# Petrology, Geochemistry, and Tectonic Significance of Crosscutting Dikes in Nahant, MA


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## Introduction

During the late Proterozoic the Avalon Terrane rifted away from the Gondwana supercontinent. As the terrane was moving towards the modified margin of Laurentia, around 488 Ma the Nahant Gabbro intruded. This was later intruded by a series of dikes in the late Devonian. Drone imagery and field survey was used to map multiple sets of cross cutting dikes outcropping along the Castle Rock shoreline in Nahant, MA. In a key area we see five cross cutting dikes. These intersecting dikes are analyzed for their petrology and geochemistry in an attempt to identify different magmatic events.

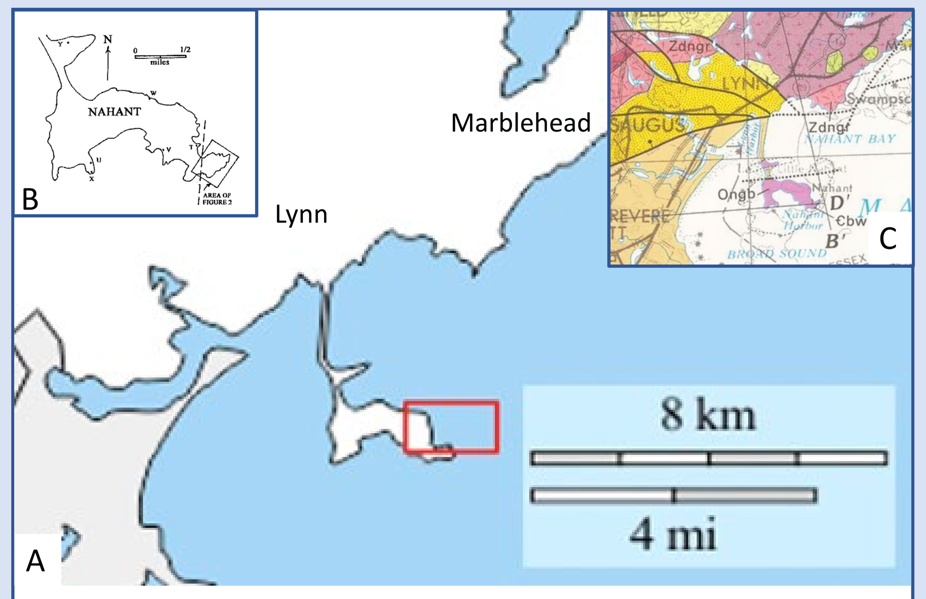


**Figure 1:** (A) Locus map of Essex County with a focus on Nahant, MA. (B) Map of the location area within Nahant of reference dikes from Ross and Baily (2001). (C) Bedrock geologic map of this portion of Essex County.

## Mapping

A DJI Phantom 4 Pro Drone was used to obtain a map of Castle Rock. In the field many dikes are observed, and a set of four cross cutting dikes were selected for sampling due to their clear special relationships.

