



THE GEOLOGY OF SCULPTING STONE

NORTH CASCADES DUNITE

Michael E. Yeaman

1

WHY SHOULD YOU CARE ABOUT THE GEOLOGY OF SCULPTING STONE?

- Stone makes our chosen art form unique from all others
- Knowing more about the stone will allow you to:
 - Select stone that has a compelling history
 - Marvel at its various elements of grain, color and texture as you work it
 - Consider how your chosen artistic form relates to the science of the stone
 - Weave into your final art work story a geologic component that enhances the interest in the your work by the potential buyer

OUTLINE

- The Stone Defined
 - General Description, Physical/Chemical Properties and Historic Use
 - Specimens (macro and thin section)
 - Specific Occurrences
- Geology
 - Age and Geologic Description
 - Formation Environment and Processes
 - Global Paleogeographic Setting
 - Modern Analogs
- Select Creations
 - Art
 - Architecture

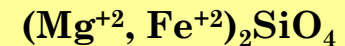
GENERAL DESCRIPTION, PHYSICAL/CHEMICAL PROPERTIES AND HISTORIC USE

- Dunite is an ultramafic rocks (i.e. a rock with a large amount of iron and magnesium). It is composed mainly of the mineral olivine and may contain minor amounts of chromite, pyroxene, spinel and magnetite. Dunite is a dense and hard mineral (special gravity of 3.0 and Moh's hardness of 6.5-7 compared to common granite of 2.6 and 6-7 respectively). It is commonly coarse grained, green in color and quickly weathered to an orange-red rind.
- Dunite is found in the North Cascades where it makes up the entire Twin Sisters Mountains, south of Mt Baker and is approximately 16 km long and 5.5 Km wide.
- This area has been mined since the early 20th century and although Washington State is the largest producer in the USA, we extract less than 100,000 tons per year
- Dunite/Olivine is used as a slag conditioner, refractory and foundry sand and as a fertilizer. In addition, its physical properties are useful in abrasives. Peridot, its crystalline gem form, is popular for jewelry
- An intriguing potential future use would use Olivine to remove CO₂ from the atmosphere to slow down global warming



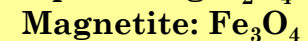
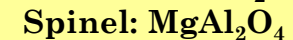
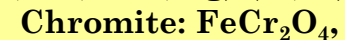
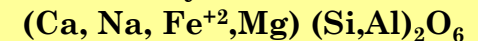
Chemical Composition of:

Dunite:



with minor amounts of

Pyroxene:



GLOBAL DISTRIBUTION



Ophiolites/Dunite Localities

SPECIMENS: MACRO



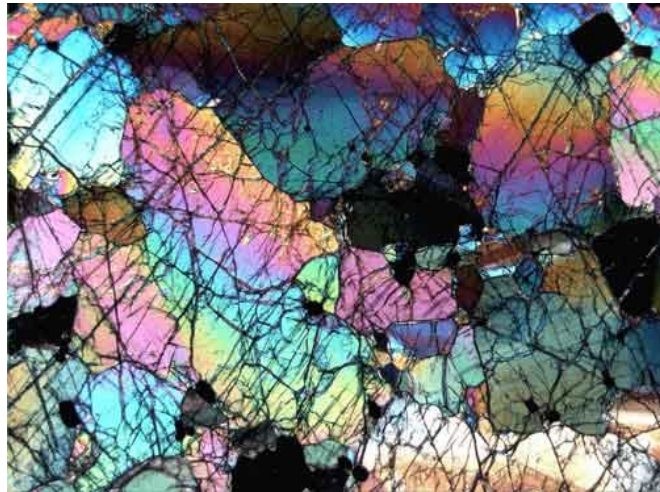
Weathered Outcrop



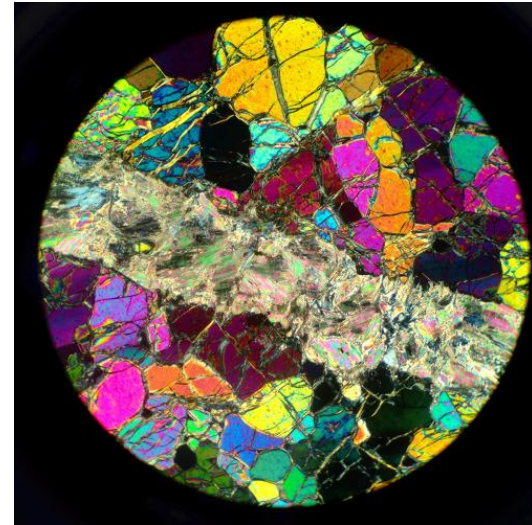
Olivine Corporation Quarry
Fresh Outcrop

SPECIMENS: THIN SECTIONS

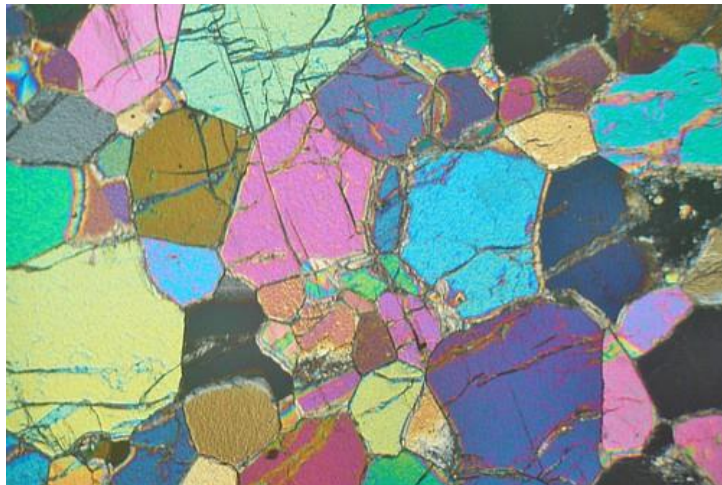
(POLARIZED LIGHT AT ABOUT 100X MAGNIFICATION)



