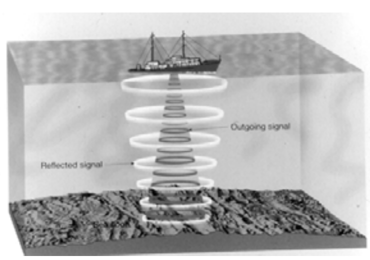
SEA-FLOOR SPREADING

In the 1950's and early 1960's detailed study of the oceans revealed the following surprising information:-

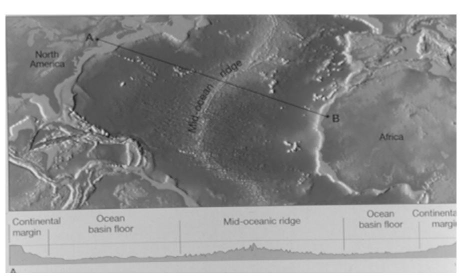
- Detailed bathymetric (depth) studies showed that there was an extensive submarine ridge system that extended around the globe. These became known as MID-OCEAN RIDGES.

- Sampling by dredging showed that these mid-ocean ridges were formed of young basalt, referred to as MORB (mid-ocean ridge basalt).

Mid-Ocean Ridges



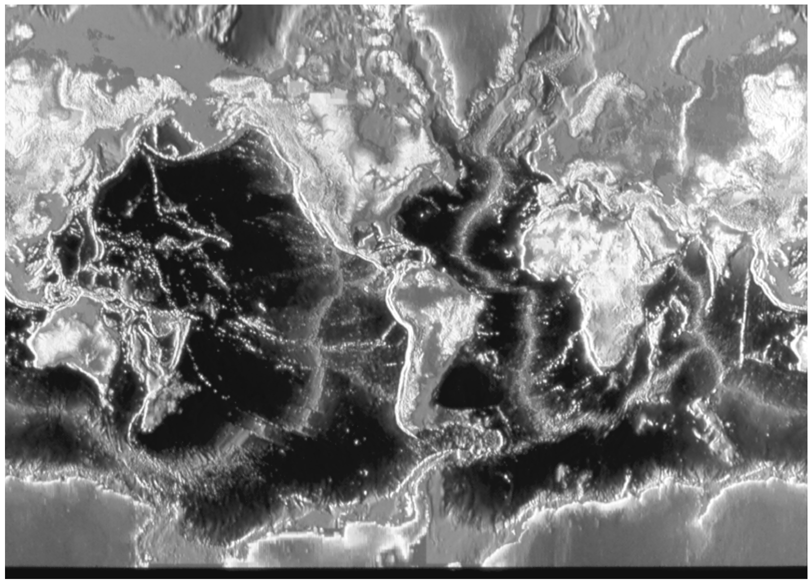
Echo Sounding



Mid-Atlantic Ridge

The entire Mid-Atlantic Ridge

The World-Wide Ocean Ridge System
(65,000 km in length)

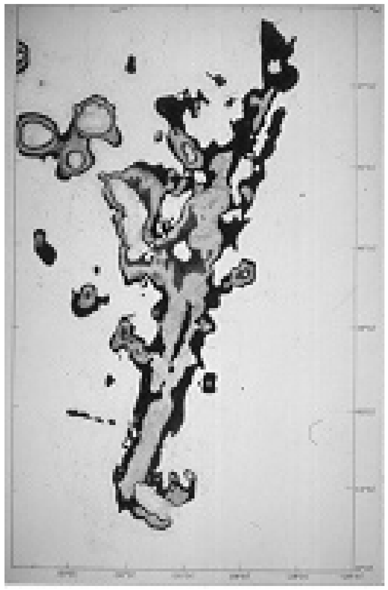


Oceanic Crust – is uniformly thick throughout the worlds oceans (5 - 7 km). Assuming this is made from basaltic magma (both extrusive and intrusive) then:-