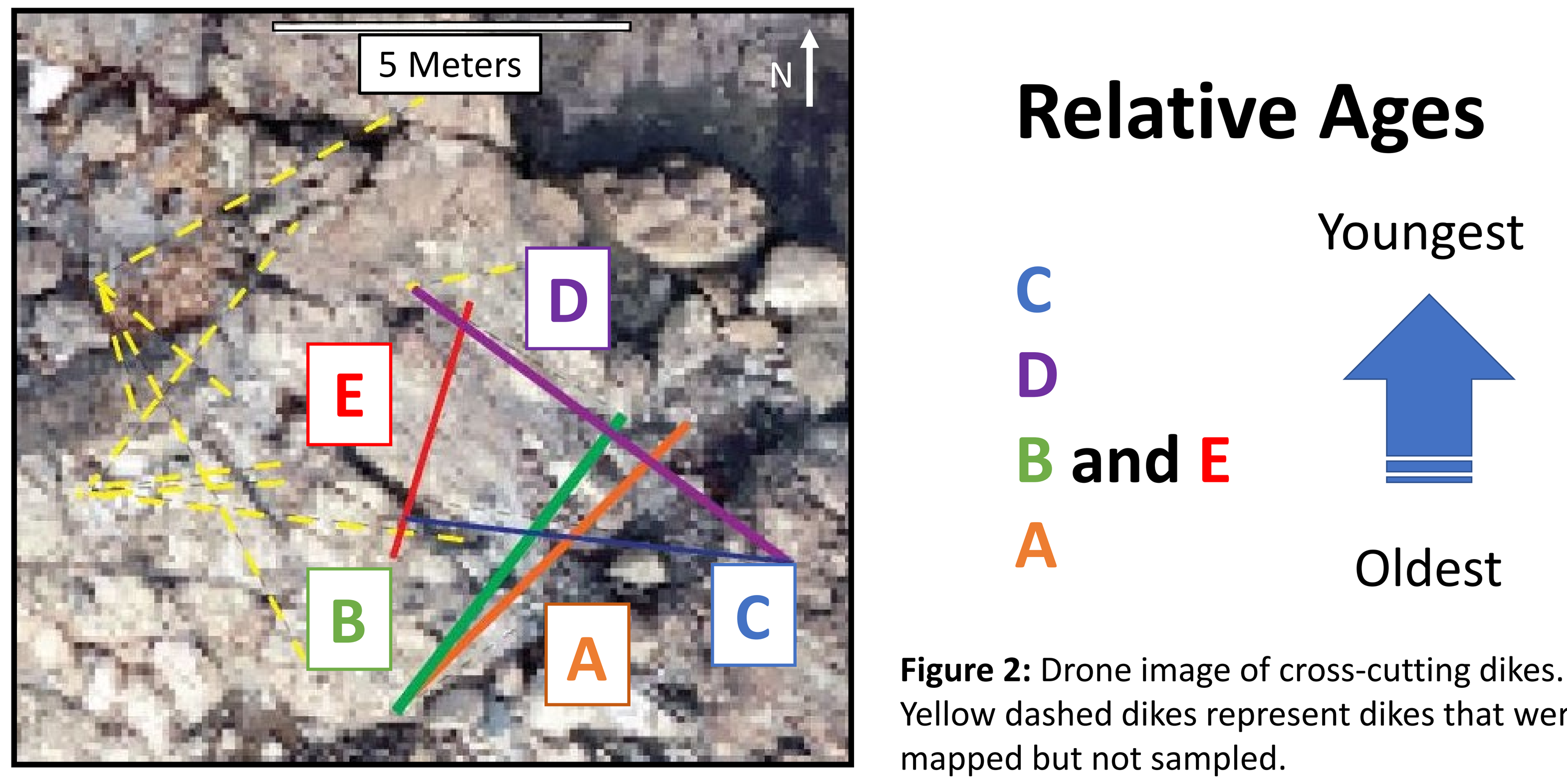


**Figure 2:** Drone image of cross-cutting dikes. Yellow dashed dikes represent dikes that were mapped but not sampled.

## Samples and Field work

Thin sections were produced for the four samples collected as well as the contact between dike B and C.

- Dike B is aphanitic-porphyritic, trending at 038°, 30-45 cm thick.
- Dike E is aphanitic-porphyritic, 20-27 cm thick, and trending at 086°.
- Dike D is aphanitic, 25-33 cm thick, and trending at 150°.
- The youngest, dike C, is aphanitic, 11-16 cm thick, and trending at 096°.