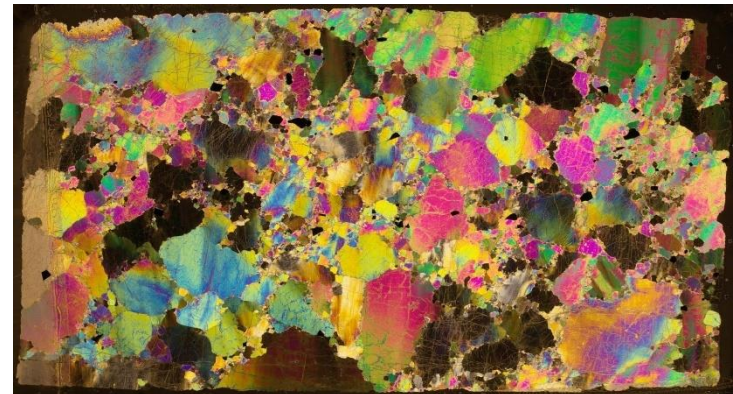
DUN MOUNTAIN, DUNITE NEW ZEALAND



BIREFRINGENT OLIVINE GRAINS WITH SERPENTINE (GRAY AND WHITE) AND TALC (HIGH PASTEL BIREFRINGENCE)



TS DUNITE WITH RECRYSTALLISATION, AND A CRYSTALLOBLASTIC TEXTURE, WITH COMMON 120° ANGLES BETWEEN GRAINS.



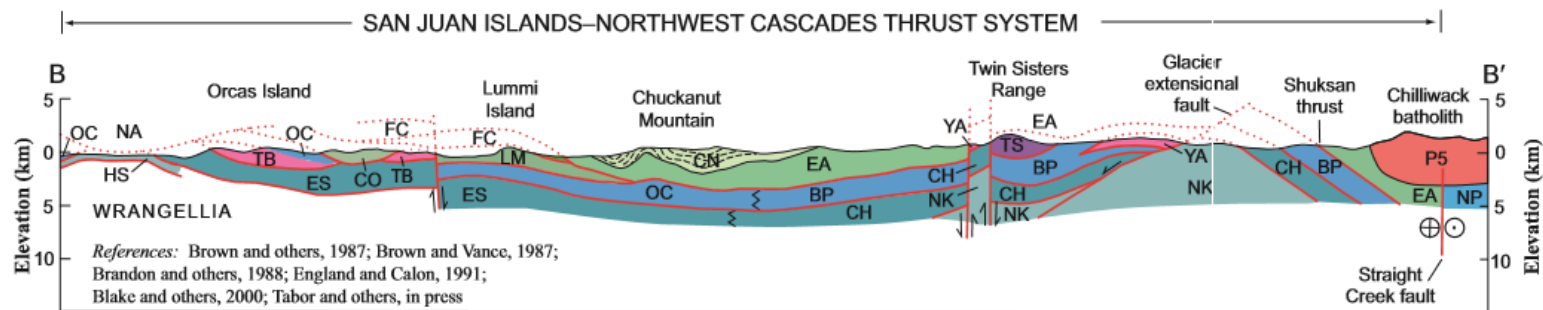
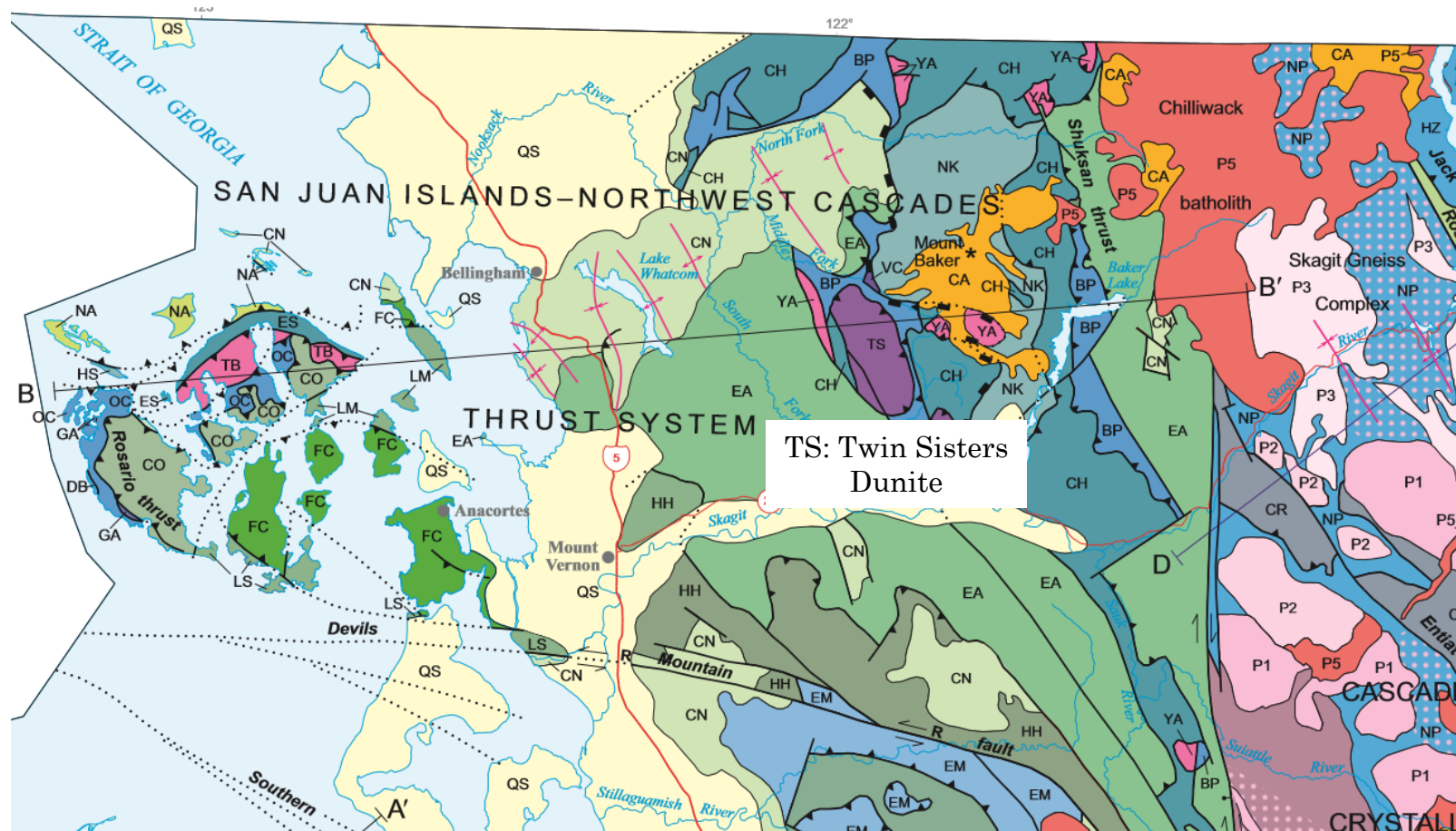
TS DUNITE WITH STRAINED OLIVINE AND PYROXENE GRAINS WITH DEFORMATION BANDING.

