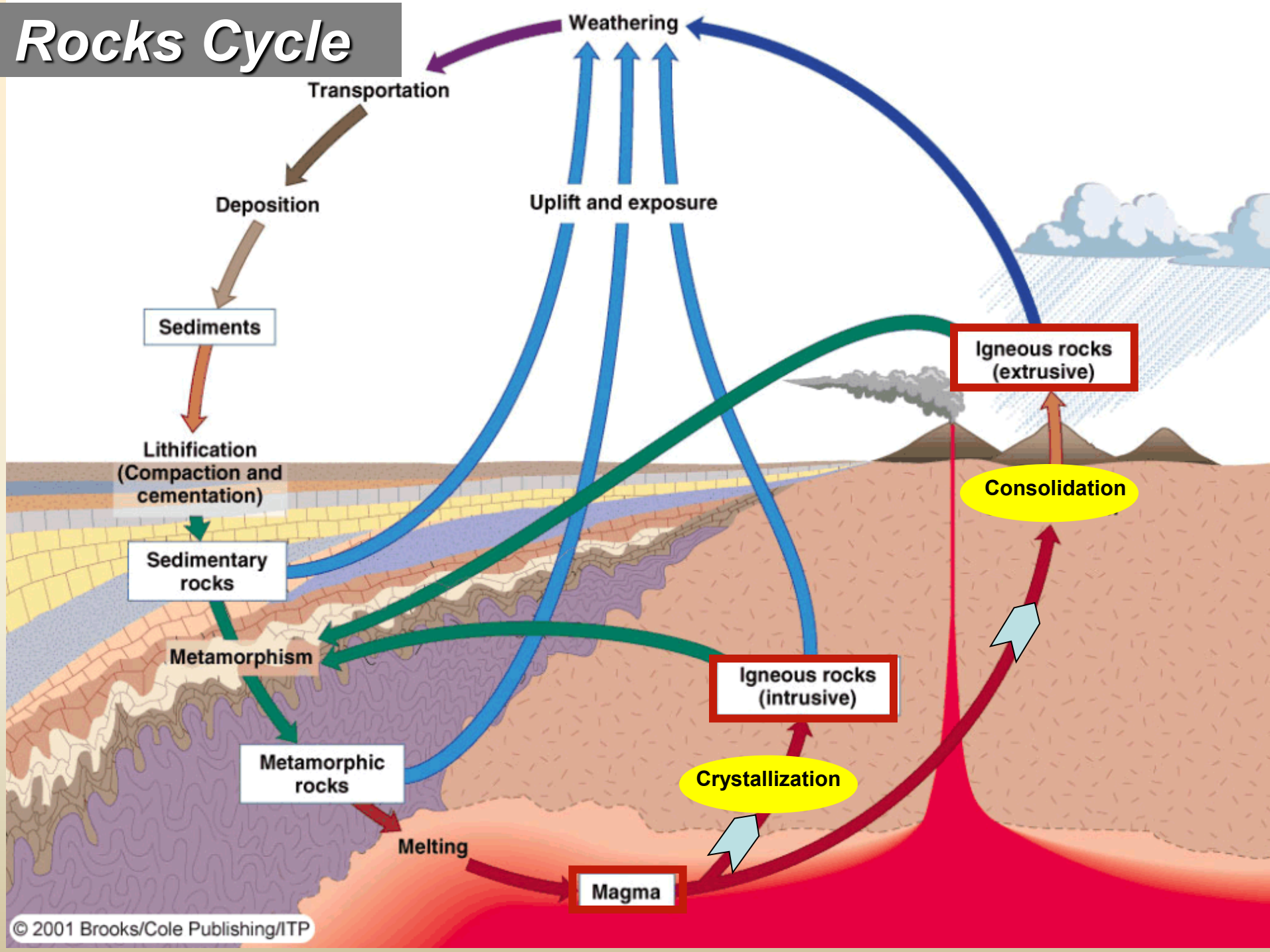
Module 7
Igneous Rocks

IGNEOUS ROCKS

- ***Igneous Rocks is formed by crystallization of molten rock material***
  - **Molten rock material below Earth's surface is called *magma***
  - **Molten rock material erupted above Earth's surface is called *lava***
  - **The name changes because the composition of the molten material changes as it is erupted due to escape of volatile gases**
  - **The origin of magma is commonly from the upper mantle of the earth**

Rocks Cycle


Weathering
Transportation
Deposition
Uplift and exposure
Sediments
Lithification
(Compaction and
cementation)
Sedimentary
rocks
Metamorphism
Metamorphic
rocks
Melting
Magma
Igneous rocks
(extrusive)
Consolidation
Igneous rocks
(intrusive)
Crystallization
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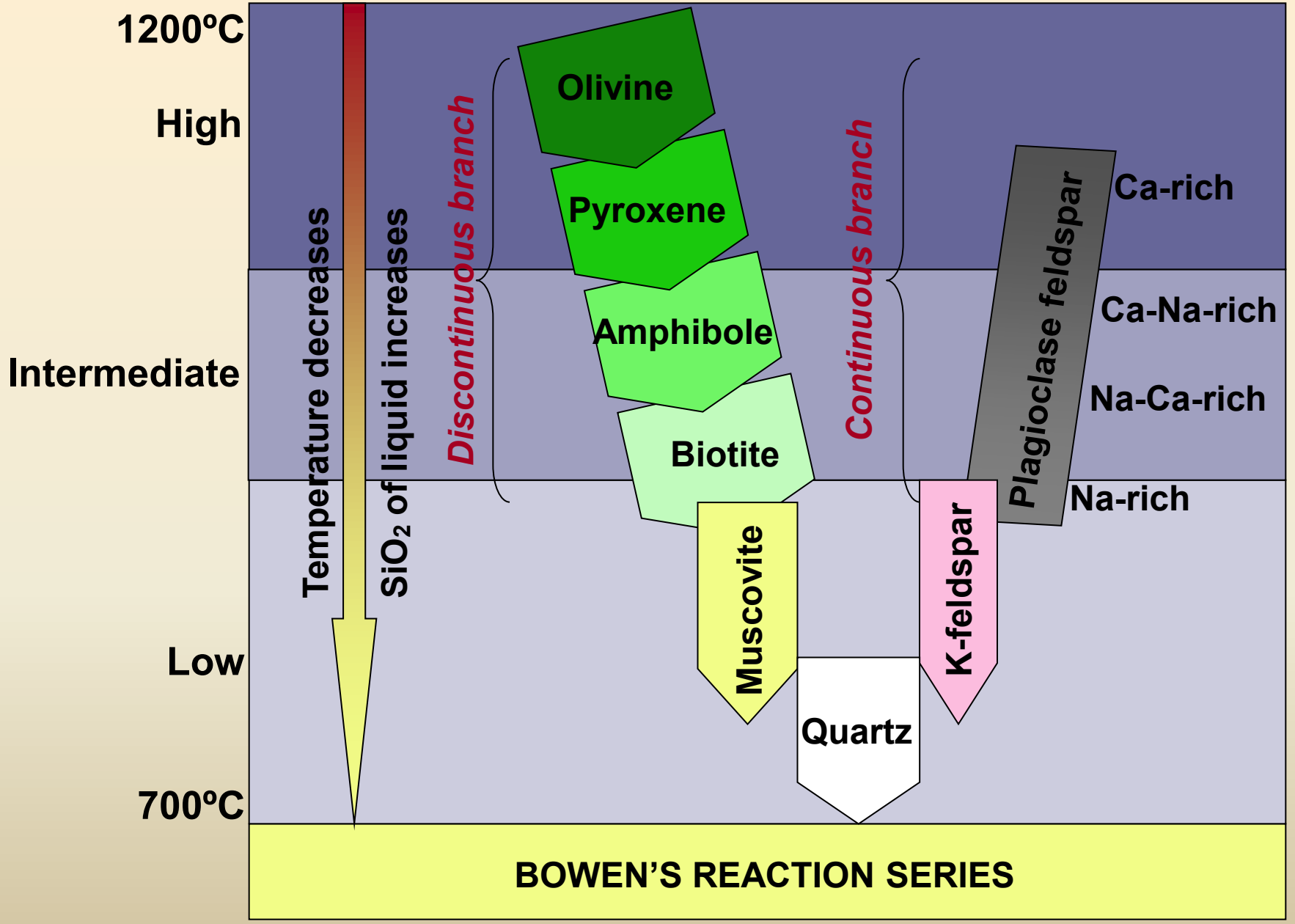
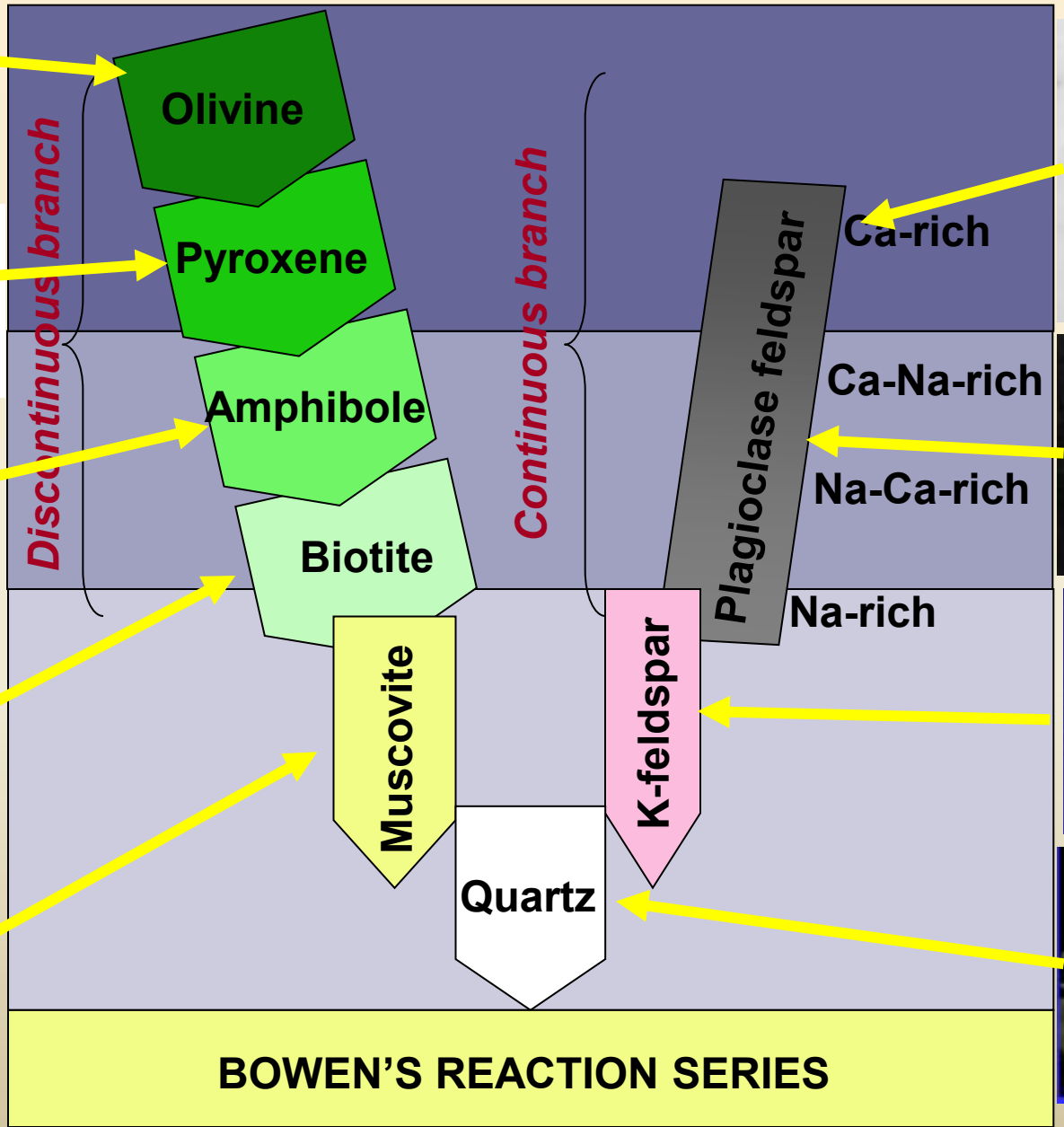
Rock Forming Minerals