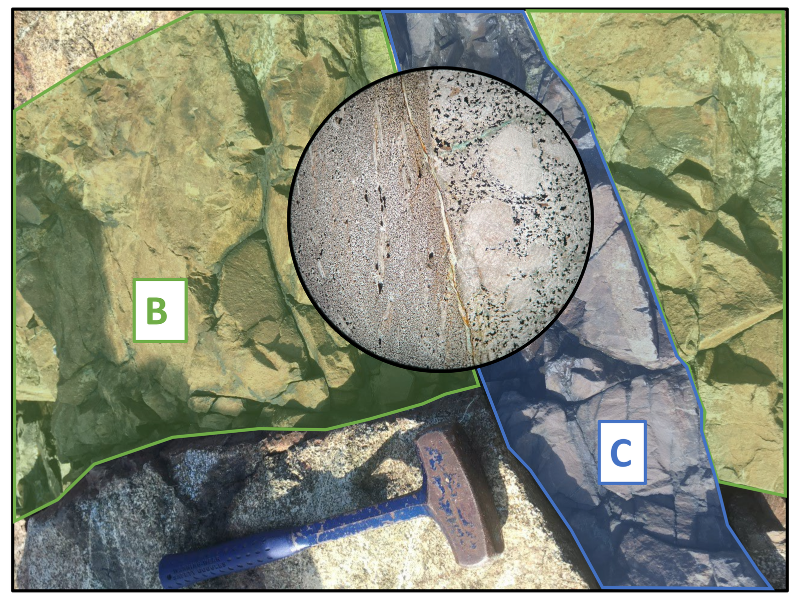


**Figure 3:** Field image of dike C cross cutting dike B. The insert shows a thin section image of the contact itself showing the different textures (Diameter of whole view: 5mm).

## Rock Type

Samples were analyzed for whole rock major and trace elements using X-Ray Fluorescence (XRF) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS).

When plotted on a TAS diagram the dike's composition ranges from basalt to trachybasalt. This distribution overlaps with compositions previously obtained from Nahant dikes by Ross and Bailey (2001).

