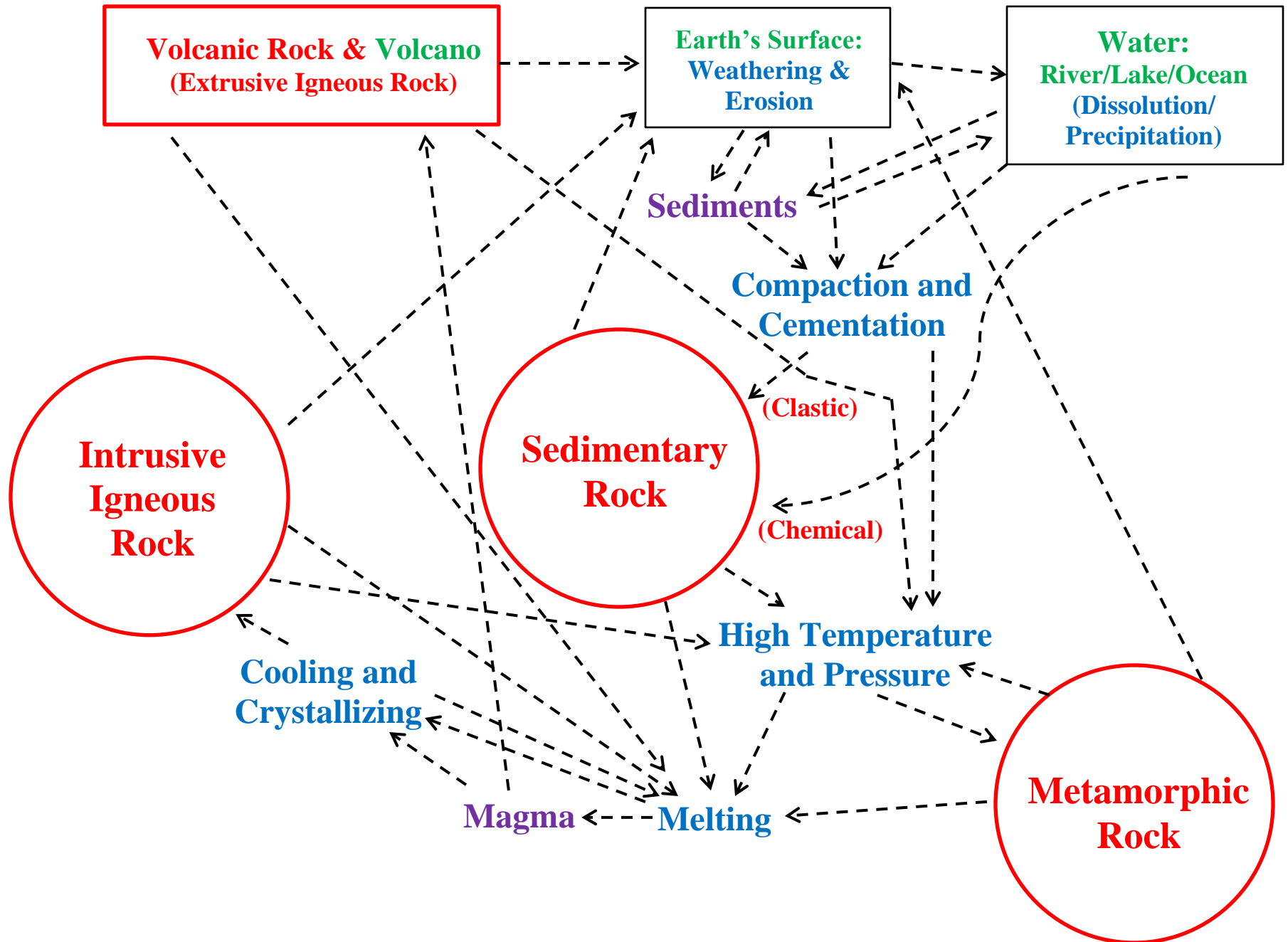