SPECIFIC OCCURRENCES



View looking to the south of the North and South Twin Sisters

SPECIFIC OCCURRENCES

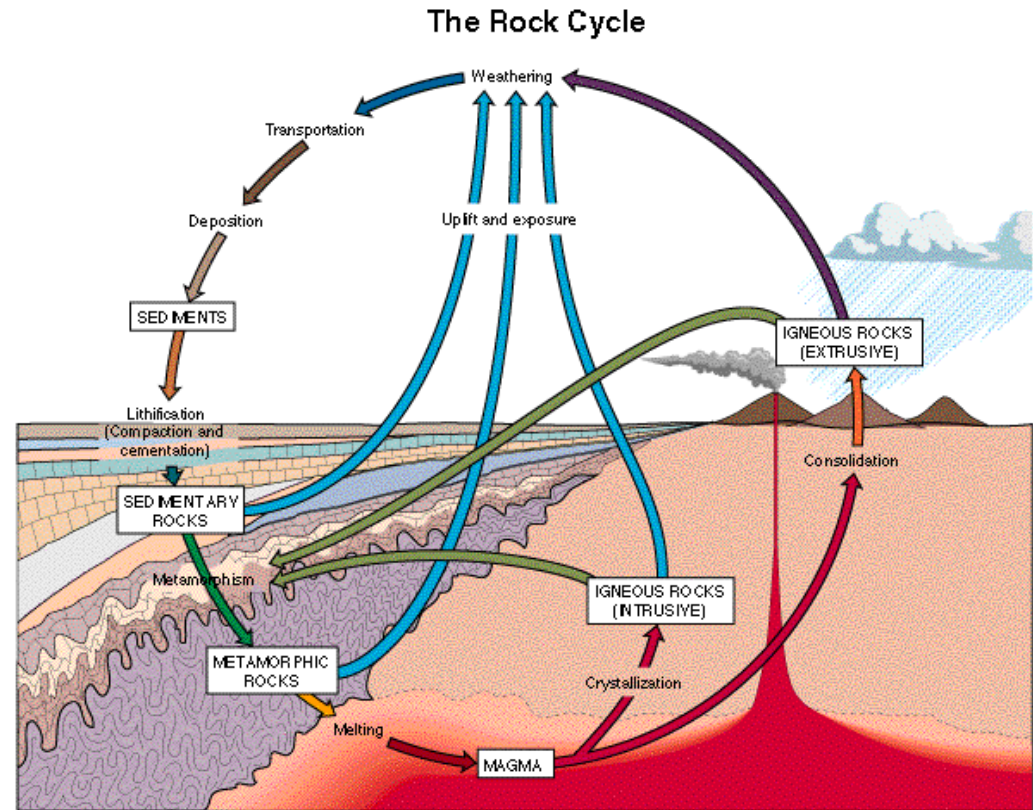


AGE AND GEOLOGIC DESCRIPTION

First a few basics

There are three types of rock:

- **Sedimentary:** A rock formed from the accumulation and consolidation of sediment, usually in layered deposits. (e.g. sandstone)
- **Igneous:** A rock formed by the crystallization of a liquid magma (intrusive, e.g. granite) or lava (extrusive)
- **Metamorphic:** A rock formed by the alteration of the minerals, textures and/or composition of another rock (sedimentary, igneous or metamorphic) caused by exposure to heat, pressure and/or chemical actions. (e.g. quartzite)
- **Dunite** is an igneous rock from the Earth's upper mantle



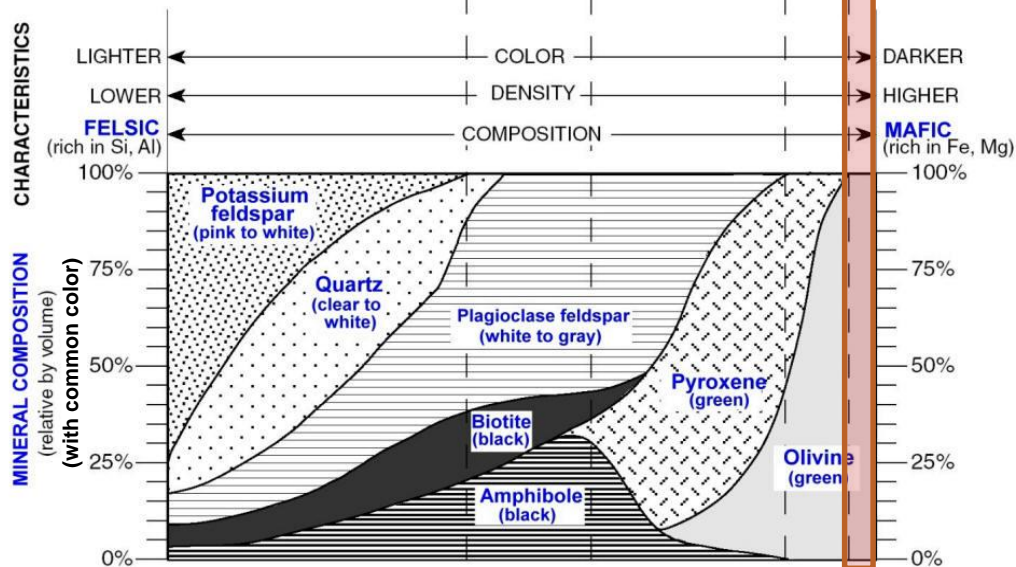
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AGE AND GEOLOGIC DESCRIPTION