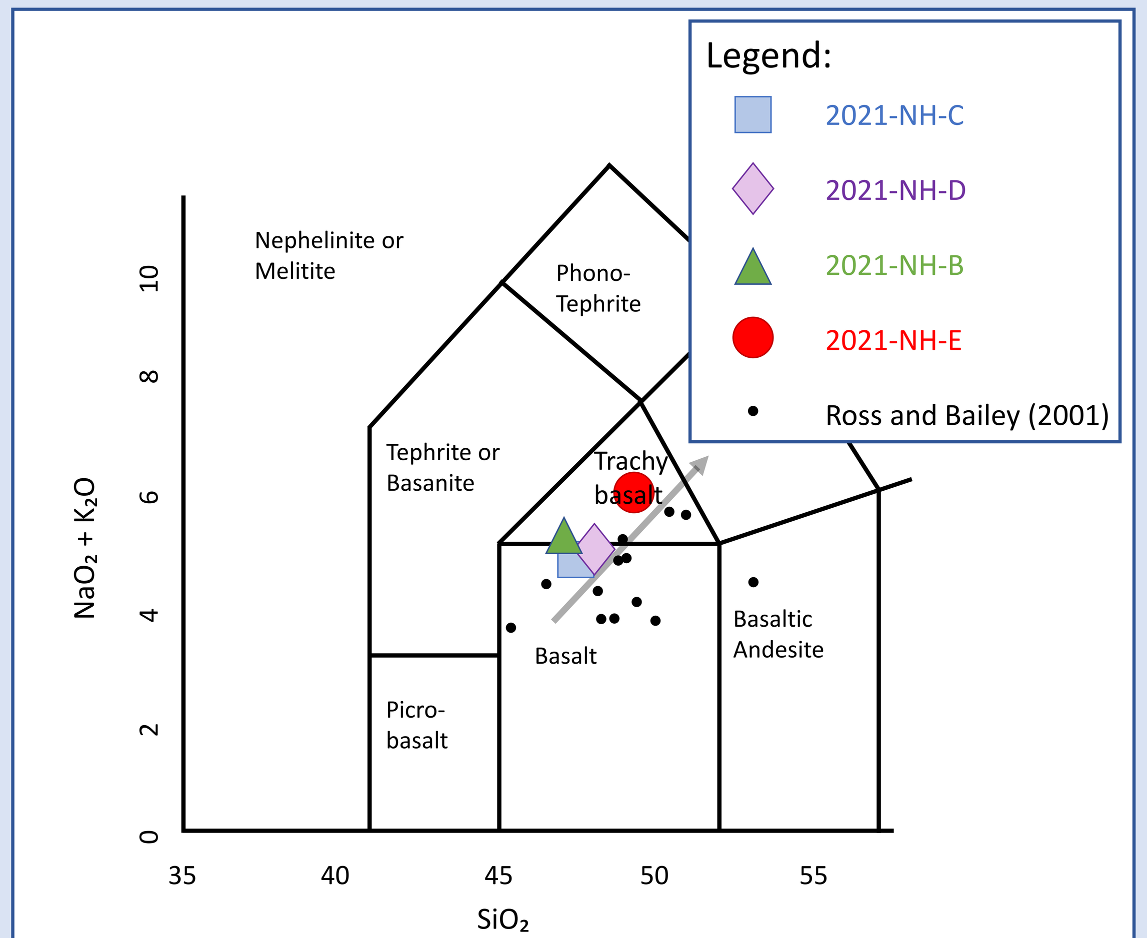


**Figure 4:** TAS diagram modified from Le Maitre et al. (1989). The arrow indicates the expected trajectory of fractional crystallization from more primitive to more evolved. Reference dikes from Ross and Baily (2001).

The youngest dike (dike C) appears to be within the most primitive suggesting a complex history of magma recharge.

## Fractional Crystallization

Indications of fractional crystallization can be obtained by plotting the compositions available on Harker Diagrams (Figure 5).

CaO and MgO are compatible elements. FeO transitions from incompatible to compatible; while $Al_2O_3$, $Na_2O$ and $K_2O$ remain mostly incompatible.

This could indicate that the main mineral phases fractionating in this systems are olivine and clinopyroxene, while plagioclase doesn't appear to have a major role.