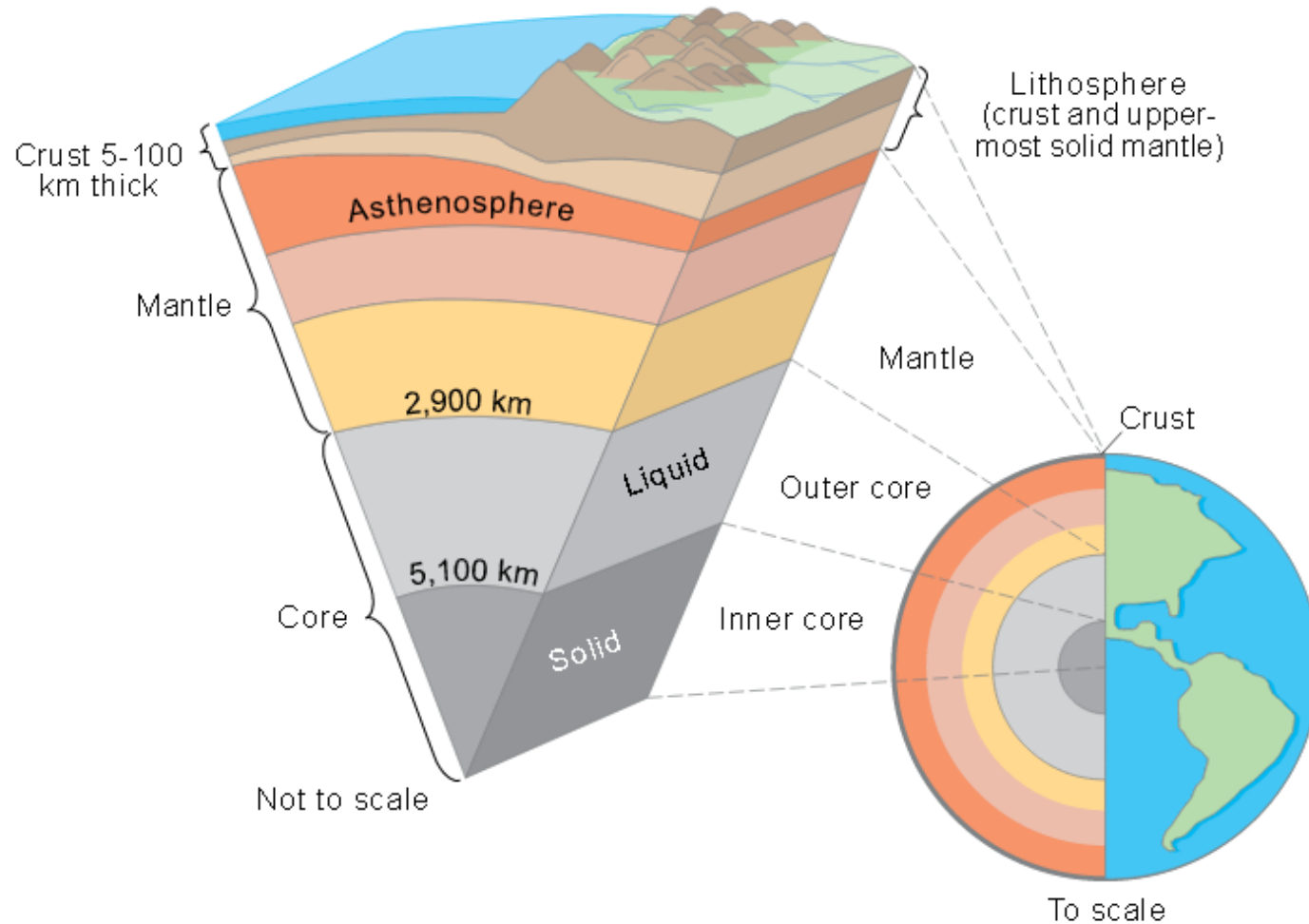