- Dunite is one of the most Mafic of igneous rocks
- The Twin Sisters Dunite original formation age is Triassic to Middle Jurassic (240 to 180 mya)
- The emplacement of the Twin Sisters Dunite against North America is interpreted to have happened in the mid-late Cretaceous (100 -65 mya)

Simplified
Scheme for Igneous Rock Identification

ENVIRONMENT OF FORMATION		CRYSTAL SIZE			TEXTURE		
		less than 1 mm	1 mm to 10 mm	10 mm or larger	Glassy	Non-vesicular	
IGNEOUS ROCKS	EXTRUSIVE (Volcanic)	Obsidian (usually appears black)		Basaltic glass	non-crystalline	Glassy	Non-vesicular
		Pumice		Scoria			Vesicular (gas pockets)
		Vesicular rhyolite	Vesicular andesite	Vesicular basalt	Fine	Non-vesicular	
	Rhyolite	Andesite	Basalt				
	INTRUSIVE (Plutonic)	Granite	Diorite	Diabase	Coarse	Non-vesicular	
Pegmatite			Gabbro				
				Peridotite	Very coarse		



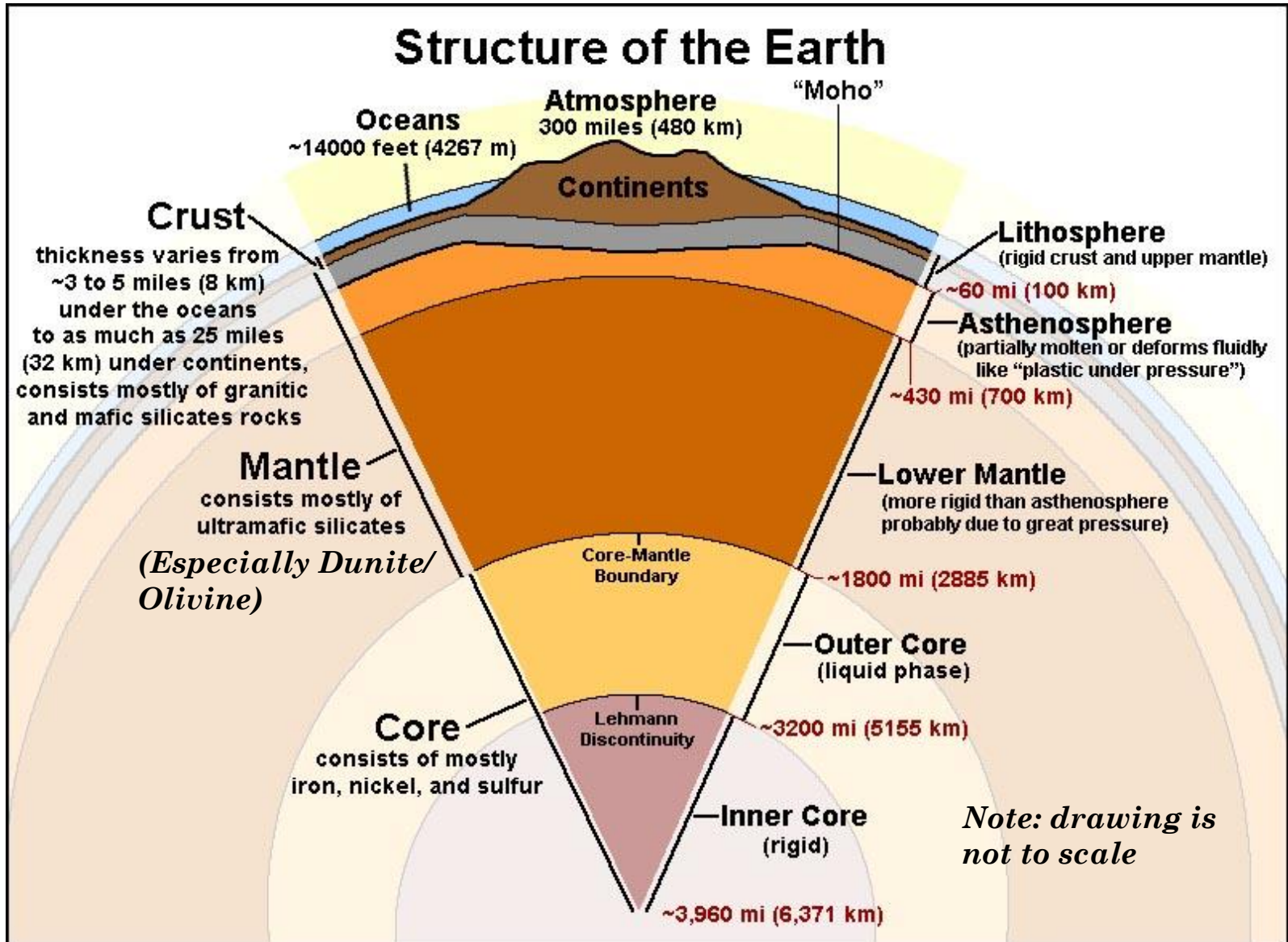
AGE AND GEOLOGIC DESCRIPTION

- The Twin Sisters Dunite high iron content causes it to weather rapidly, forming a reddish-orange rind
- Cobbles with this rind are commonly found in the Nooksack which flows around the Twin Sisters Mountains
- Fresh faces of Twin Sisters Dunite are commonly fibrous green (olivine) with black spots (chromite) and display veins, which when polished display coarser olivine grains