Plagioclase Minerals

- Anortite
- Bitownite
- Labradorite
- Andesine
- Oligoclase
- Albite

Rock Forming Minerals



Rock Forming Minerals

High Temperature Mineral Suite

Olivine

- Isolated Tetrahedra Structure
- Iron, magnesium, silicon, oxygen
- Bowen's Discontinuous Series

Augite

- Single Chain Structure (Pyroxene)
- Iron, magnesium, calcium, silicon, aluminium, oxygen
- Bowen's Discontinuos Series

Calcium Feldspar

- Framework Silicate Structure (Plagioclase)
- Calcium, silicon, aluminium, oxygen
- Bowen's Continuous Series

Rock Forming Minerals

Intermediate Temperature Mineral Suite

Hornblende

- Double Chain Structure (Amphibole)
- Iron, magnesium, calcium, silicon, aluminium, oxygen
- Bowen's Discontinuos Series

Biotite

- Sheet Silicate Structure (Mica)
- Iron, magnesium, potassium, silicon, aluminium, oxygen
- Bowen's Discontinuos Series

Sodium Feldspar

- Framework Silicate Structure (Plagioclase)
- Sodium, silicon, aluminium, oxygen
- Bowen's Continuous Series

Rock Forming Minerals

Low Temperature Mineral Suite

Muscovite

- Sheet Silicate Structure (Mica)
- Calcium, potassium, silicon, aluminium, oxygen
- Bowen's Discontinuos Series

Potassium Feldspar

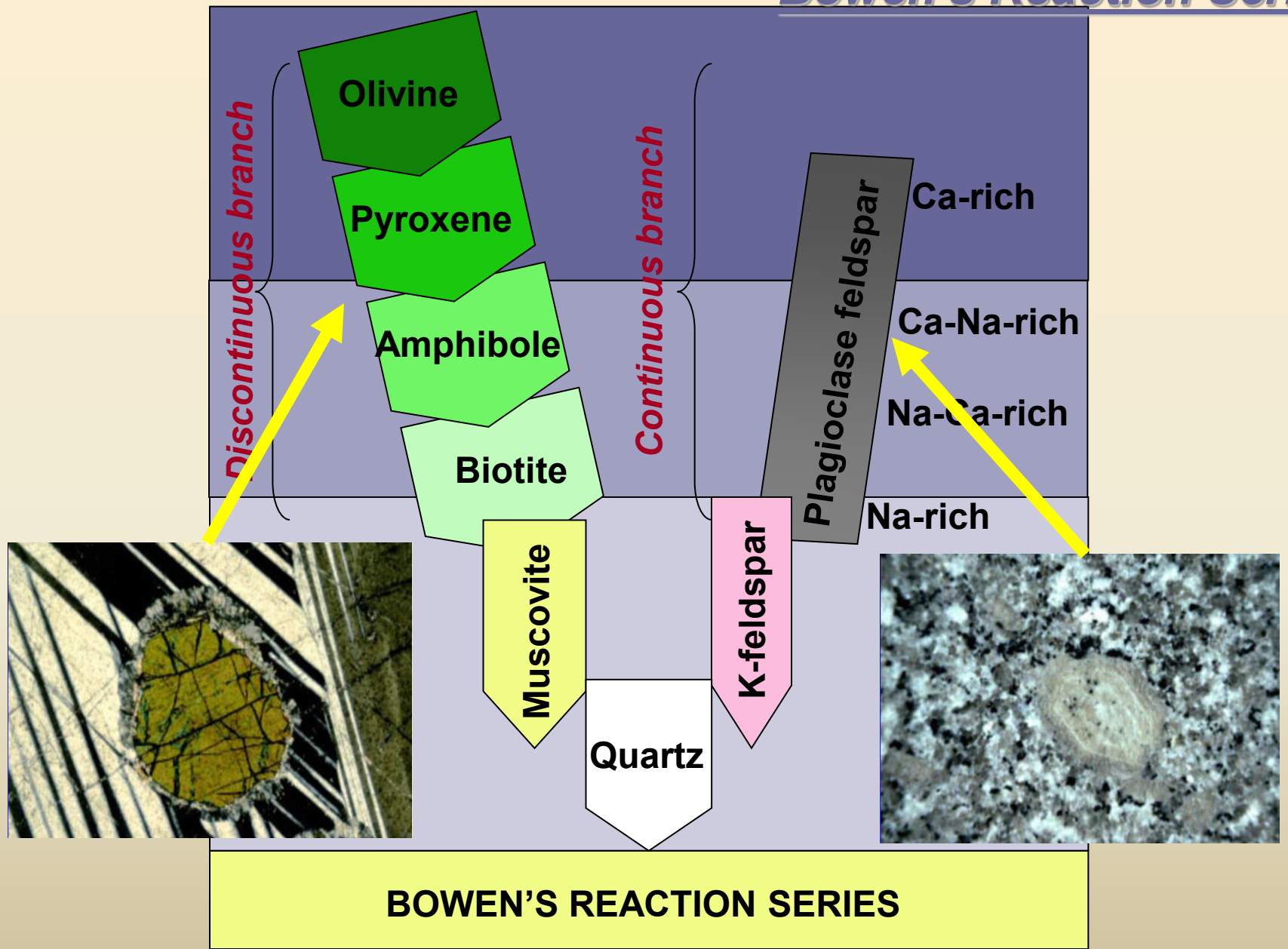
- Framework Silicate Structure (Orthoclase)
- Potassium, silicon, aluminium, oxygen
- Bowen's Continuous Series

Quartz

- Framework Silicate Structure
- Silicon, oxygen
- Last to crystallize from magma

Rock Forming Minerals

Bowen's Reaction Series



Effect of Cooling Rate on Crystal Size

- **Crystals are formed by ions arranged in orderly patterns**
- **Crystal size is determined by the rate of cooling**
  - ***Extremely fast cooling***
  - ***Fast cooling***
  - ***Slow cooling***

Effect of Cooling Rate on Crystal Size

Extremely fast cooling

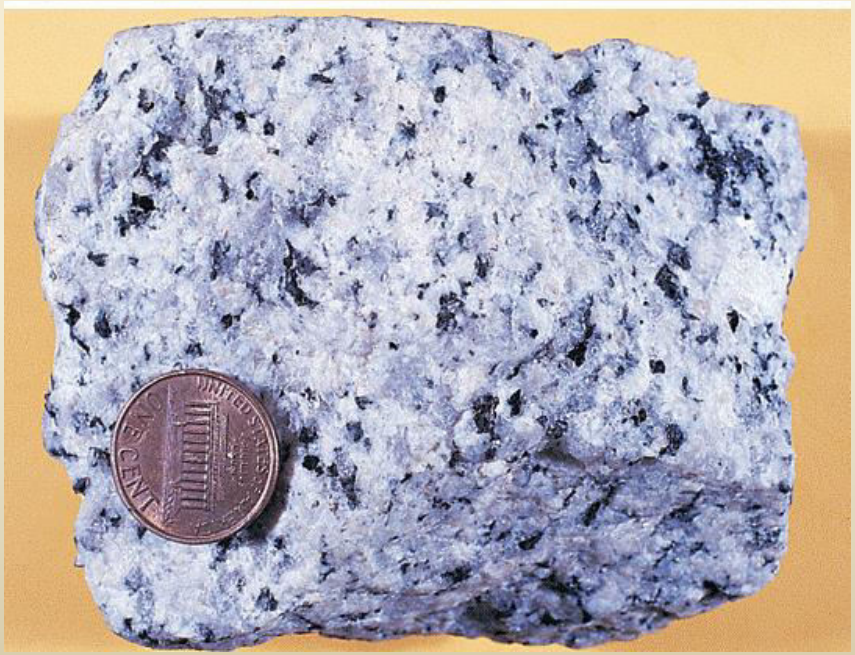
- ❑ Forms glass, not crystals
- ❑ Occurs above Earth's surface under water or ice
- ❑ Yields obsidian, volcanic glass

Effect of Cooling Rate on Crystal Size

Fast cooling

- Forms very small invisible crystals
- Crystallized out less slowly
- Magma moves more rapidly
- Occurs closer to Earth's surface
- Typical in small intrusions and conduit

Effect of Cooling Rate on Crystal Size

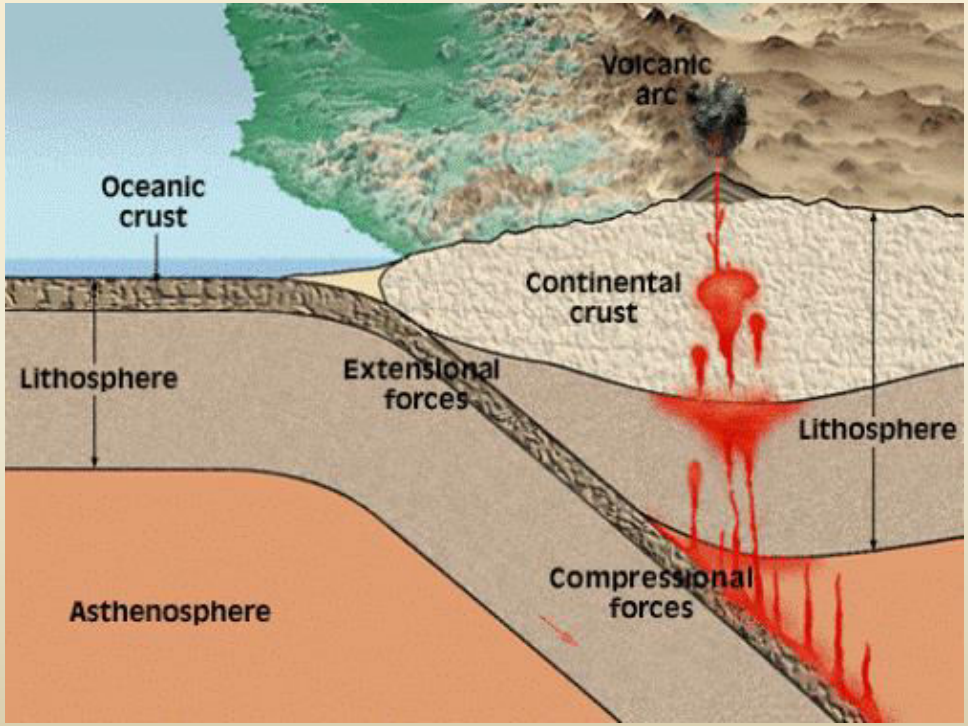


Slow cooling

- ❑ Forms large, visible crystals
- ❑ The slower the cooling rate, the larger the crystals formed
- ❑ Occurs below Earth's surface
- ❑ Typical of plutonic rocks