The Rock Cycle



The next few pages have graphics that help illustrate plate tectonics and where major types of ore deposits are found in tectonic settings.

The Earth is layered, with a relatively thin crust.



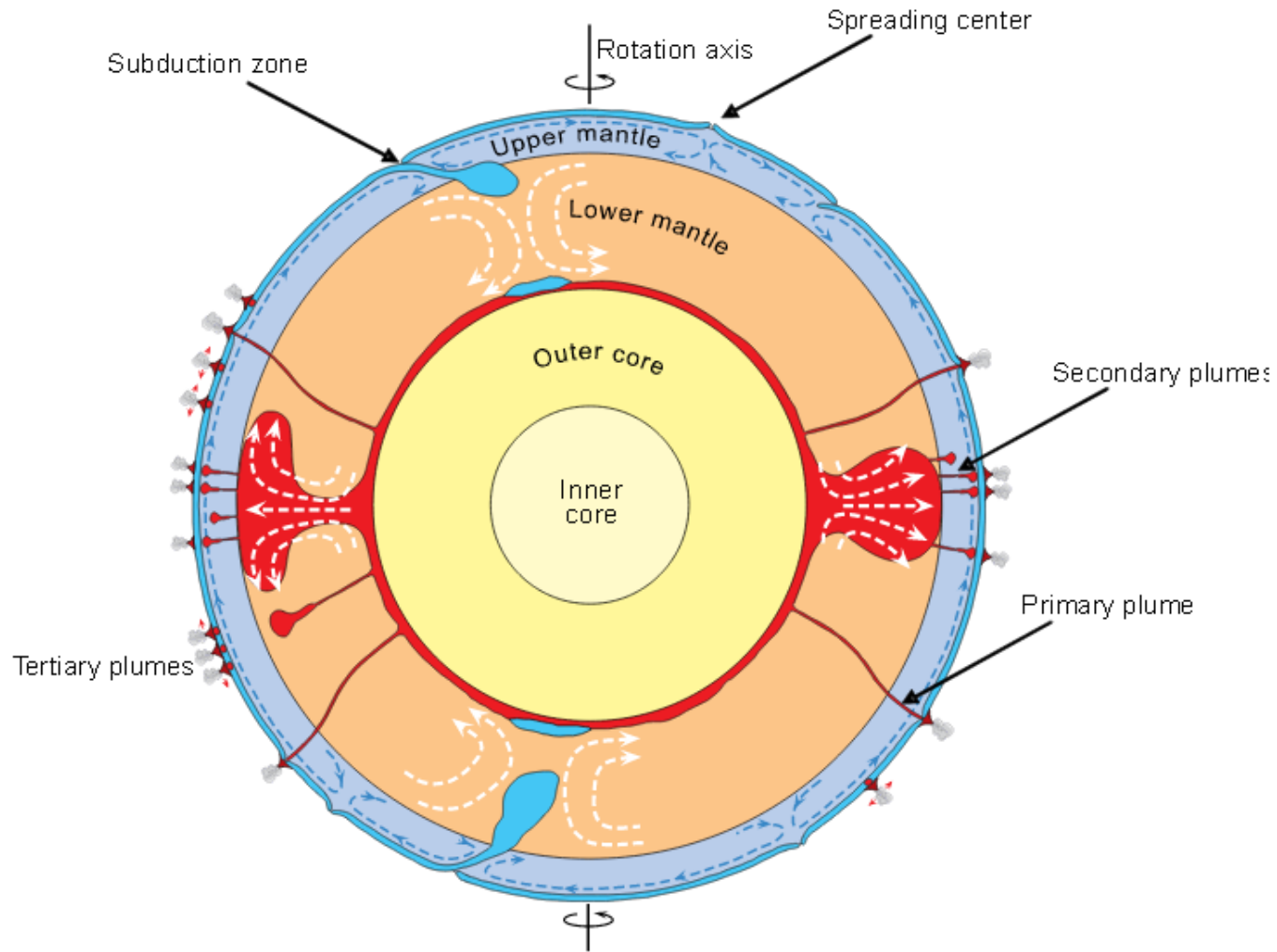
Sketches showing the layered internal structure of the Earth. The three major layers (crust, mantle, and core) comprising the Earth are schematically portrayed in the sectional wedge (not to scale). The cutaway view in the lower right shows the layers drawn to scale, from Zientek, M. L., and Orris, G.J, 2005, *Geology and nonfuel mineral deposits of the United States: U.S. Geological Survey Open-File Report 2005-1294A*, 179 p., <http://pubs.usgs.gov/of/2005/1294/a/of2005-1294a.pdf>.

The Earth's crust is broken into tectonic plates.



