METAMORPHISM OF OCEANIC CRUST

Ocean-floor metamorphism is a concept that has arisen from recent studies of present oceanic ridges and fracture zones where new crust is being generated, altered, and deformed.

Metamorphism in modern oceanic crust. The most widely recognized variety of ocean-floor metamorphism is that resulting from burial and hydrothermal alteration in the high heat-flow and geothermal regime at mid-ocean ridges. New minerals are produced that show progressive changes with depth.

There has been a very great deal of interest worldwide in the metamorphism and hydrothermal alteration of oceanic crust. After all there are few geological situations where you have a large red-hot magma chamber below and a 3 km column of ocean water on top trying to dowse it.

There is no doubt that ophiolite complexes (obducted bits of ocean crust in mountain belts) are usually >90% altered, and there was debate during the 60's and 70's whether this was a result of metamorphism in the mountain belt during orogensis, or resulted from ocean floor metamorphism. The latter is now the favoured explanation. Many of the samples of ocean crust recovered from the ocean floor by drilling or dredging are altered.

Metamorphism Of Oceanic Crust

Cann (1979) recognises 5 different mineral assemblage facies in oceanic basalts recovered by dredging, drilling etc. The rocks characteristically preserve igneous textures.

(1) **Brownstone Facies**

Low temperature ocean floor weathering or cool hydrothermal alteration. Products usually have yellowish brown tint due to oxidising conditions (bluish grey if reducing). Mineral assemblages not in equilibrium; just replace specific primary phases.

(i). Olivine replaced by Celadonite (K-rich dioctahedral Fe-illite) under more extreme alteration. This fills vesicles and replaces glass.

(ii). Plagioclase remains fresh, though under extreme alteration may be partly replaced by K-feldspar.

(iii). Baasalt glass is commonly associated with a low temperature zeolite Phillipsite.

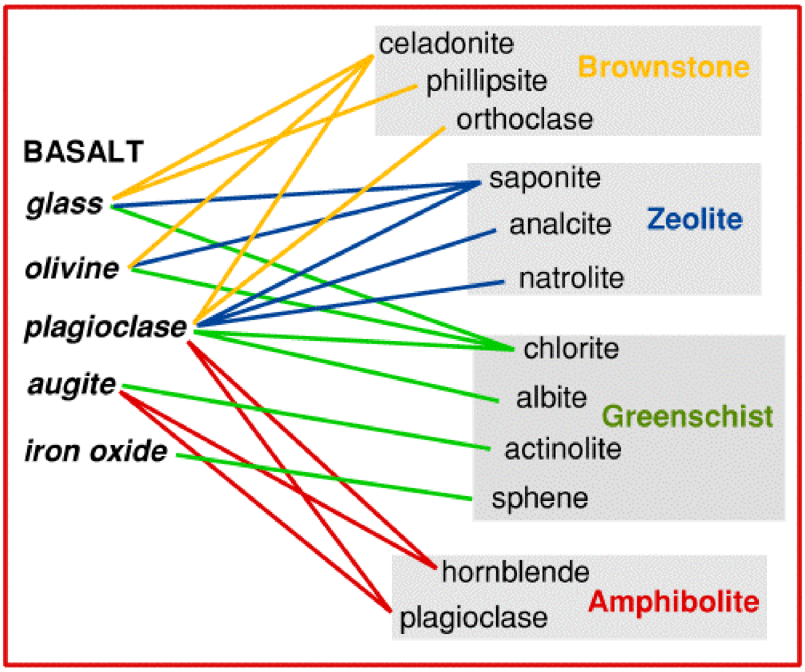

Fig. 1. Diagram from Cann (1979) tries to indicate how the minerals in a basalt affected by hydrothermal activity contribute to the secondary phases. At low temperatures it is mainly the basalt glass and olivine which are unstable and contribute to brownstone facies minerals, but plagioclase and then augite and iron oxide become progressively involved at higher grades until the whole rock recrystallises.

(2) **Zeolite facies** (Temperature above 50-100°C.)

Here Phillipsite is replaced by higher temperature zeolites - Analcite and Natrolite. Mafic minerals replaced by Saponite but coarser grained than in Brownstone Facies. Plagioclase may also be partly replaced by saponite, but augite stays fresh.
Upper limit of facies (250-300°C) marked by disappearance of zeolites and saponite and incoming of albite and chlorite.

(3) Greenschist Facies

Albite ± chlorite ± actinolite ± epidote ± sphene.
Degree of alteration variable, primary assemblages may be completely replaced. Augite is commonly a relic, veins are common, often quartz-bearing. Assemblages may or may not be equilibrium ones. Upper limit of facies marked by disappearance of albite, chlorite and actinolite and the appearance of green aluminous hornblende associated with more calcic plagioclase.

(4) Amphibolite Facies

Hornblende+Ca-plagioclase.

This assemblage is most commonly developed in coarser grained rocks - dykes and gabbros - obviously of deeper origin. Degree of metamorphism variable. Some primary hornblende occurs in gabbros or diorites, but it is clear that amphibolite facies metamorphic assemblages are superimposed on this. So metamorphism closely follows magmatic activity.

Summary of Mineral Assemblages in Altered Crust

Facies	*BASALT*	*PERIDOTITE*
Brownstone	Celadonite +	Phillipsite + Palagonite + Saponite ?
Zeolite	Saponite + mixed layers + analcite + natrolite	?
Greenschist	Chlorite + Albite + Actinolite + Epidote + sphene	Lizardite Chrysotile Magnetite
Amphibolite	Hornblende + Plagioclase + Iron Oxide	Tremolite + Olivine + Enstatite
Gabbro	Augite + Plagioclase + Hypersthene + Iron Oxide +	Olivine Enstatite + Diopside Chromite

General Comments:

Greenschist and amphibolite facies metamorphism of the ocean floor differs from these facies in normal regional metamorphism in that:

(a) The thermal gradient is very high: can be several-100°C per km compared with 30 - 50°C/km in regional metamorphism.

(b) No garnet is developed in mafic rocks (pressures are not high enough).

(c) The rocks lack deformation textures (except in samples recovered from transform fracture zones)

(d) Very variable degree of recrystallization, because lower grade metamorphic assemblages are superimposed on earlier higher grade ones. This is because hydrothermal activity continues under cooler conditions as crust progressively moves away from ridge. (In regional metamorphism it is more common for the rocks to equilibrate at one set of P-T conditions)