IGNEOUS ROCKS CLASSIFICATION

- Based on the location of their frozen/cooling:
  - Intrussive
  - Extrussive
- Based on their texture:
  - Plutonik: phaneritic
  - Volcanic: aphanetic

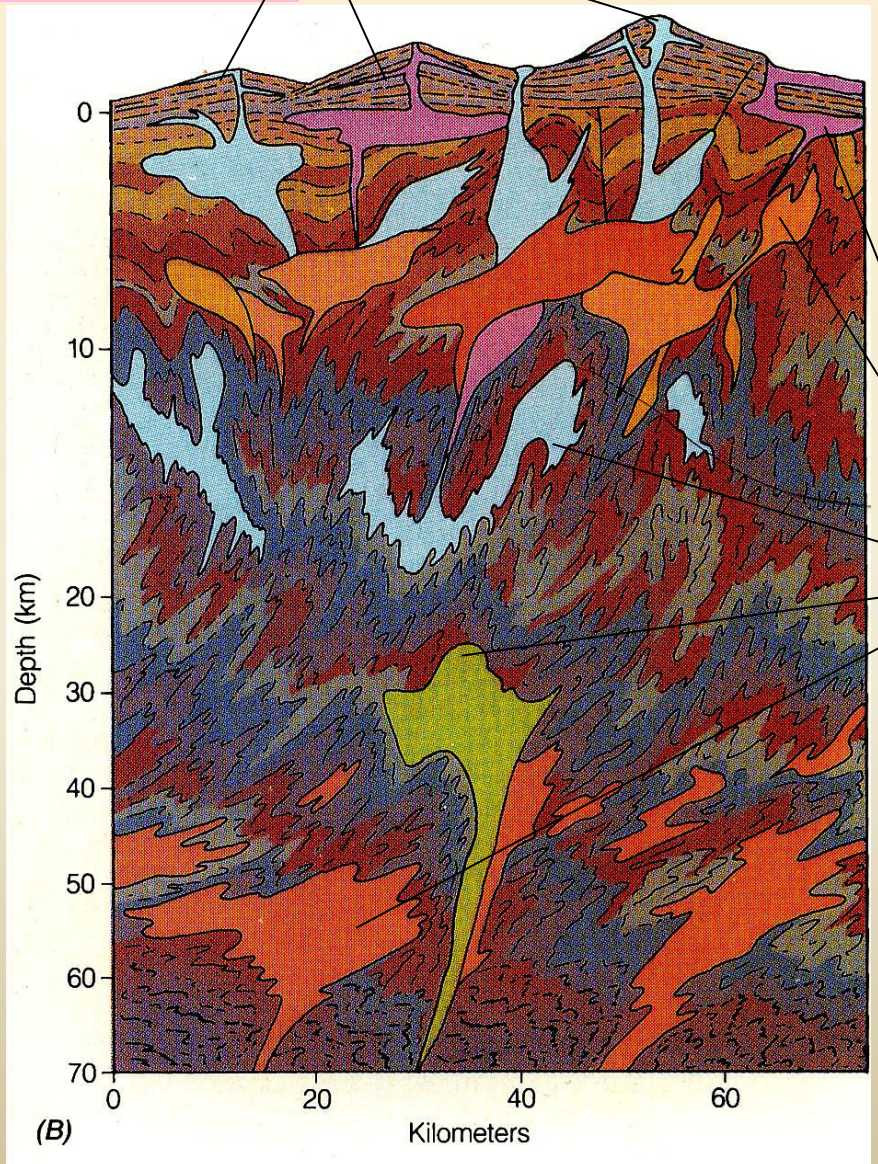


Classification Based on Silica (SiO_2) Content

- Ultra basic (Silica content < 45% of total composition)
- Basic (Silica content 45% - 52%)
- Intermediate (Silica content 52% - 66%)
- Acidic (Silica content > 66%)

Where do the igneous rocks form?

Volcanic (Extrusive) Igneous Rocks



Plutonic (intrusive) Igneous Rocks

Where do the igneous rocks form?

Plutonic (intrusive) Igneous Rocks

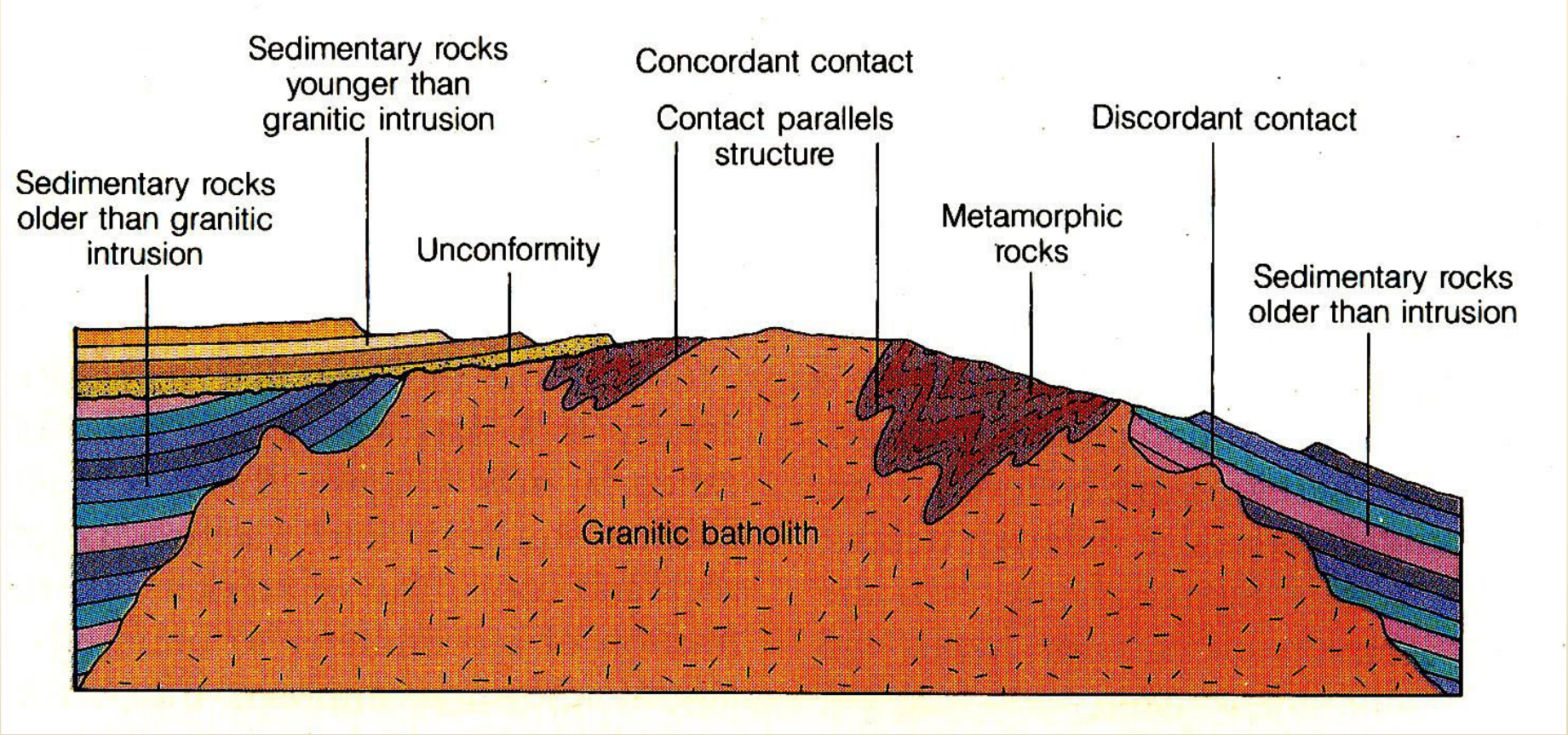
Plutonic (intrusive) Igneous Rocks
Formed by crystallization of molten rock material below Earth's surface

Coarse-grained plutonic rocks
Crystallized out very slowly in large magma chambers 12-20 km beneath Earth's surface

Fine-grained plutonic rocks
Crystallized out less slowly, more rapidly, in small intrusions and conduits closer to Earth's surface

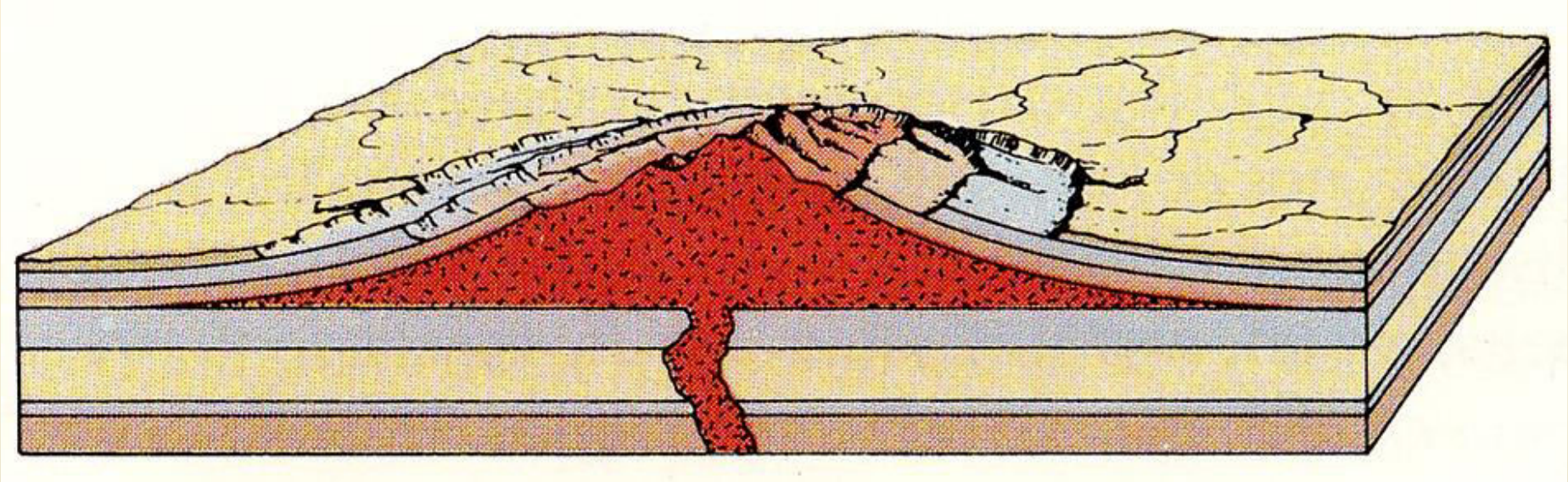
Where do the igneous rocks form?