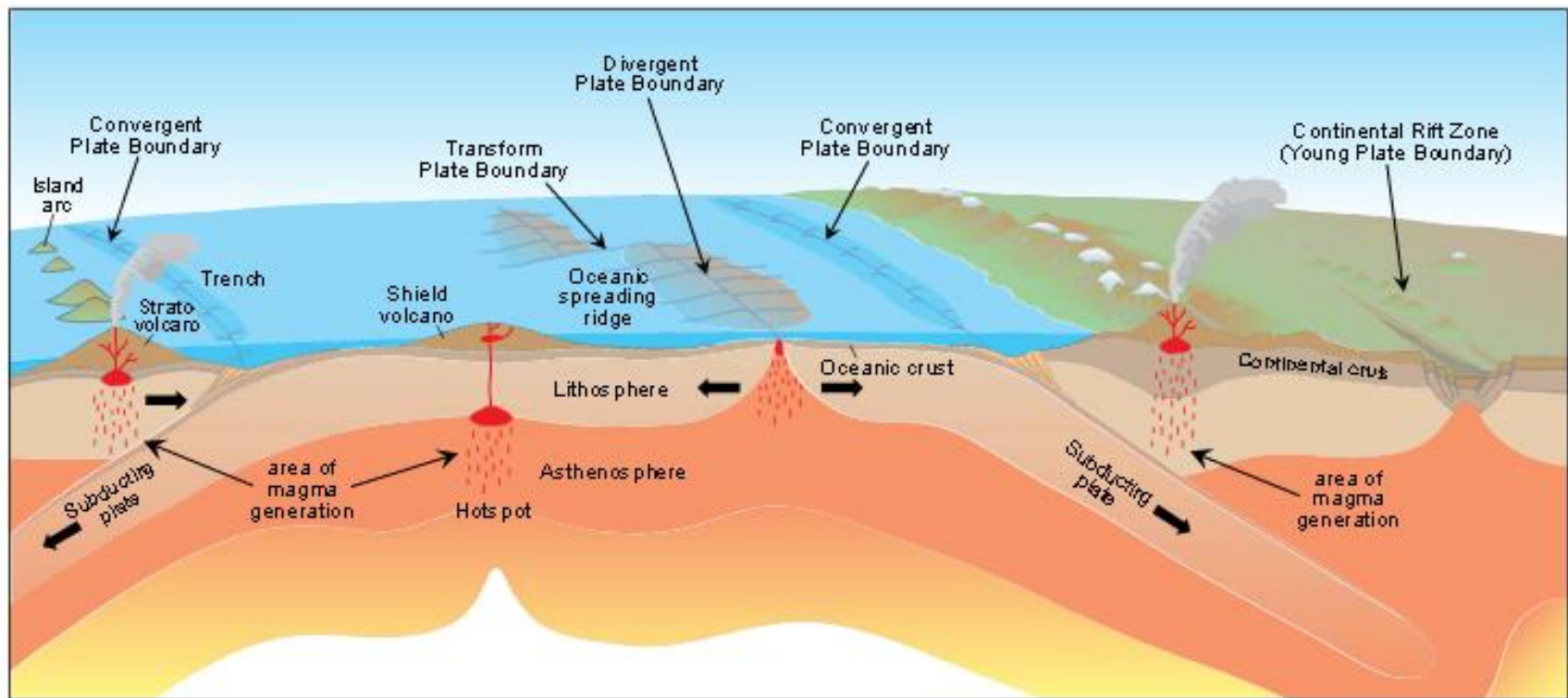
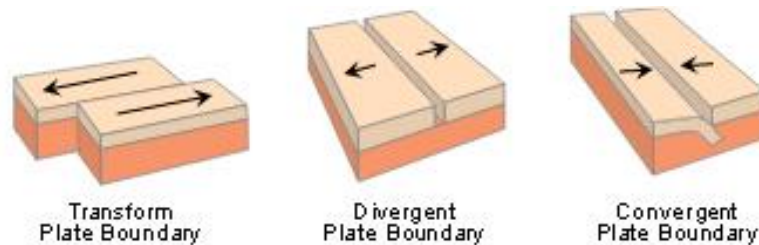
Red dots are active volcanoes. Black lines are plate boundaries.

Convection of heat from the Earth's interior drives plate tectonics.