Volume/Year = Thickness x Spreading Rate x Length
About 5 - 20 km^3/year (depending on assumptions)
length ~ 65,000 km
thickness 5 - 7 km
spreading rates 1 –10 cm/yr

For Comparison:
Hot-Spot Volcanism ~ 1 -2 km^3/year
Subduction Volcanism ~ 2 km^3/year

Therefore ocean ridge volcanism is the most important mechanism for differentiation of the earth – converting mantle peridotite to oceanic crust

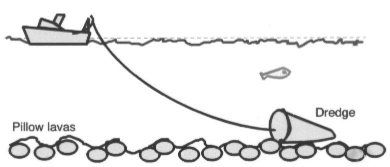


Detailed bathymetry shows that ocean ridges are segmented, often *en echelon* separated by fracture zones or small offsets (OCR's)

In many respects, these segments resemble elongated shield volcanoes with rift zones

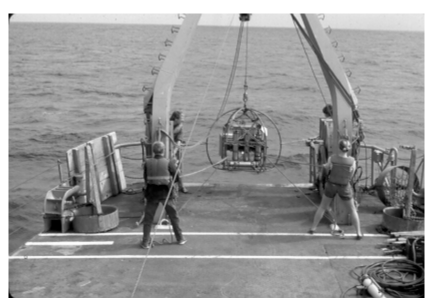
Part of the Juan de Fuca Ridge

Sampling Mid-Ocean Ridges



The basic idea behind dredging.

Launching a dredge

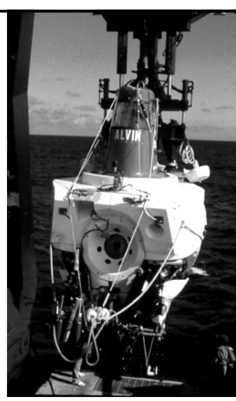


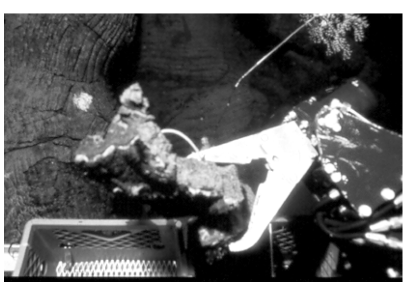
Launching a camera

Basalts on Mid-Ocean Ridges

These types of basaltic lava are called "pillow lavas" (rather similar to pahoehoe)

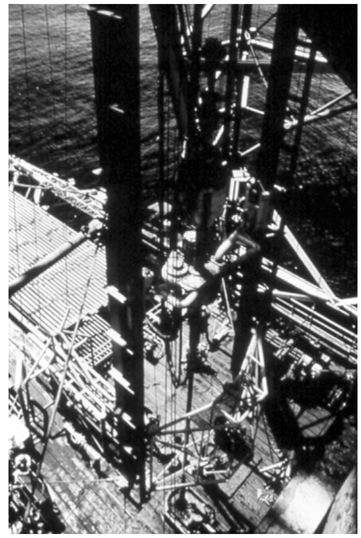
Exploring Mid-Ocean Ridges with the Alvin Submarine