Plutonic (intrusive) Igneous Rocks



Where do the igneous rocks form?

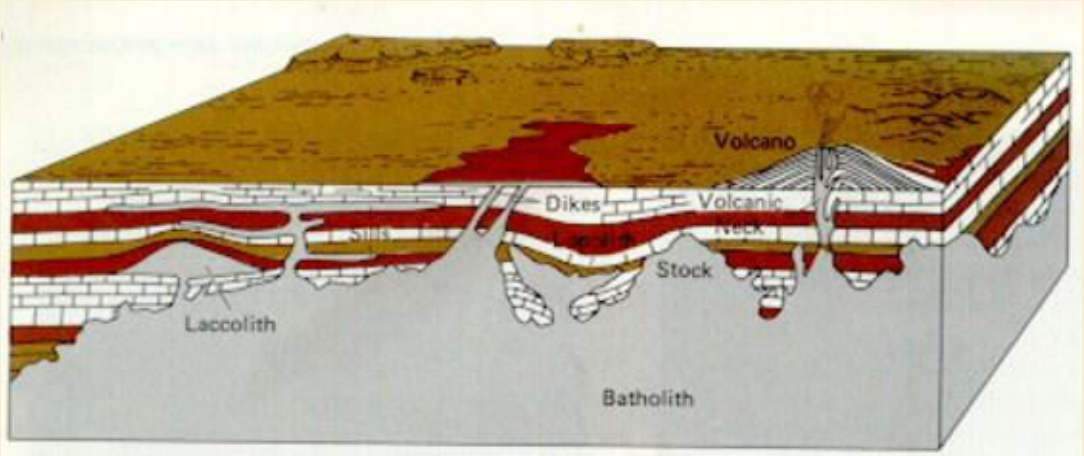
Plutonic (intrusive) Igneous Rocks



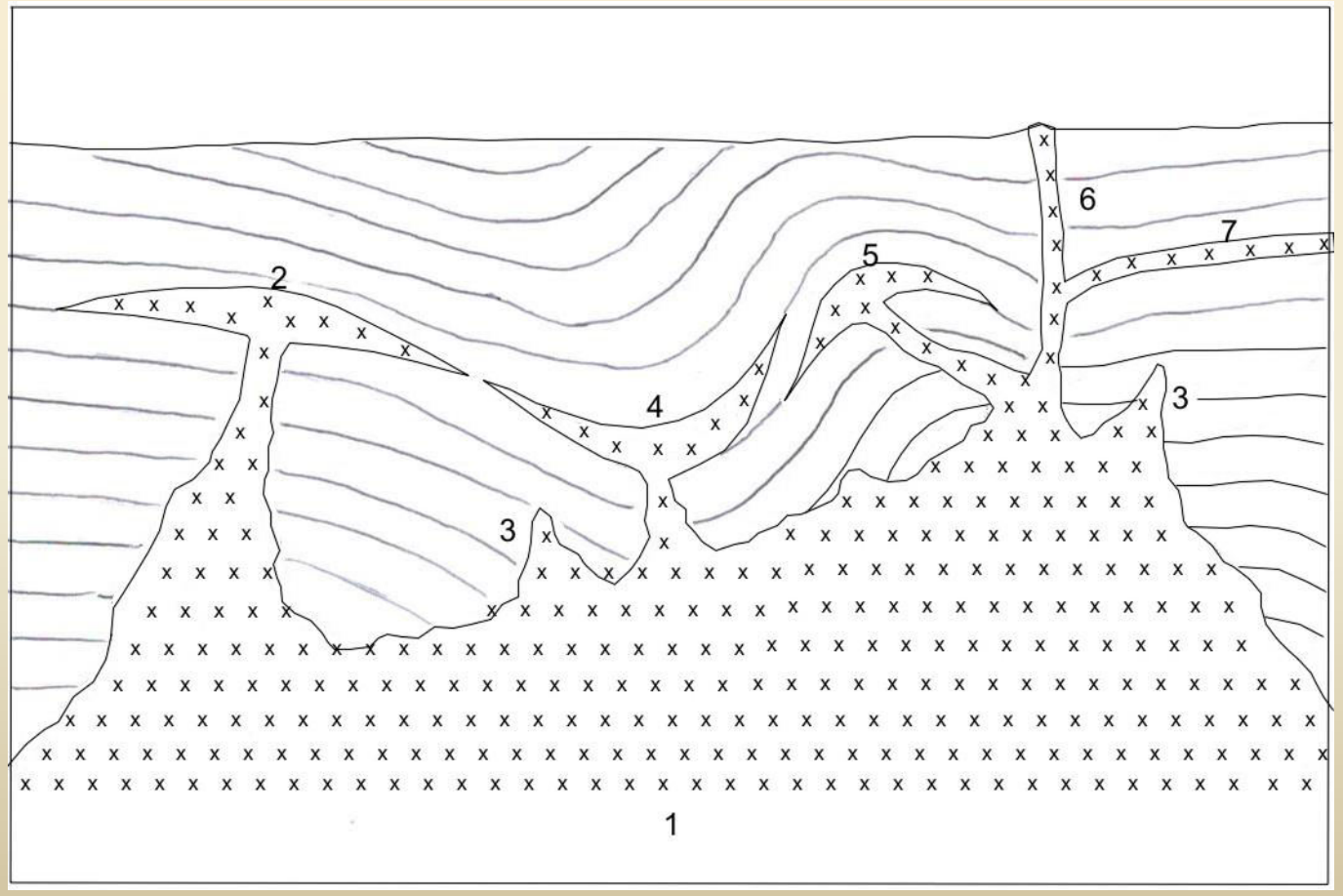
Laccoliths

- are masses of igneous rock between layers of the surrounding rock

Intrusion Structures

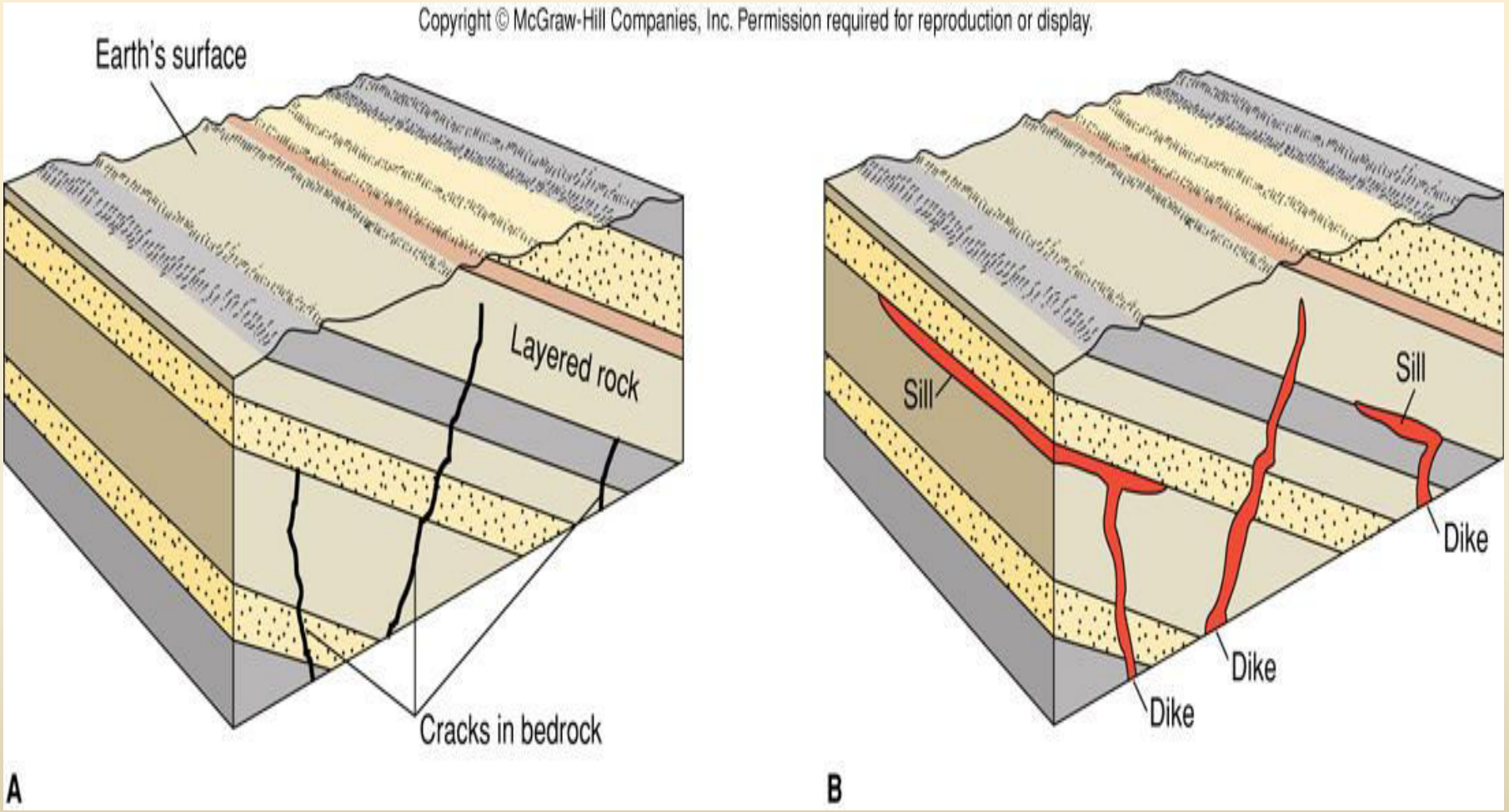


1. Batholith
2. Lacolith
3. Stock
4. Loppolith
5. Phacolith
6. Dyke / Pipe
7. Sill



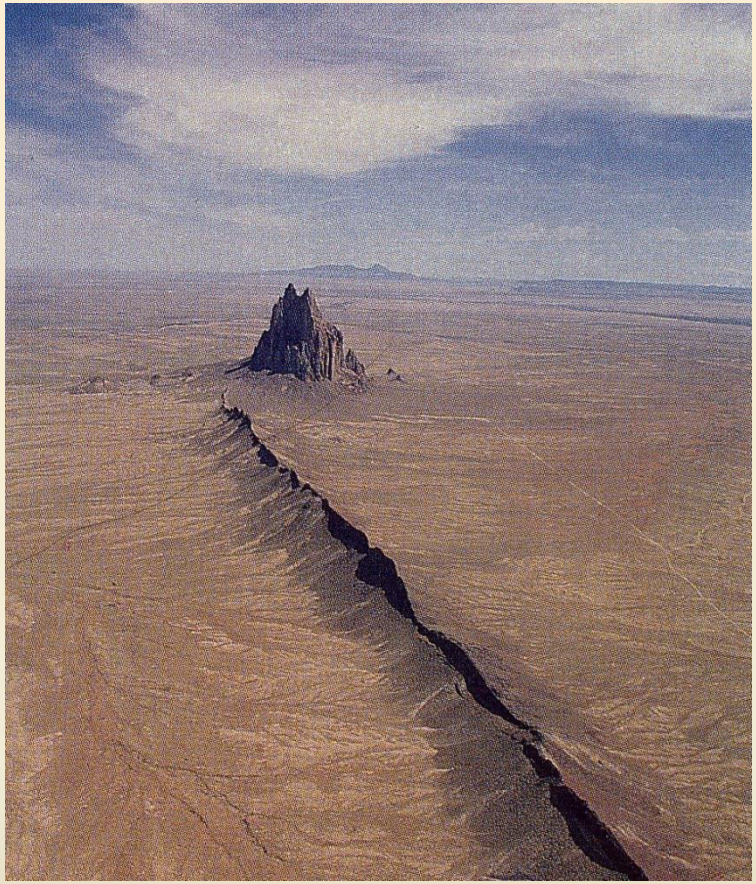
Where do the igneous rocks form?