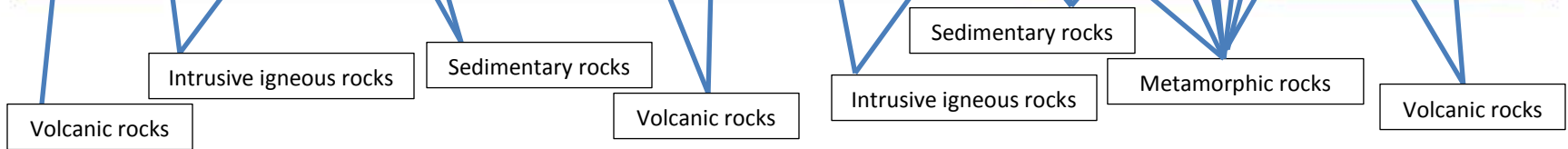
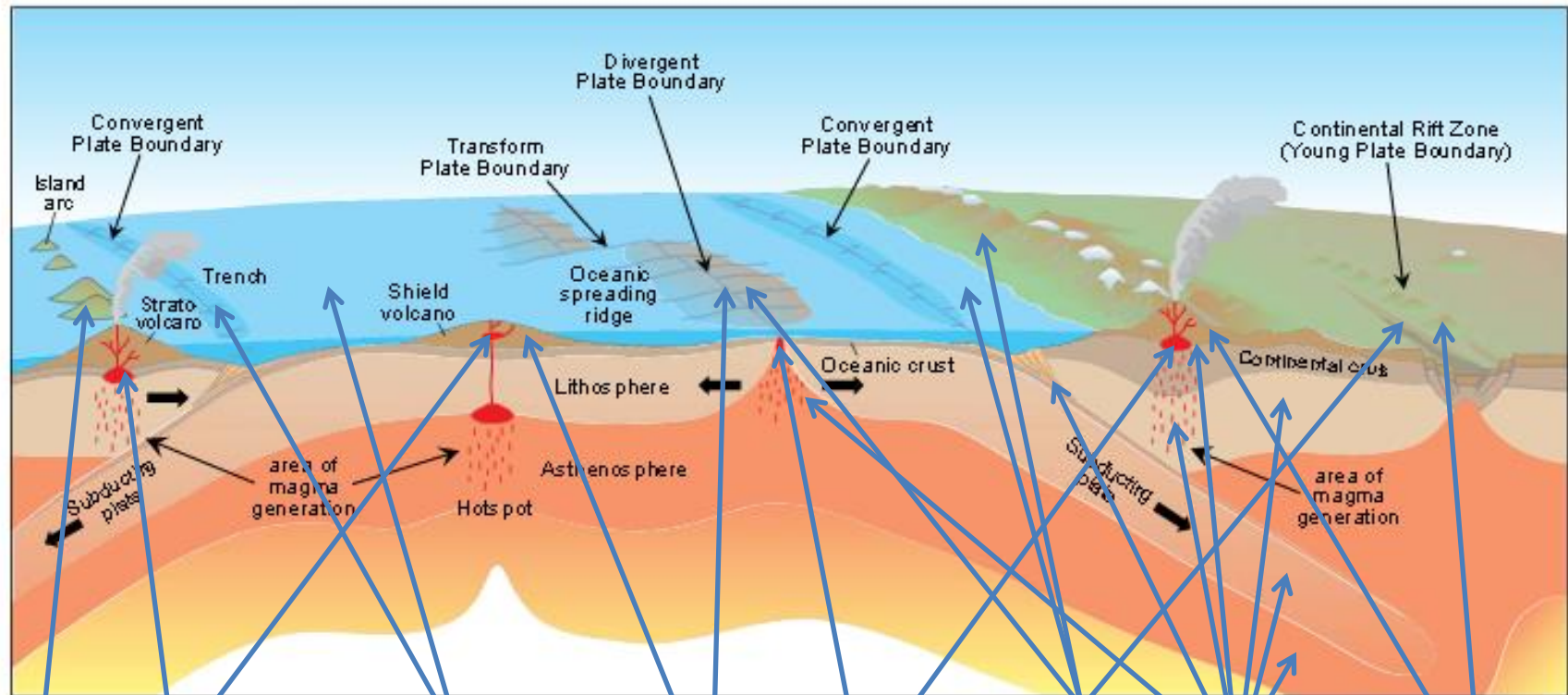
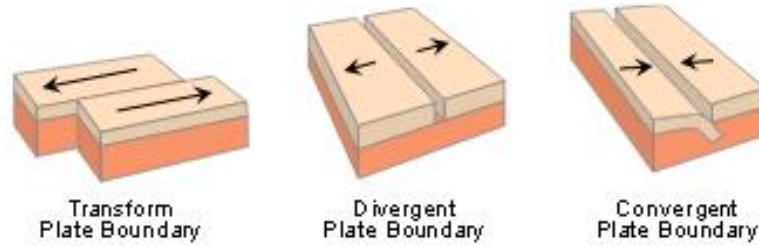
Schematic cross section of the Earth illustrating three types of mantle plumes. ‘Primary’ or main, deeper plumes possibly come from the lowermost mantle boundary layer. ‘Secondary’ plumes possibly come from the top of domes near the depth of the transition zone between the lower and upper mantle. ‘Tertiary’ hotspots may have a near surface origin, linked to tensile stresses in the lithosphere and decompression melting. Dashed lines with arrows show flow directions of rocks within the layers, from Zientek, M. L., and Orris, G.J., 2005, *Geology and nonfuel mineral deposits of the United States: U.S. Geological Survey Open-File Report 2005-1294A*, 179 p., <http://pubs.usgs.gov/of/2005/1294/a/of2005-1294a.pdf>.

The primary plate boundaries are ocean ridges (divergent boundaries), subduction zones (convergent boundaries), and transform faults.