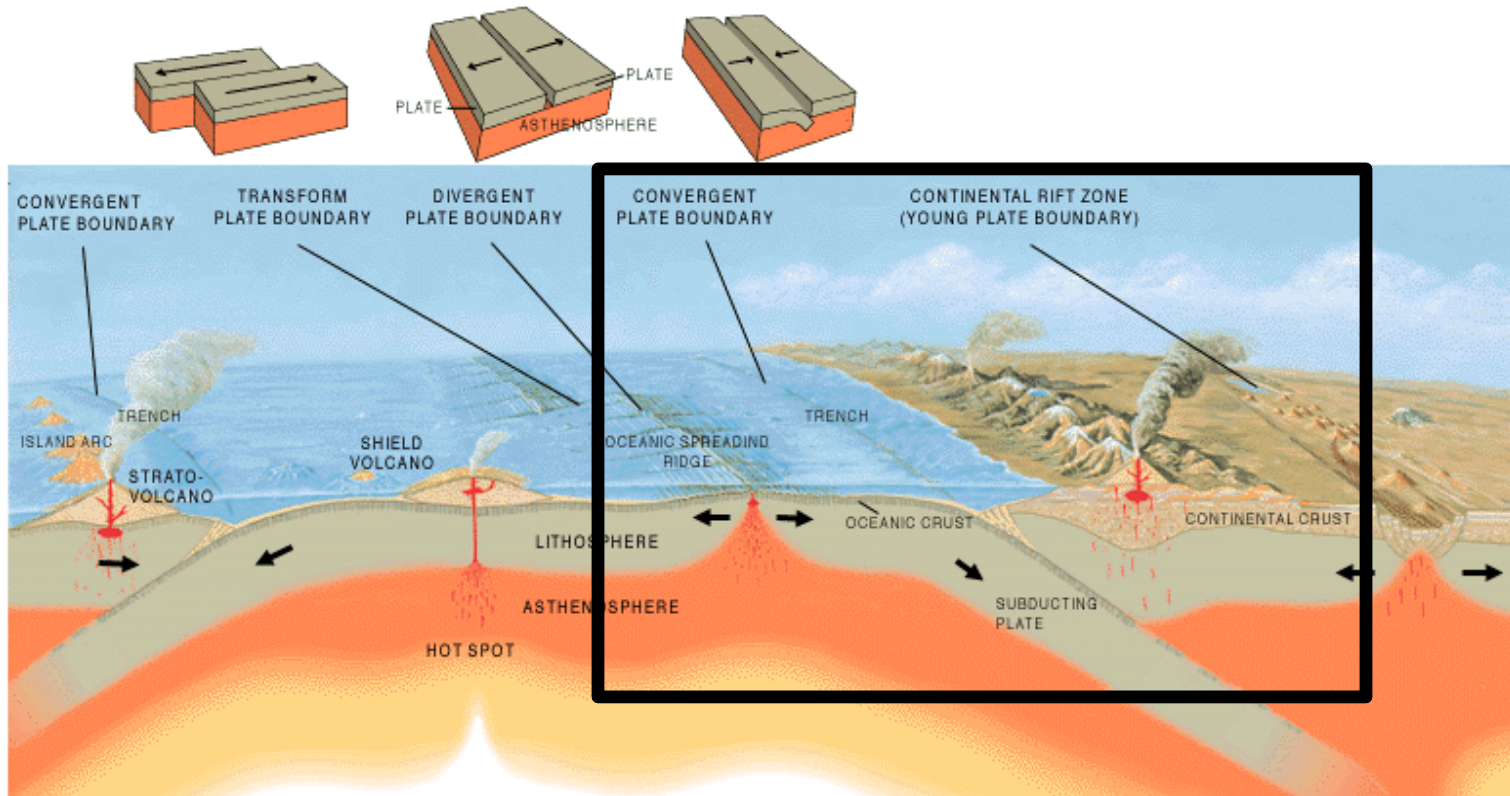
AGE AND GEOLOGIC DESCRIPTION

Where did the Twin Sisters Dunite come from? Lets' begin with a overview of the physical and chemical makeup of the Earth.