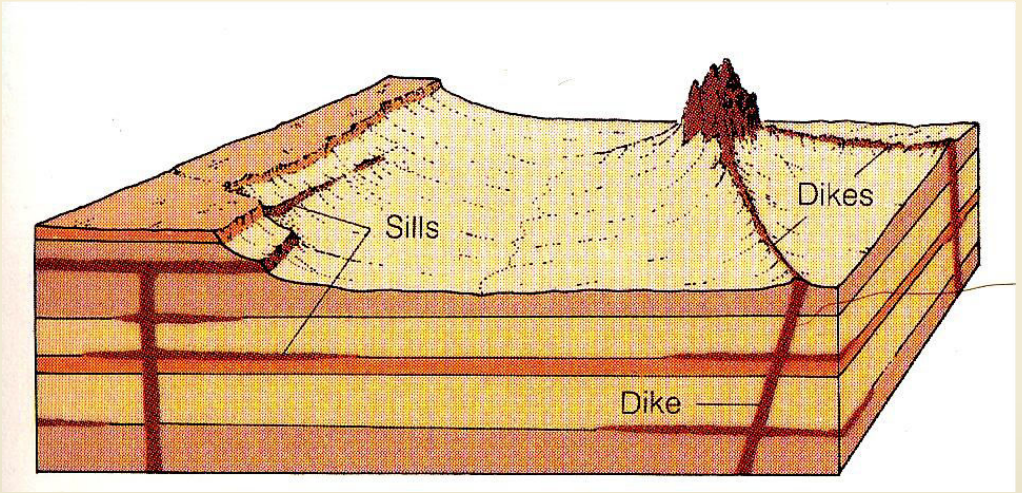
SILL DAN DIKE



Where do the igneous rocks form?

Plutonic (intrusive) Igneous Rocks



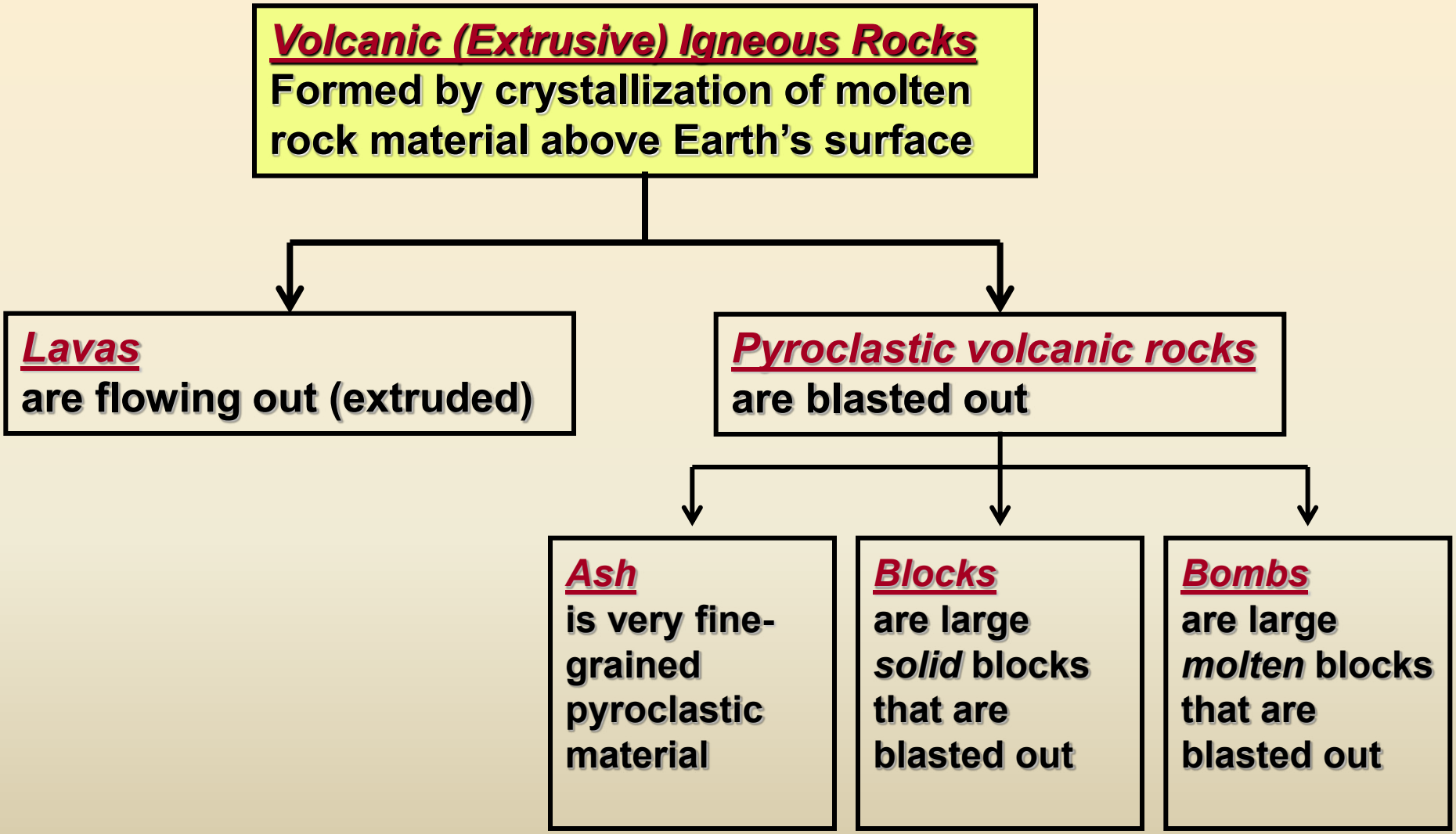


Dikes and Sills

- are tabular intrusive bodies.
- Dikes cut across layer of the surrounding rock
- Sills are injected between layers of strata

Where do the igneous rocks form?

Volcanic (extrusive) Igneous Rocks



Where do the igneous rocks form?

Volcanic (extrusive) Igneous Rocks

B

A lava fountain and rapidly flowing basalt

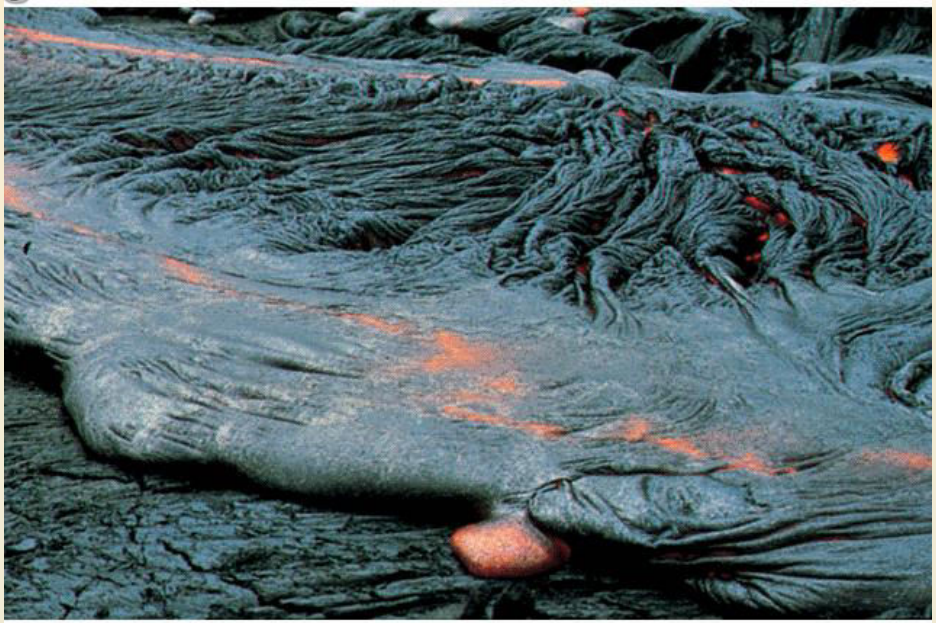


Photo by D. W. Peterson, U.S. Geological Survey

Photo by J. D. Griggs, U.S. Geological Survey

Pahoehoe, a smooth-surfaced, ropy form of basalt that crystallizes out near the beginning of a basalt flow

AA, a jagged-surfaced form of basalt that crystallizes out at the end of a basalt flow

Basalt, a mafic composition lava

Where do the igneous rocks form?

Volcanic (extrusive) Igneous Rocks

Andesite flow,
Mexico

Andesite flow,
Cascade Range, Oregon

Andesite, an intermediate composition lava

Where do the igneous rocks form?