The Glomar Challenger

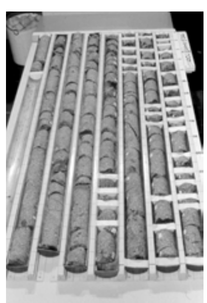
Glomar Challenger



View of the drill rig

More Glomar Challenger

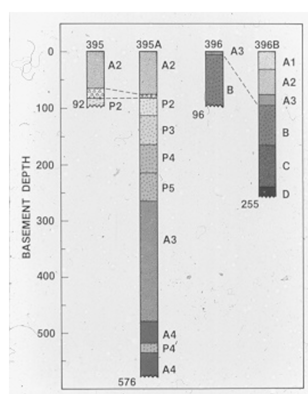
View from rig

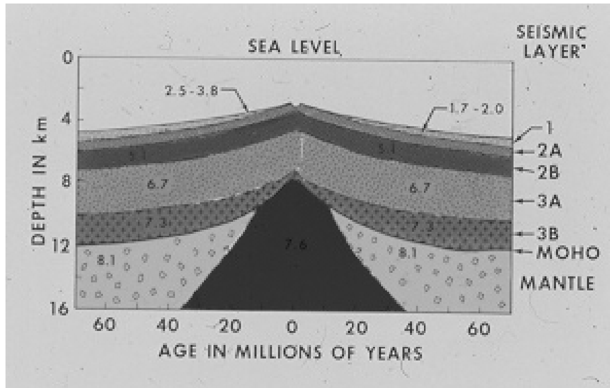


Drill core

Drill bits

Core logs





Geophysical surveys showed that the oceanic crust is composed of layers of increasing seismic velocities (reflecting different densities). This led to the OPHIOLITE model.

Oceanic Crust and Upper Mantle Structure

Typical Ophiolite Sequence

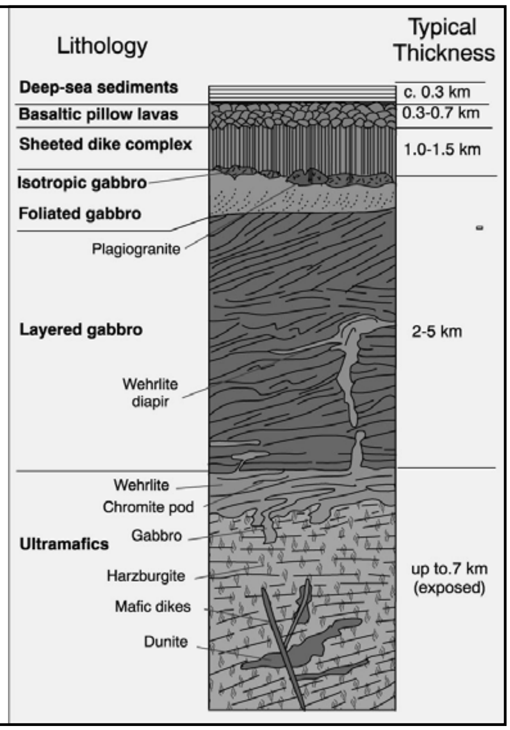
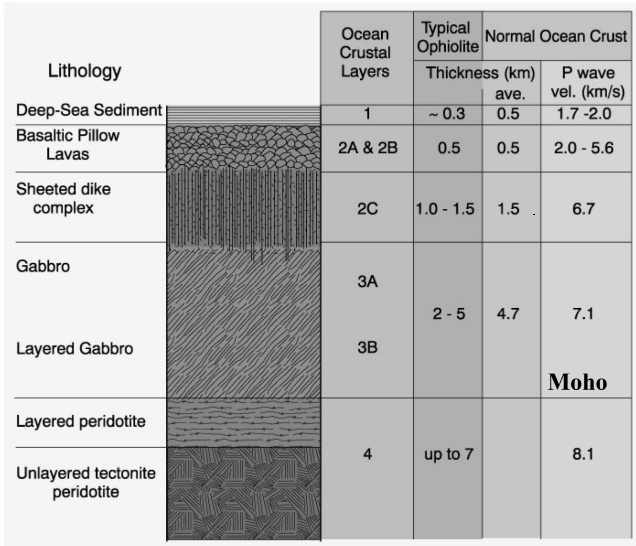
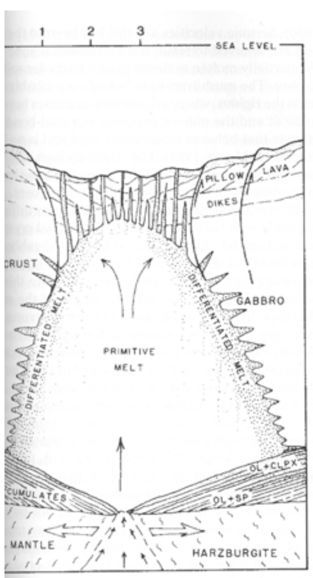


Figure 13-3. Lithology and thickness of a typical ophiolite sequence, based on the Samial Ophiolite in Oman. After Boudier and Nicolas (1985) Earth Planet. Sci. Lett., 76, 84-92.