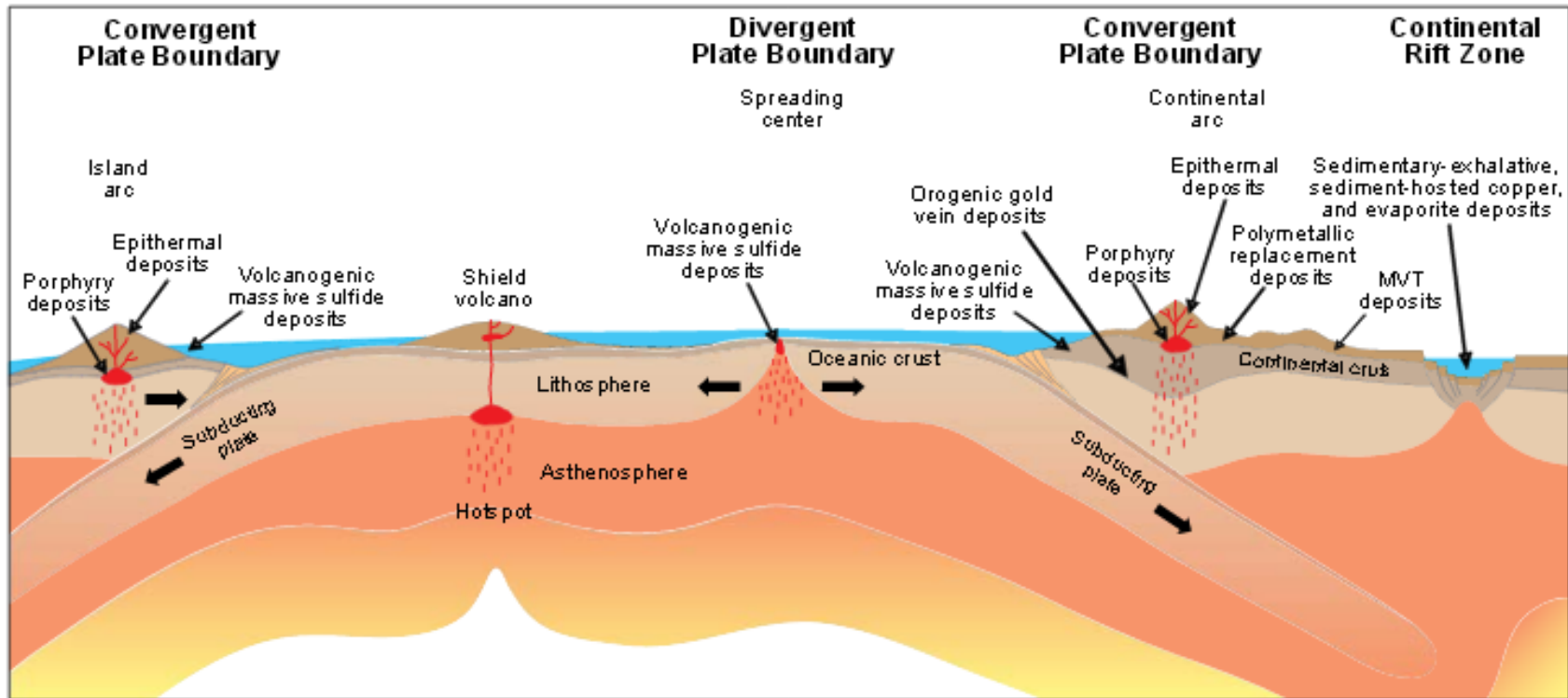


Perspective diagram and cross section of the uppermost layers of the Earth illustrating the main types of tectonic boundaries, from from Zientek, M. L., and Orris, G.J, 2005, Geology and nonfuel mineral deposits of the United States: U.S. Geological Survey Open-File Report 2005-1294A, 179 p., <http://pubs.usgs.gov/of/2005/1294/a/of2005-1294a.pdf>.

The primary rock types (sedimentary, metamorphic, and both intrusive and extrusive igneous rocks/volcanic rocks) are found at specific locations in plate-tectonic settings.



Ore deposits also are found at specific locations in plate-tectonic settings.



Cross section of the uppermost layers of the Earth illustrating the distribution of mineral deposits in relation to the main types of tectonic plate boundaries, from Zientek, M. L., and Orris, G.J, 2005, *Geology and nonfuel mineral deposits of the United States*: U.S. Geological Survey Open-File Report 2005-1294A, 179 p., <http://pubs.usgs.gov/of/2005/1294/a/of2005-1294a.pdf>. Porphyry deposits are major sources of copper, molybdenum, rhenium, gold, and silver. Epithermal deposits are primarily mined for gold, silver, and mercury. Volcanogenic massive sulfide deposits (involving interaction of sea water with volcanic rocks on the ocean floor— “black smokers”) are major sources of copper, zinc, gold, and silver. Orogenic gold vein (Mother Lode type) deposits are typically found in metamorphic rocks near subduction zones. Polymetallic replacement deposits are commonly associated with porphyry deposits and are major sources of copper, iron, zinc, lead, silver, and gold. Mississippi Valley type (MVT) deposits are major sources of lead and zinc. Sedimentary-exhalative deposits include barite, iron, copper, cobalt, zinc, lead, silver, and gold deposits. Evaporite deposits include gypsum, salt, and potash (potassium) hard-rock deposits in chemical sedimentary rocks and lithium brines.

Rock-cycle data sheet

Start at _____ rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Roll: ____ Go to _____ Process/ Location/ Constituent/ Rock Roll: ____ = _____, _____, _____ years

Geologic history sheet

Using the data you generated create your geologic history. At the end of the activity:

I am a _____ rock, from present to _____, _____, _____, _____ years ago.