Volcanic (extrusive) Igneous Rocks

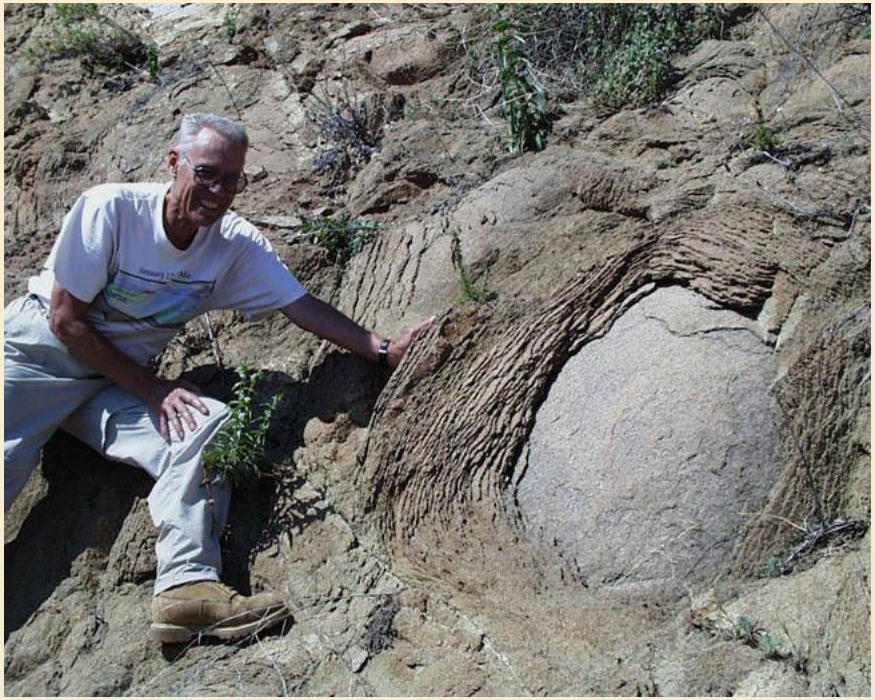
Rhyolite dome,
Mono Craters, California

Rhyolite flow showing columnar jointing, MacDougalls Island, New Brunswick

Rhyolite, a felsic composition lava

Igneous rocks structures

Columnar joint



Spheroidal wheatering

Sheeting joint in lava

Lava structures

Roppy lava

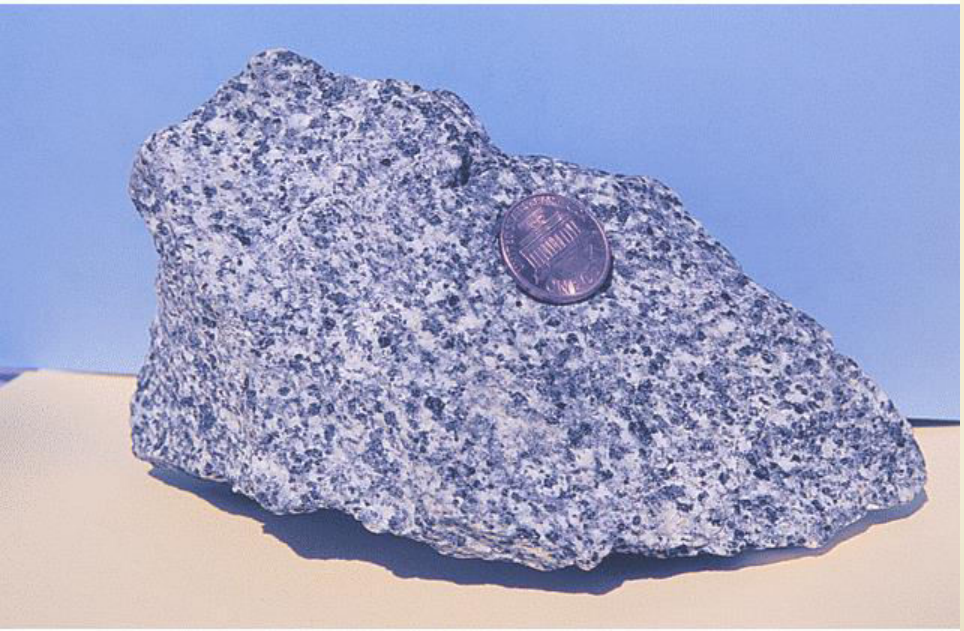
Pillow lava

Igneous rocks structures

- Columnar joint and sheeting joint are structures formed by the cooling of magma
- Ropy structure will be formed when low viscosity lava is cooled
- Pillow structure will be formed when low viscosity lava is cooled in water environment.
- Blocky fragmental structure will be formed when viscose lava is cooled.

Igneous Rocks Texture

IGNEOUS ROCK TEXTURE PROVIDES INSIGHT INTO THE COOLING HISTORY OF THE ROCK



Diorite

Photo by C. C. Plummer

A phaneritic texture

- Consists of visible grains
- Is formed by very slow cooling below Earth's surface
- Characteristic of plutonic igneous rocks *i.e.* gabbro, diabase, diorite, granite

Igneous Rocks Texture

Photo by C. C. Plummer

Aphanitic texture

- Consists of invisible grains formed by fast rate of cooling
- Characteristic of the lavas: ***basalt, andesite, rhyolite***

Igneous Rocks Texture

Glassy texture

- Consists of visible grains
- Is not crystalline, is formed by extremely rapid cooling
- Characteristic of *Obsidian*

Igneous Rocks Texture

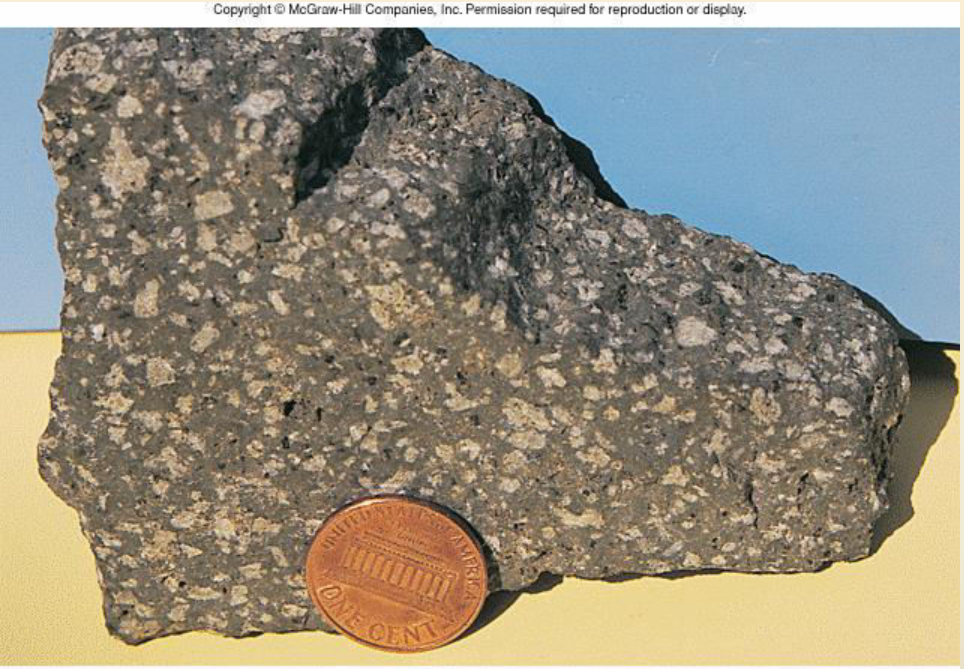
Photo by C. C. Plummer

Photo by C. C. Plummer

Vesicular structure

- Is bubbly, formed by trapped bubbles of gas
- Characteristic of *scoria* (vesicular basalt) and *pumice* (vesicular rhyolite)

Igneous Rocks Texture



Andesite (porphyritic)

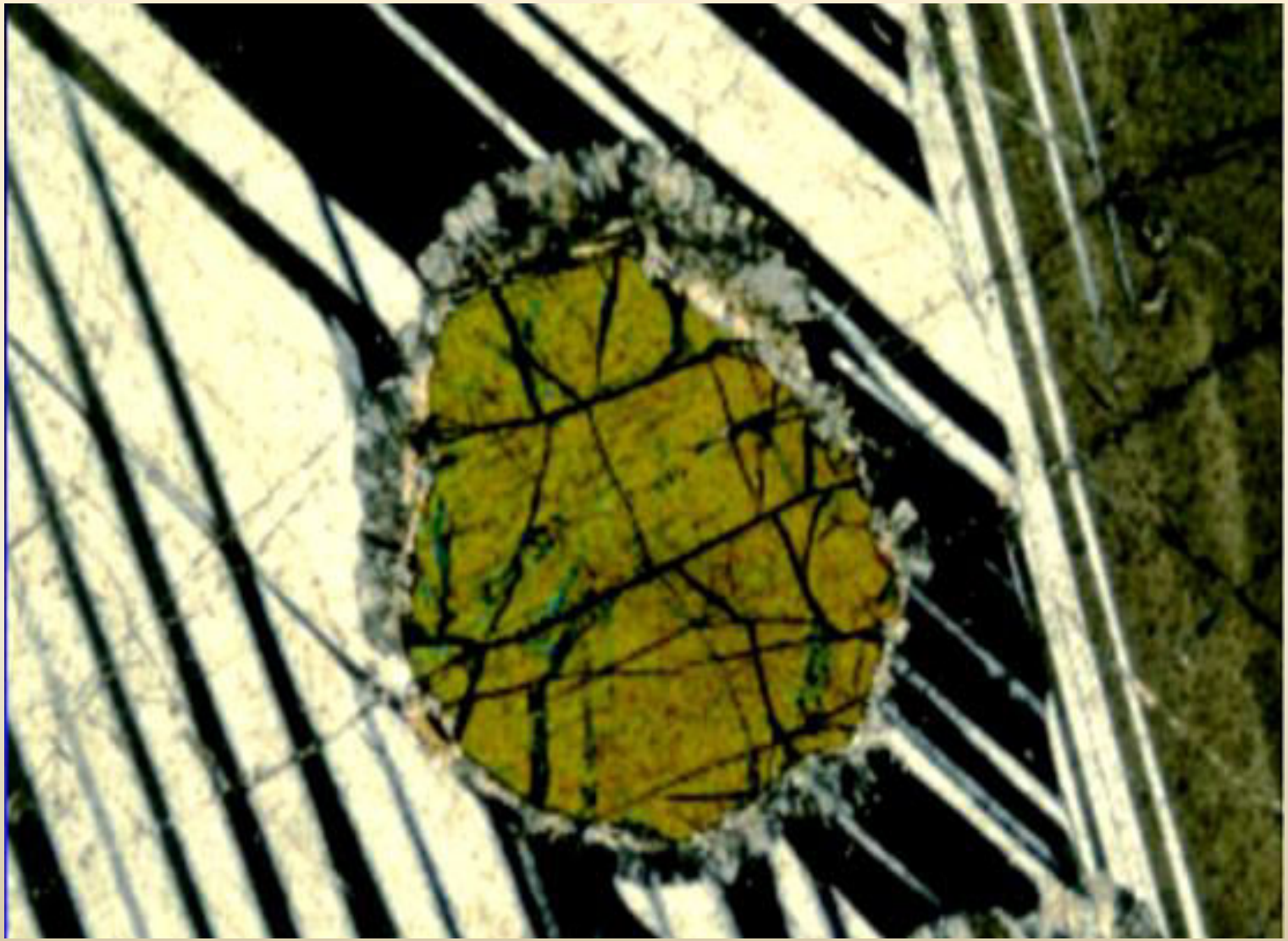
Photo by C. C. Plummer

Porphyritic texture

- Consists of phaneritic (visible) grains in an aphanitic matrix
  - Phaneritic crystals form by very slow cooling below Earth's surface
  - Aphanitic crystals form by very rapid cooling above Earth's surface
- Characteristic of the lavas: *basalt*, *andesite*, *rhyolite*
- Formed when a lava is erupted as a crystal mush

