

SYENITIC COMPOSITE DIKES AT CAT COVE, SALEM, MASSACHUSETTS

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The Cape Ann Plutonic Series (CAPS) consists of alkaline plutonic granites, syenites, and mafic fractionates produced in a rift environment during the late Ordovician (Paige, 1990; Hon, 1993). An outcrop in Cat Cove, separated from the Beverly Syenite (of the CAPS) by a small bay, presents similar mineralogy and geochemistry, indicating a similar, if not related, origin. According to the Bedrock Geologic Map of Massachusetts (Zen et al., 1984), Proterozoic Z mafic plutonic rocks form the bedrock throughout Salem Neck in Salem, MA. Recent radiometric dates of other mafic Proterozoic Z rocks range from Ordovician to Devonian (Hepburn et al., 1998), suggesting the possibility that the Cat Cove rocks may also be younger and part of the CAPS event.

The outcrop at Cat Cove is located on the coast of Salem Neck, at the Northeastern Massachusetts Aquaculture Center (NEMAC). It consists of three plutonic groups: Proterozoic Z (originally termed Essexite (Sears, 1891), but also referred to as Salem gabbro-diorite), nepheline syenite, and basalt. The gabbro-diorite serves as country rock to syenitic dikes that enclose basaltic pillows. Possible syenite temperatures range high enough for both melts to be liquid at the same time, allowing for mixing in some instances, even though the density difference largely constricts them to immiscible fluid behavior.

Pillows range from one inch to two feet in width, generally elongate proportional to width. Pillow deformation is evident in some dikes; others exhibit very little. Some pillows have chilled margins, indicating rapid cooling on contact with the syenite, and these pillows can fracture and be separated by the fluid syenite. Other pillows behave fluidly with the syenite, with flow features and mineral exchange.

The syenite also chemically interacts with the gabbro-diorite. Angular chunks of the country rock break off into the dikes, forming reaction zones at the perimeters. We found evidence of almost complete dissolution into the syenite, represented in one sample that appears as very coarse syenite. In this sample, virtually all-mafic minerals have been replaced by pegmatitic biotite. The geochemistry of this sample is much more mafic than the other syenites, and the REE's plot along the gabbro-diorite trend, with essentially the same values.

The syenite is found with fine, medium, and pegmatitic textures, commonly with all three in one sample. The fine-grained syenite shows crystal alignment in trachytic flow features, indicating a fluid source. The others may originate in a less fluid environment, e.g. a fractionated crystal mush. The trace element values indicate variabilities in LILE's (Large Ionic Lithophile Elements), particularly in Ba, Sr, Pb, and Zr, and also Ti. This variability does not extend to the REE's, but could originate from a heterogeneous magma, or, as discussed below, a mixing of a relatively primitive magma with a more evolved fluid. Interestingly, the sample richest in the light REE's also shows the only large negative Ba anomaly.

Geochemical analyses indicate that all three rock groups are related. Although the major oxide distributions vary, the REE signatures are very close and trend along lines that are similar to other alkaline rift facies rocks (Kampuzu, 1991). Fractionation of mantle basalt would account for their inter-relatedness. Two syenitic trends are evident, one rich in light REE's (LREE's) relative to the basalt and gabbro-diorite, and one poor relative to those facies. The LREE rich samples exhibit negative Eu anomalies, indicating that plagioclase had been removed from the source magma. The LREE poor samples show a pronounced positive Eu anomaly, even relative to the basalt and gabbro-diorite. These samples appear to originate from less evolved magma, a finding that is confirmed by noting the partition coefficients of the other elements in the sample. The values presented here fit well with other geochemical data of the area (Paige, 1990), consistent with the interpretation that these plutons are probably part of the CAPS.