I came from _____, where I was for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

Before that I was _____ for _____, _____, _____, _____ years.

The **youngest rock** is _____ rock at an age from _____ the present _____ to _____ years ago.

The middle rock was _____ rock at an age from _____ to _____ years ago.

The oldest rock was _____ rock at an age from _____ to _____ years ago.

EXAMPLE - Geologic history sheet – EXAMPLE 1

Using the data you generated create your geologic history. At the end of the activity:

I am a Volcanic rock, from present to 50,000 years ago.

I came from Magma, where I was for 1,000,000 years.

Before that I was Melting for 10,000 years.

Before that I was High Temperature & Pressure for 100,000,000 years.

Before that I was Metamorphic Rock for 60,000,000 years.

Before that I was High Temperature & Pressure for 50,000,000 years.

Before that I was Intrusive igneous rock for 200,000,000 years.

Before that I was _____ for _____ years.

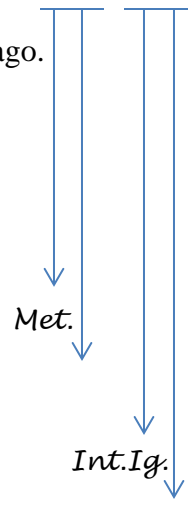
Before that I was _____ for _____ years.

Before that I was _____ for _____ years.

Before that I was _____ for _____ years.

Before that I was _____ for _____ years.

Before that I was _____ for _____ years.



The **youngest rock** is Volcanic rock at an age from the present to 50,000 years ago.

The middle rock was Metamorphic rock at an age from 101,060,000 to 161,060,000 years ago.

The oldest rock was Intrusive igneous rock at an age from 211,060,000 to 411,060,000 years ago.

EXAMPLE - Rock-cycle data sheet – EXAMPLE 2

Start at	<u>Sedimentary</u>	<u>rock</u>	Roll: <u>3</u> = _____, <u>500,000</u> years
Roll: <u>7</u>	Go to <u>Sedimentary rock</u>	Process/ Location/ Constituent/ <u>(Rock)</u>	Roll: <u>11</u> = <u>500,000,000</u> years
Roll: <u>6</u>	Go to <u>Earth's Surface: W & E</u>	<u>(Process/ Location)</u> Constituent/ Rock	Roll: <u>5</u> = _____, <u>1,000,000</u> years
Roll: <u>9</u>	Go to <u>Compact. & Cement.</u>	<u>(Process)</u> Location/ Constituent/ Rock	Roll: <u>4</u> = _____, <u>500,000</u> years
Roll: <u>11</u>	Go to <u>Sedimentary rock (clastic)</u>	Process/ Location/ Constituent/ <u>(Rock)</u>	Roll: <u>8</u> = _____, <u>1,000,000</u> years
Roll: <u>9</u>	Go to <u>Earth's Surface: W & E</u>	<u>(Process/ Location)</u> Constituent/ Rock	Roll: <u>9</u> = _____, <u>1,000,000</u> years
Roll: <u>3</u>	Go to <u>Sediments</u>	Process/ Location/ <u>(Constituent)</u> Rock	Roll: <u>12</u> = _____, <u>500,000</u> years
Roll: <u>7</u>	Go to <u>Sediments</u>	Process/ Location/ <u>(Constituent)</u> Rock	Roll: <u>4</u> = _____, <u>50,000</u> years
Roll: <u>2</u>	Go to <u>Sediments</u>	Process/ Location/ <u>(Constituent)</u> Rock	Roll: <u>5</u> = _____, <u>100,000</u> years
Roll: <u>4</u>	Go to <u>Water</u>	<u>(Process/ Location)</u> Constituent/ Rock	Roll: <u>7</u> = _____, <u>50,000</u> years
Roll: <u>8</u>	Go to <u>Sedimentary rock (chemical)</u>	Process/ Location/ Constituent/ <u>(Rock)</u>	Roll: <u>7</u> = <u>100,000,000</u> years
Roll: _____	Go to _____	Process/ Location/ Constituent/ Rock	Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____	Process/ Location/ Constituent/ Rock	Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____	Process/ Location/ Constituent/ Rock	Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____	Process/ Location/ Constituent/ Rock	Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____	Process/ Location/ Constituent/ Rock	Roll: _____ = _____, _____, _____ years

EXAMPLE - Geologic history sheet – EXAMPLE 2

Using the data you generated create your geologic history. At the end of the activity:

I am a <u>Sedimentary (chemical)</u> rock, from present to	__, <u>100,000,000</u> years ago.	
I came from <u>Water</u> , where I was for	__, ____, <u>50,000</u> years.	
Before that I was <u>Sediments</u> for	__, ____, <u>650,000</u> years.	
Before that I was <u>Earth's surface</u> for	__, ____, <u>1,000,000</u> years.	
Before that I was <u>Sedimentary Rock (clastic)</u> for	__, ____, <u>1,000,000</u> years.	Sed. (clast.) ↓
Before that I was <u>Compaction & Cementation</u> for	__, ____, <u>500,000</u> years.	
Before that I was <u>Earth's surface</u> for	__, ____, <u>1,000,000</u> years.	
Before that I was <u>Sedimentary Rock (clastic or chemical)</u> for	__, <u>500,500,000</u> years.	Sed. ↓
Before that I was _____ for	__, ____, ____, ____ years.	
Before that I was _____ for	__, ____, ____, ____ years.	
Before that I was _____ for	__, ____, ____, ____ years.	
Before that I was _____ for	__, ____, ____, ____ years.	
Before that I was _____ for	__, ____, ____, ____ years.	
The youngest rock is <u>Sedimentary (chemical)</u> rock at an age from <u>the present</u> to <u>100,000,000</u> years ago.		
The middle rock was <u>Sedimentary (clastic)</u> rock at an age from <u>101,700,000</u> to <u>102,700,000</u> years ago.		
The oldest rock was <u>Sedimentary</u> rock at an age from <u>104,200,000</u> to <u>604,700,000</u> years ago.		

EXAMPLE - Rock-cycle data sheet – EXAMPLE 3

Start at	<u>Volcanic</u> rock		Roll: <u>6</u> = _____, <u>50,000</u> years
Roll: <u>5</u>	Go to <u>Earth's Surface: W & E</u> Process/ Location Constituent/ Rock		Roll: <u>7</u> = _____, <u>500,000</u> years
Roll: <u>3</u>	Go to <u>Sediments</u> Process/ Location Constituent / Rock		Roll: <u>12</u> = _____, <u>500,000</u> years
Roll: <u>10</u>	Go to <u>Compact. & Cement.</u> Process / Location/ Constituent/ Rock		Roll: <u>11</u> = <u>10,000,000</u> years
Roll: <u>4</u>	Go to <u>Sedimentary rock (clastic)</u> Process/ Location/ Constituent/ Rock		Roll: <u>7</u> = <u>100,000,000</u> years
Roll: <u>7</u>	Go to <u>Sedimentary rock</u> Process/ Location/ Constituent Rock		Roll: <u>7</u> = <u>100,000,000</u> years
Roll: <u>10</u>	Go to <u>Sedimentary rock</u> Process/ Location/ Constituent Rock		Roll: <u>7</u> = <u>100,000,000</u> years
Roll: <u>8</u>	Go to <u>High T & P</u> Process / Location/ Constituent/ Rock		Roll: <u>5</u> = <u>100,000,000</u> years
Roll: <u>4</u>	Go to <u>Metamorphic Rock</u> Process/ Location/ Constituent/ Rock		Roll: <u>7</u> = <u>50,000,000</u> years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years
Roll: _____	Go to _____ Process/ Location/ Constituent/ Rock		Roll: _____ = _____, _____, _____ years

EXAMPLE - Geologic history sheet – EXAMPLE 3

Using the data you generated create your geologic history. At the end of the activity:

<p>I am a <u>Metamorphic</u> rock, from present to</p> <p>I came from <u>High Temperature & Pressure</u>, where I was for</p> <p>Before that I was <u>Sedimentary Rock (clastic)</u> for</p> <p>Before that I was <u>Compaction & Cementation</u> for</p> <p>Before that I was <u>Sediments</u> for</p> <p>Before that I was <u>Earth's surface</u> for</p> <p>Before that I was <u>Volcanic Rock</u> for</p> <p>Before that I was _____ for</p> <p>Before that I was _____ for</p> <p>Before that I was _____ for</p> <p>Before that I was _____ for</p> <p>Before that I was _____ for</p> <p>Before that I was _____ for</p> <p>The youngest rock is <u>Metamorphic</u> rock at an age from <u>the present</u> to <u>50,000,000</u> years ago.</p> <p>The middle rock was <u>Sedimentary (clastic)</u> rock at an age from <u>150,000,000</u> to <u>450,000,000</u> years ago.</p> <p>The oldest rock was <u>Volcanic</u> rock at an age from <u>461,000,000</u> to <u>461,050,000</u> years ago.</p>	<p>____, ____ <u>50,000,000</u> years ago.</p> <p>____, ____ <u>100,000,000</u> years.</p> <p>____, ____ <u>300,000,000</u> years.</p> <p>____, ____ <u>10,000,000</u> years.</p> <p>____, ____ <u>500,000</u> years.</p> <p>____, ____ <u>500,000</u> years.</p> <p>____, ____ <u>50,000</u> years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p> <p>____, ____ _____ years.</p>
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