Oceanic Crust and Upper Mantle Structure

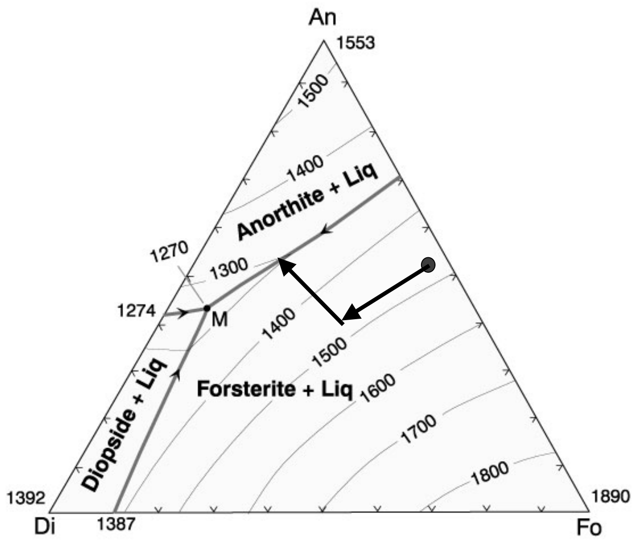


Lithology	Ocean Crustal Layers	Typical Ophiolite Thickness (km)	Normal Ocean Crust Thickness (km) ave.	Normal Ocean Crust P wave vel. (km/s)
Deep-Sea Sediment	1	~ 0.3	0.5	1.7 -2.0
Basaltic Pillow Lavas	2A & 2B	0.5	0.5	2.0 - 5.6
Sheeted dike complex	2C	1.0 - 1.5	1.5	6.7
Gabbro	3A	2 - 5	4.7	7.1
Layered Gabbro	3B			Moho
Layered peridotite	4	up to 7		8.1
Unlayered tectonite peridotite				



Hypothetical view of a shallow magma chamber beneath the central axis (rift valley) of the Mid-Atlantic Ridge illustrates how the layers might have been formed.

- The common MORB crystallization sequence is: olivine (± Mg-Cr spinel), olivine + plagioclase (± Mg-Cr spinel), olivine + plagioclase + clinopyroxene



Contrast this with crystallization of Hawaiian tholeiites

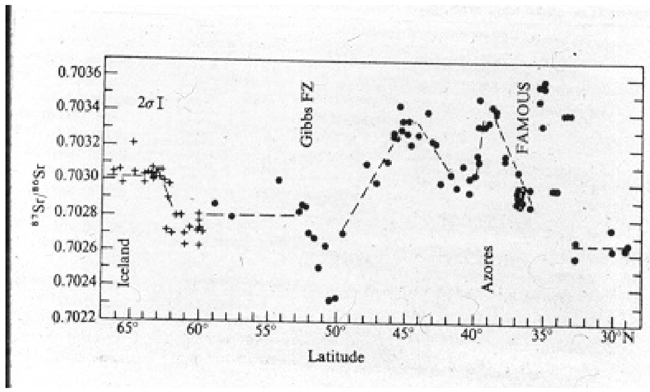
Composition of MORB

❑ Initial studies were impressed by the uniformity of MORB in different oceans.