FORMATION ENVIRONMENT AND PROCESSES

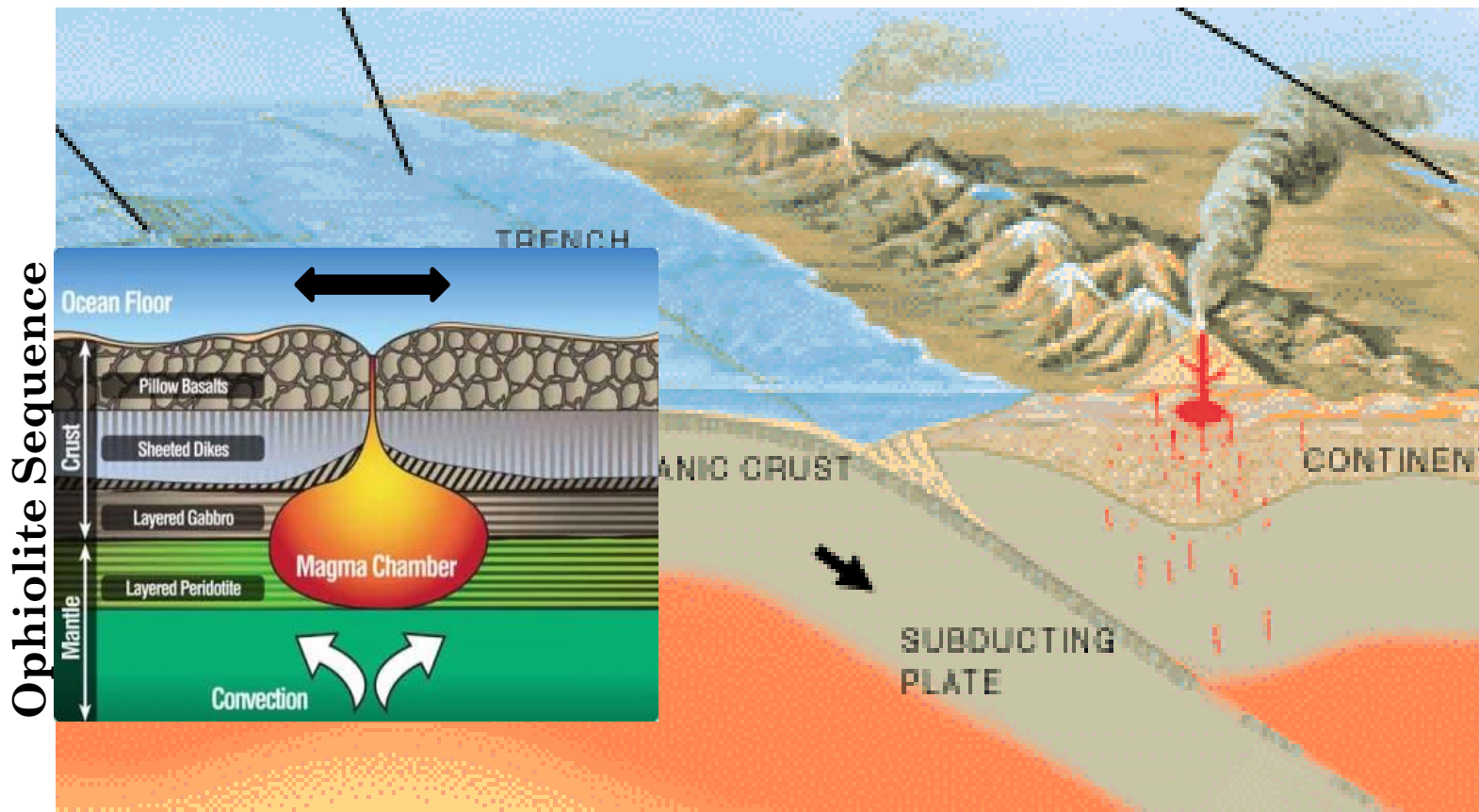
Back to our Old Friend: Plate Tectonics



- The Lithosphere is made up of relatively thin plates which move slowly about the surface.
- These plates interact by converging, diverging or sliding (transform) past one another.
- The Twin Sister Dunite was formed at a Oceanic Spreading Ridge and transported NE where it collided North American craton

FORMATION ENVIRONMENT AND PROCESSES

What is happening at a Ocean Spreading Ridge?

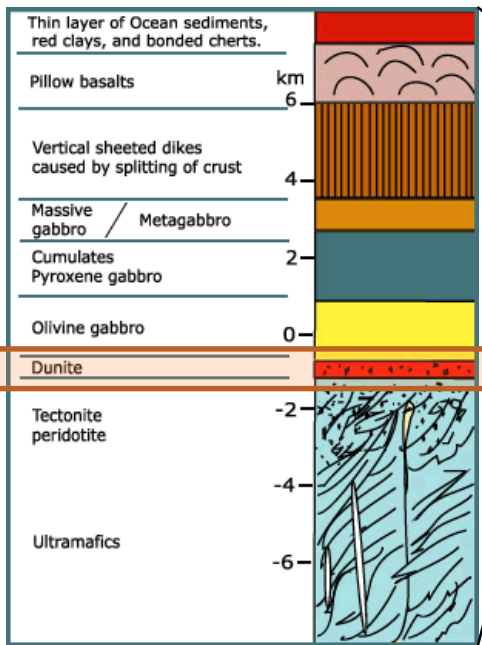


- At the center of the Ocean Spreading Ridge thermal convection is driving hot upper mantle magma to the surface where it forms distinct layers of ultra-mafic rock which cools and is carried away on the plate tectonic conveyer-belt. This pile of layer rocks is called an **Ophiolite Sequence**
- At the very base of this sequence Dunite is formed

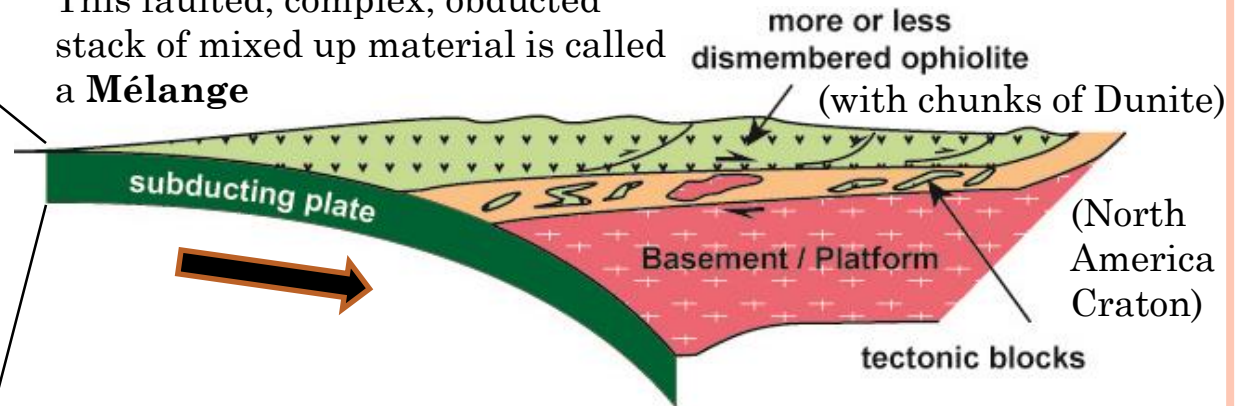
FORMATION ENVIRONMENT AND PROCESSES

- Sometimes at convergent, subducting plate boundaries, pieces of the subducting plate get scraped-off or **Obducted** and smeared onto the upper plate.
- This is how the Twin Sisters Dunite got where it is today.