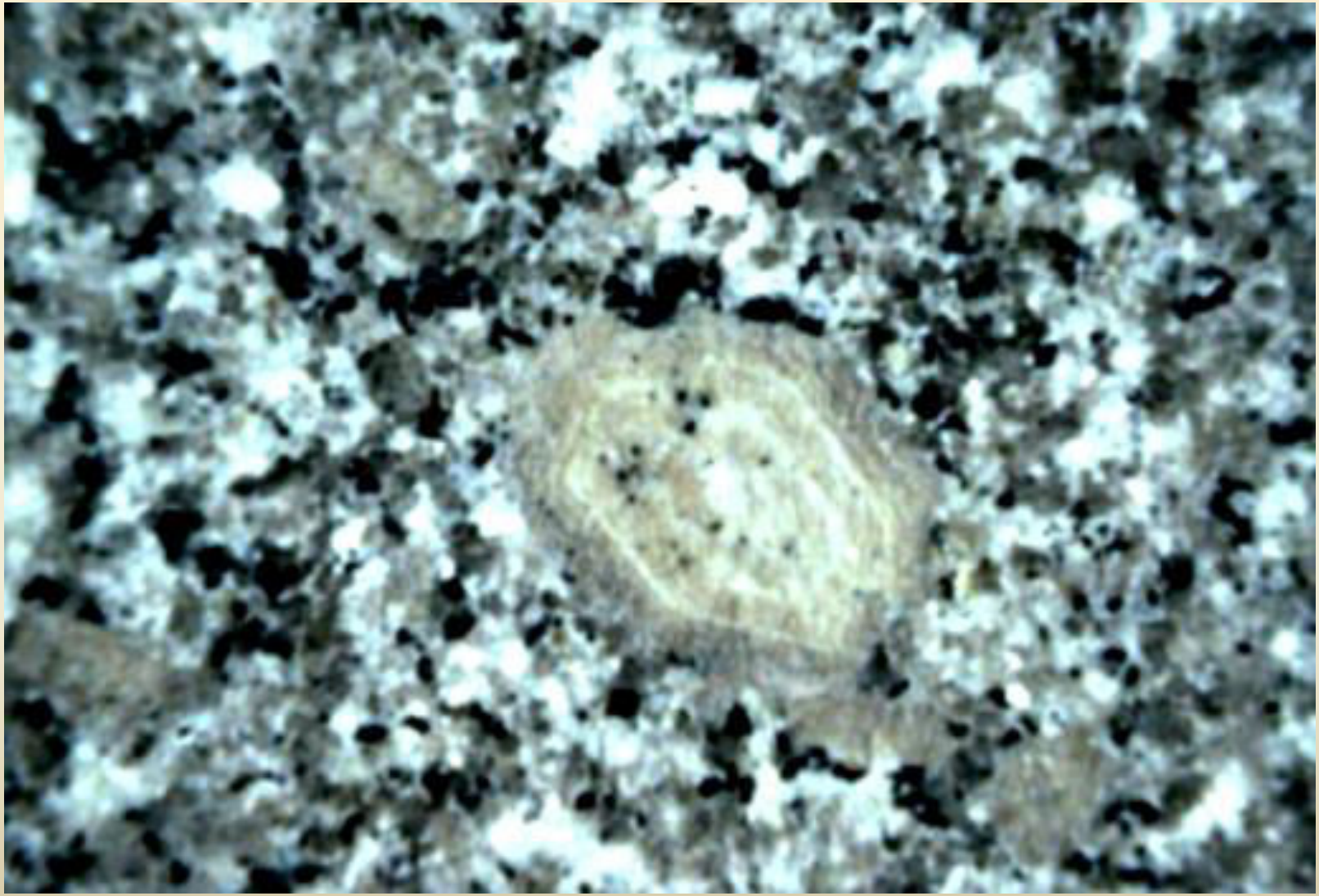
Igneous Rock Texture: holocrystaline

Bowen's Reaction Series



Igneous Rock Texture: Hypocrystalin

Bowen's Reaction Series



Texture and where they form

ABOVE EARTH'S SURFACE

Based on Where They Form and Their Texture

Glassy Texture

Vesicular Texture

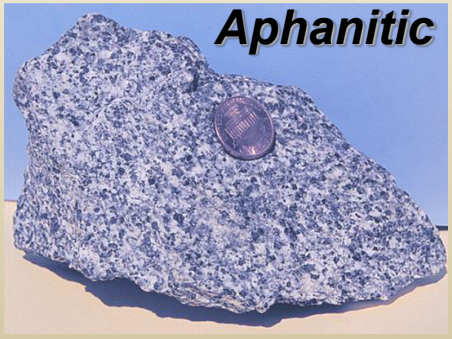
Plutonic (intrusive) Igneous Rocks

Volcanic (Extrusive) Igneous Rocks

CLOSER EARTH'S SURFACE

Aphanitic Texture

Porphyritic Texture



Phaneritic Texture

BELOW EARTH'S SURFACE

Igneous Rocks Composition

Dunit (Olivine rich)

Harzburgit (Pyroxene rich)

Ultramafic

- ***Means rich in magnesium and iron***
- **Is the average composition of Earth's mantle**
- **Composed of olivine and augite**
- **Example: *peridotite***

Igneous Rocks Composition

Gabbro

Mafic

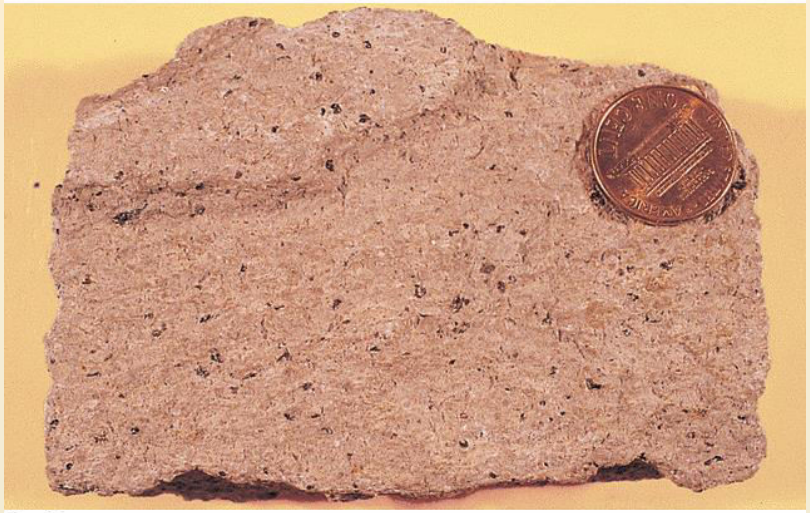
- Means rich in magnesium, iron, and/or calcium
- Is the average composition of oceanic crust
- Composed of olivine, augite, and calcium, plagioclase feldspar
- Examples: basalt, diabase, and gabbro

Igneous Rocks Composition

Intermediate

- ***Means half mafic, half felsic***
- **Is the composition of a mixture of oceanic and continental crust?**
- **Composed of hornblende and calcium-sodium plagioclase feldspar**
- **Examples: *andesite* and *diorite***

Igneous Rocks Composition



Ryolite

Felsic

- *Means rich in feldspar and silica*
- Is the average composition of continental crust
- Composed of potassium feldspar, sodium plagioclase feldspar, quartz
- Examples: *rhyolite* and *granite*

Classification and naming of igneous rocks

Identification of Plutonic Igneous Rocks

Plutonic Rocks

Phaneritic texture

Mafic composition
Dark gray

Diabase
(fine-grained)

Gabbro
(coarse-grained)