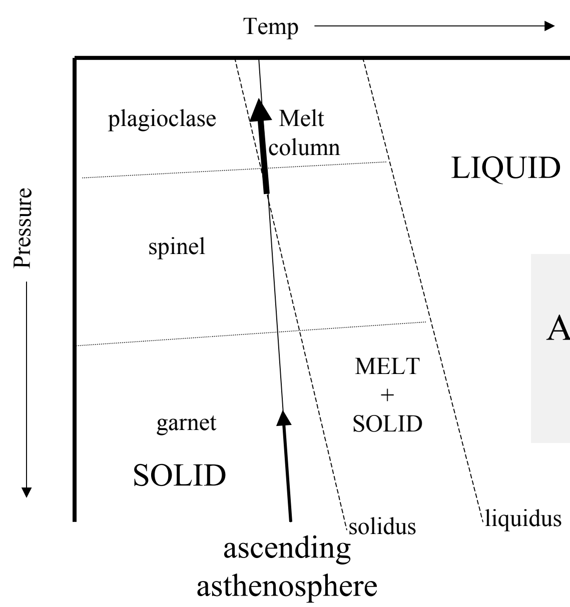
❑ Characteristically depleted in incompatible elements (K, Rb, La, Nb, Zr etc) implying a depleted mantle source.

❑ Sr isotopes ($^{87}Sr/^{86}Sr$) were low (0.7024 – 0.7029) again implying a depleted mantle source.

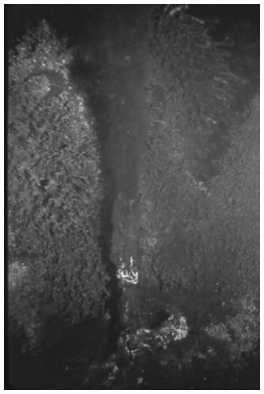
❑ This world-wide depleted mantle source (asthenosphere) was thought to be residue left after the early differentiation of the earth to produce continental crust



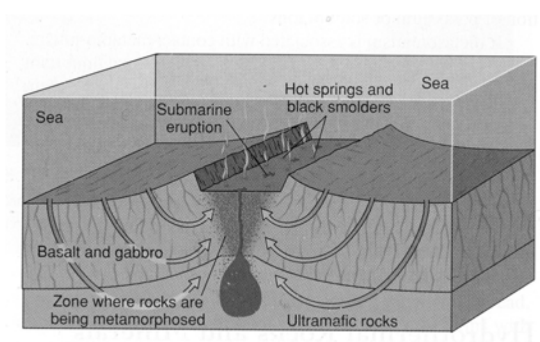
Detailed studies showed variations along mid-ocean ridges, leading to recognition of N-MORB and E-MORB implying a depleted but heterogeneous mantle. Much of this heterogeneity has been related to proximity to hotspots.



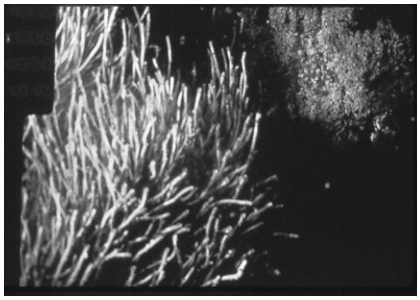
MELTING OF ASTHENOSPHERE TO PRODUCE MORB

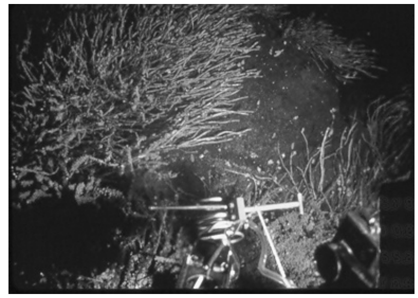


Black Smokers
Temperatures can
get up to 400 ^{o}C



Black smokers are formed by hydrothermal circulation in the oceanic crust. Seawater (~ $2^{0}C$) percolates through the oceanic crust and is heated by MORB magma. The heated seawater dissolves metals (Mn, Zn, Fe, Cu) from the basalt and circulates upwards. These metals are immediately precipitated as sulfides once the hot water comes in contact with the cold seawater, forming chimney structures at the surface.





Tube worms and clams live around these hot vents, feeding on sulfur-reducing bacteria in the vents. In turn, spider crabs feed on the tube worms. Discovery of a totally new ecosystem.