Ophiolite Sequence

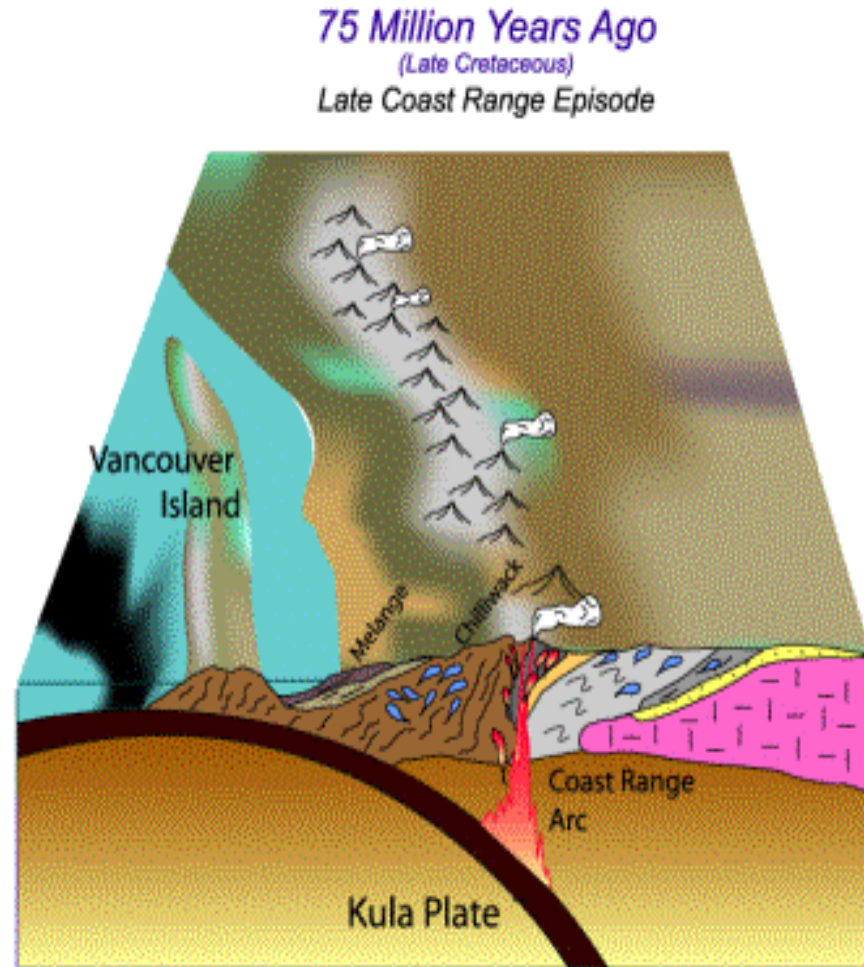


This faulted, complex, obducted stack of mixed up material is called a **Mélange**