Intermediate composition
Medium gray,
~ 50:50 black and white

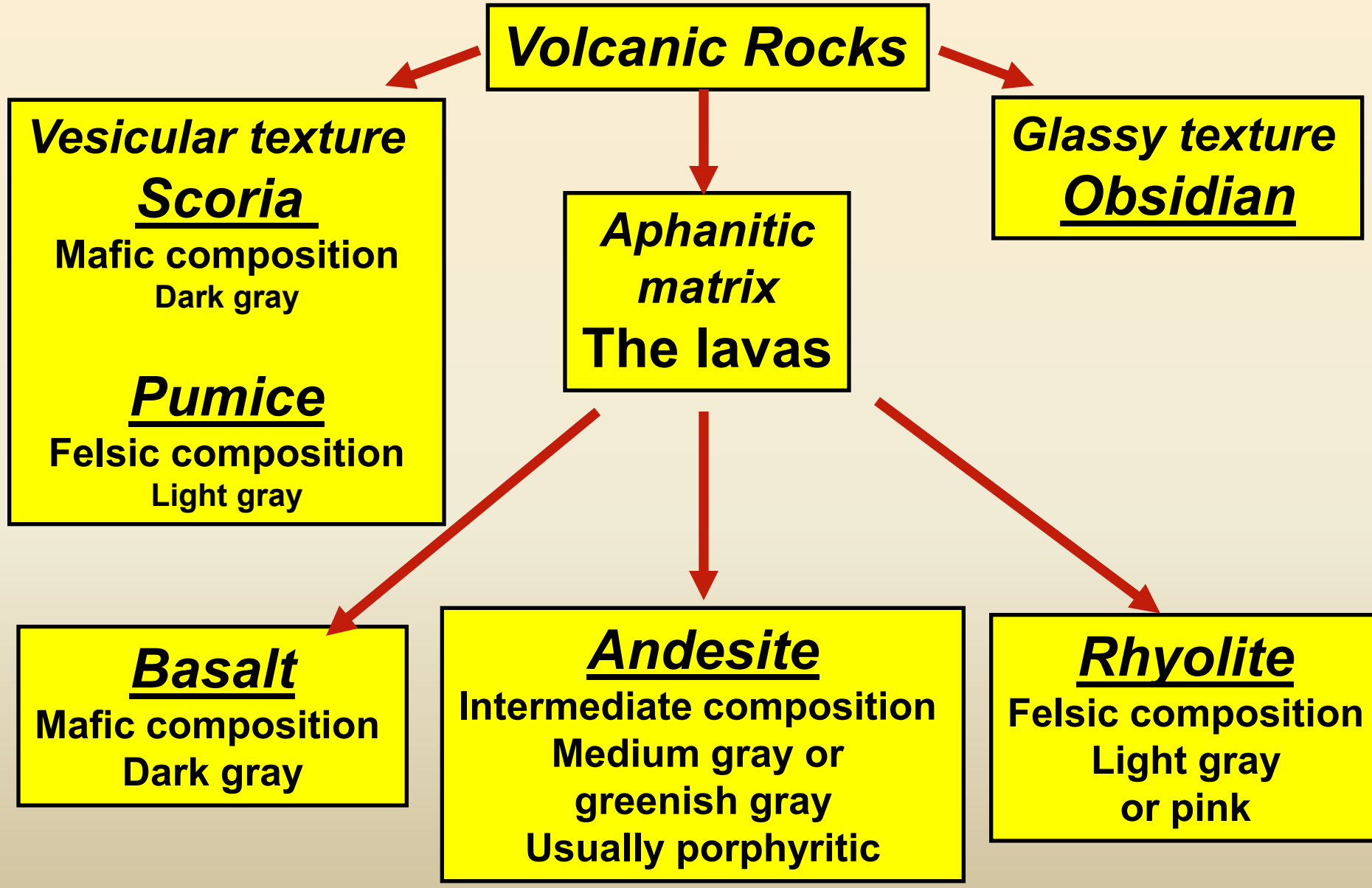
Diorite

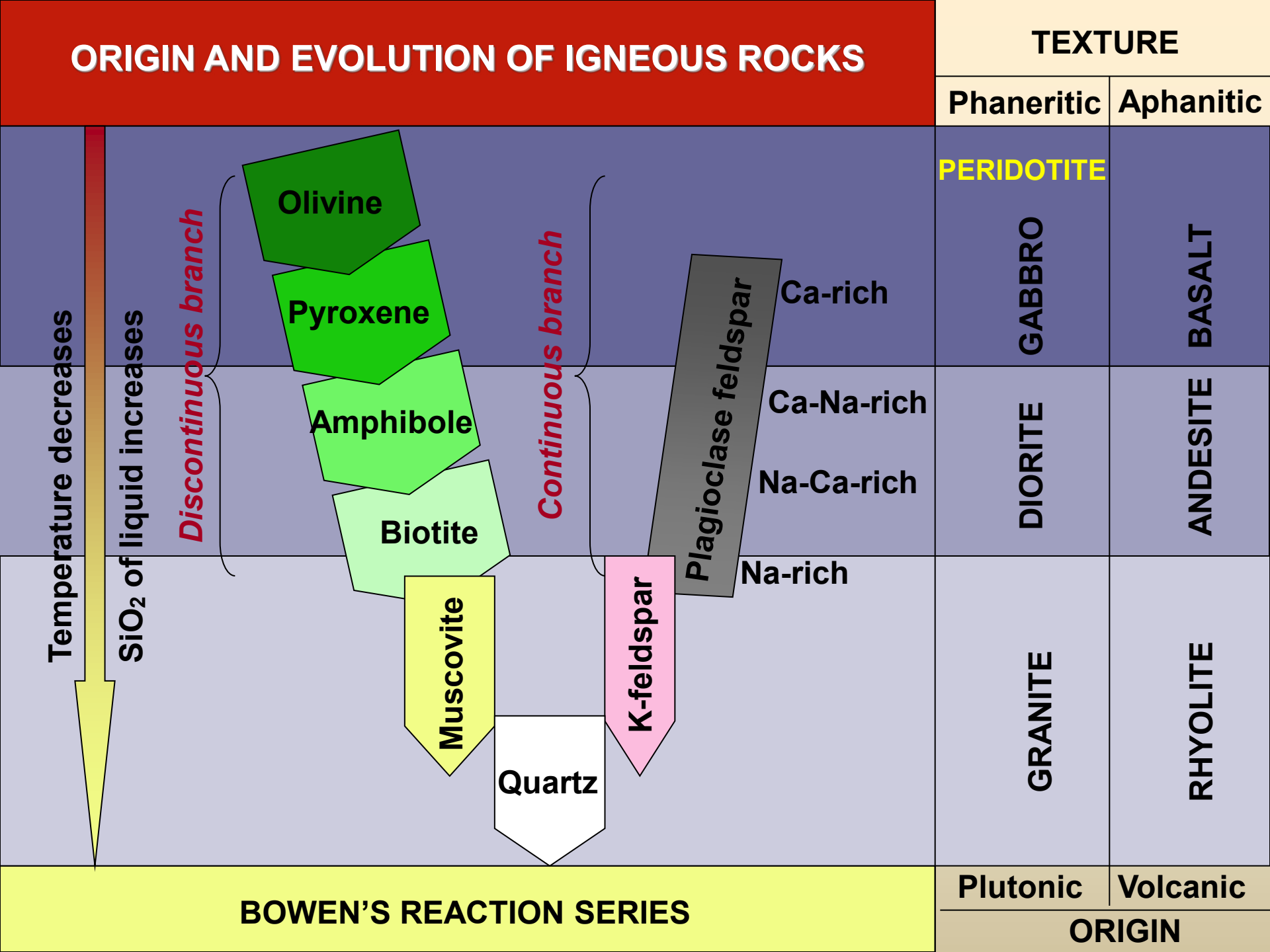
Felsic composition
Light gray
or pink

Granite

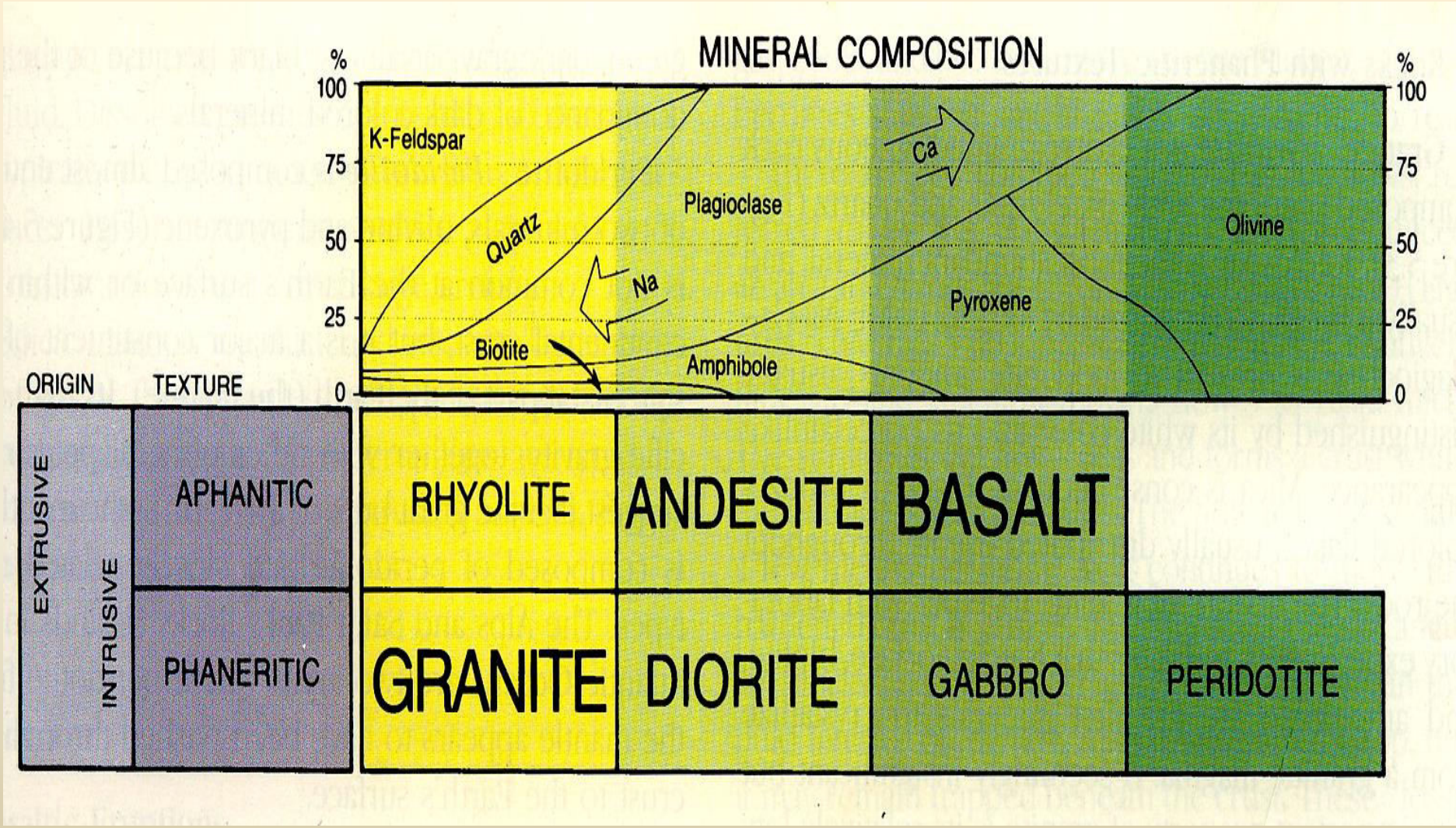
Classification and naming of igneous rocks

Identification of Volcanic Igneous Rocks




ORIGIN AND EVOLUTION OF IGNEOUS ROCKS
TEXTURE
Phaneritic
Aphanitic
PERIDOTITE
GABBRO
BASALT
DIORITE
ANDESITE
GRANITE
RHYOLITE
Temperature decreases
SiO_2 of liquid increases
Discontinuous branch
Continuous branch
Olivine
Pyroxene
Amphibole
Biotite
Plagioclase feldspar
Ca-rich
Ca-Na-rich
Na-Ca-rich
Na-rich
Muscovite
K-feldspar
Quartz
BOWEN'S REACTION SERIES
Plutonic
Volcanic
ORIGIN

Classification and naming of igneous rocks



IGNEOUS ROCK CLASSIFICATION

MINERAL COMPOSITION

OLIVINE

AUGITE

CALCIUM FELDSPAR

ROCK TEXTURE

PHANERITIC

GABBRO

APHANITIC

BASALT

IGNEOUS ROCK CLASSIFICATION

MINERAL COMPOSITION

HORNBLENDE

BIOTITE

SODIUM FELDSPAR

ROCK TEXTURE

PHANERITIC

DIORITE

APHANITIC

ANDESITE

IGNEOUS ROCK CLASSIFICATION

MINERAL COMPOSITION

MUSCOVITE

POTASSIUM FELDSPAR

QUARTZ

ROCK TEXTURE

PHANERITIC

GRANITE

APHANITIC

RHYOLITE

Obsidian (volcanic glass)

Photo by C. C. Plummer

Scoria (vesicular basalt)

Photo by C. C. Plummer

Pumice (vesicular rhyolite)

Photo by C. C. Plummer

Basalt

Basalt

Photo by C. C. Plummer

Porphyritic Andesite

Andesite (porphyritic)

Photo by C. C. Plummer

Rhyolite

Ryolite

Photo by C. C. Plummer

Gabbro

Gabbro

Diorite

Diorite

Photo by C. C. Plummer

Granite

Granite

Photo by C. C. Plummer

How to describe igneous rock?

- Color:
  - Dark color: black, dark gray, etc
  - Gray
  - Light color: light gray
- Structure: massive, vesicular, pillow, etc
- Texture: phaneritic, aphanetic, holocrystaline, hypocrystaline, holohyaline, porphiritic, etc
- Mineral Composition: olivine, pyroxene, amphibole, plagioclase, quartz, etc