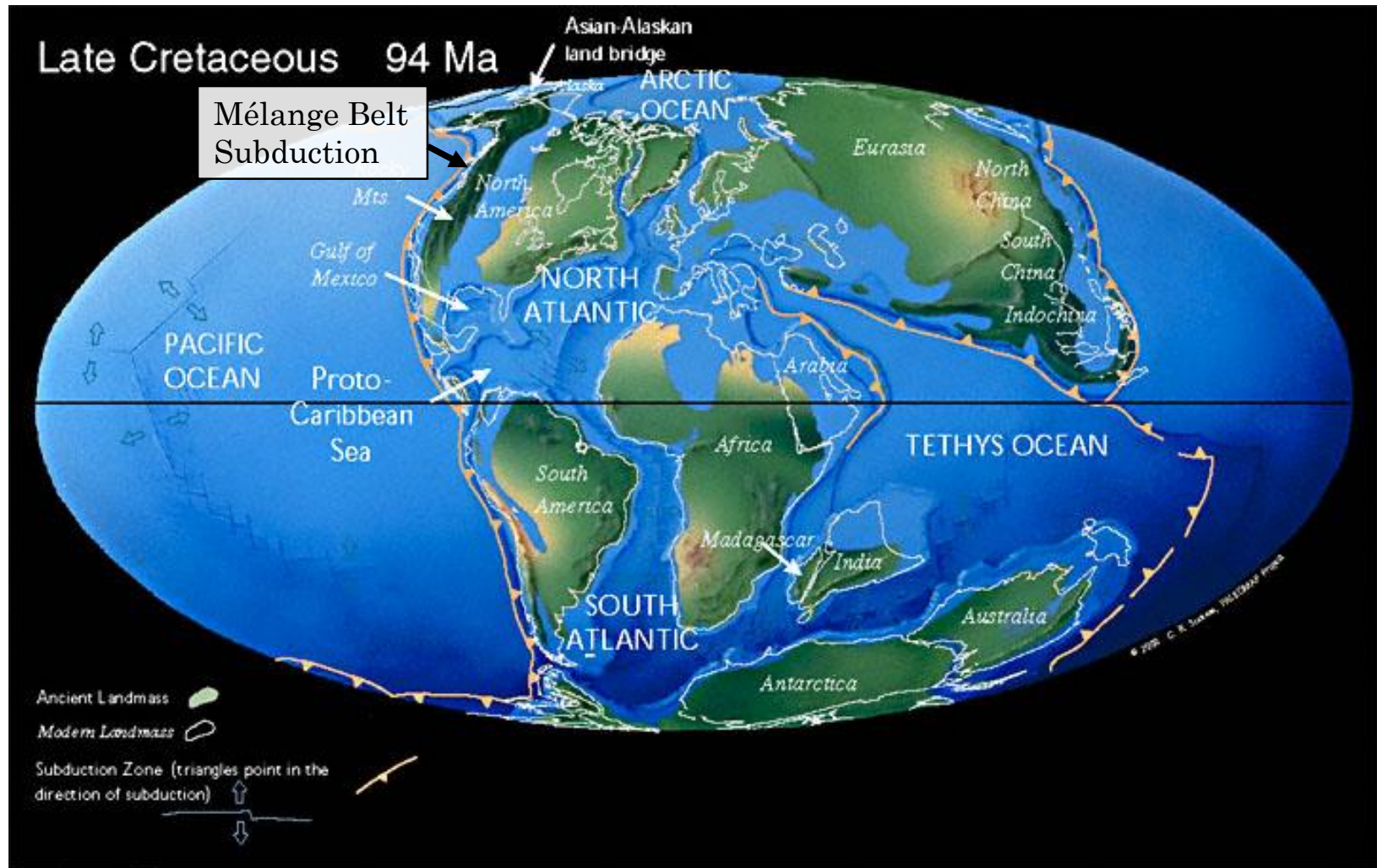


FORMATION ENVIRONMENT AND PROCESSES

- Coast Range arc plutonic activity continued into the late Cretaceous
- Sediments began to be shed off the emerging Coast Range arc mountains and from a Wrangellian land mass we now know as Vancouver Island
- The Farallon Plate fragmented into two major pieces with the north Pacific section being renamed the Kula plate
- The emplacement of the Intermontaine and Coast Range terranes had created a large embayment south of Washington State
- An west-east trending spreading center developed between these pieces and subducting sediments were scraped off the descending plate creating the Melange belt of SW Washington, which included the **Twin Sisters Dunite**



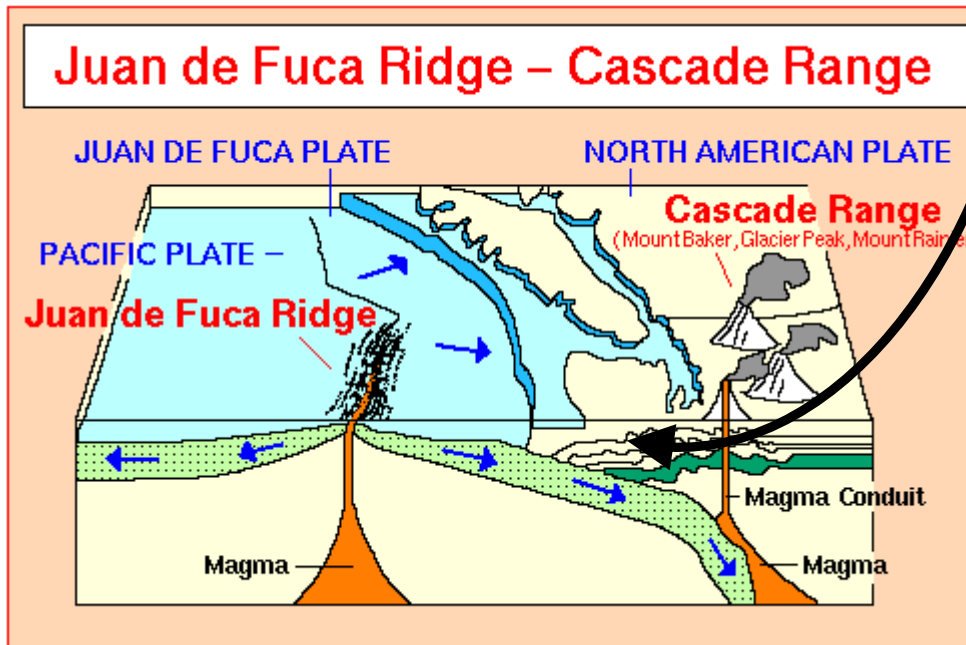
GLOBAL PALEOGRAPHIC SETTING



MODERN ANALOGS

Present Day Cascadia

Are Ophiolites from the Juan de Fuca plate Being scraped off the Subducting Plate?



ART

Artists from the NWSSA seem to be specialists in
Dunite



Pat Barton



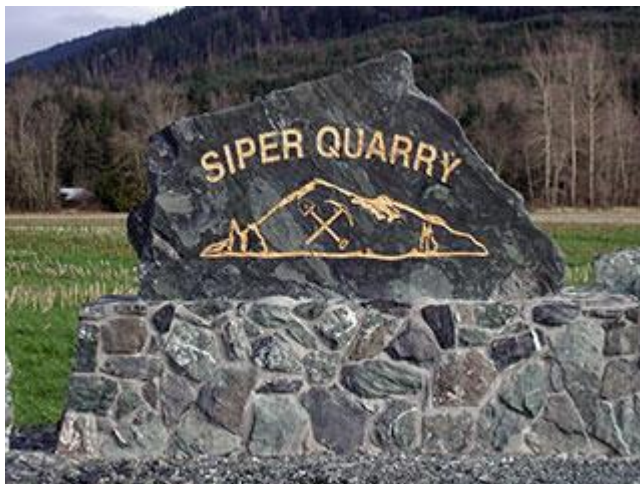
Ken Barnes



Michael Yeaman

ARCHITECTURE

- Although Peridot is often used in jewelry, Dunite/Olivine has not been used at architecture scale
- Locally, Dean Briske at Princess Jade is doing innovative work in Twin Sisters Dunite



SELECT SOURCES

- Olivine, P.W. Harben and Corky Smith Jr. Industrial Minerals & Rocks: Commodities, Markets, and Uses edited by Jessica Elzea, 2006
- Emplacement of the Twin Sisters Dunite, D. M. Regan, 1963
- Twin Sisters Dunite: Petrology and mineral chemistry, A. C. Onyeagocha, 1978