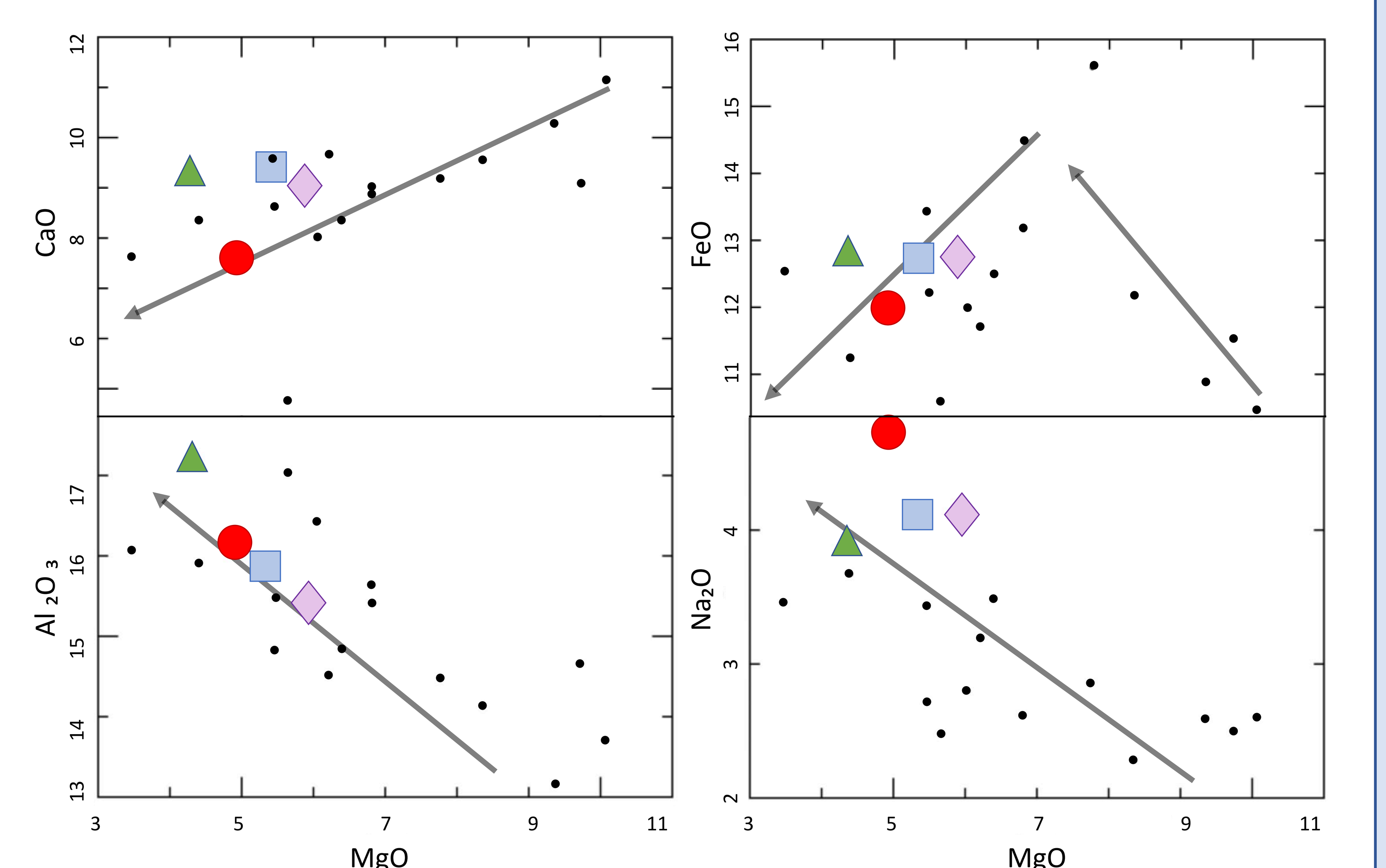


**Figure 5:** Harker diagrams for Nahant dikes. Arrows represent the liquid line of descent representing the evolution of magmas during fractional crystallization.

## Magmatic Characterization

When plotted on a spider diagram normalized by Chondrite the dikes are similar to each other and plot along a trend that is consistent with OIB (Ocean Island Basalt), represented by the orange plus signs.

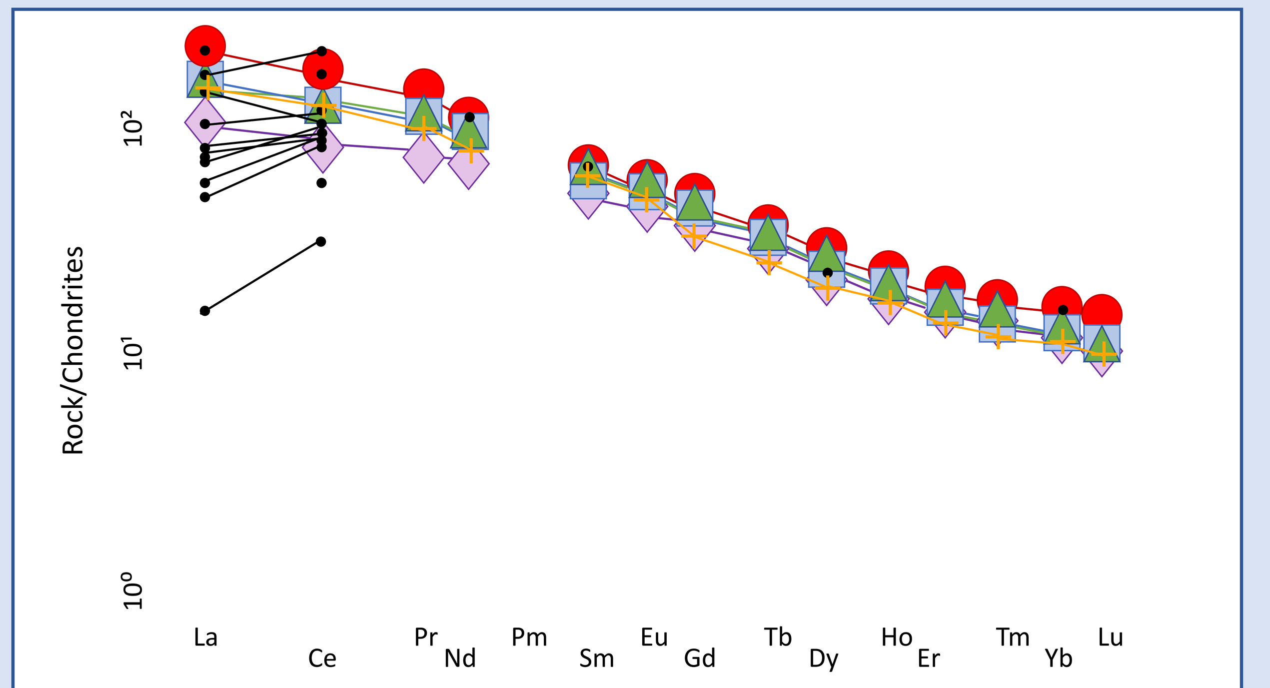


**Figure 6:** Spider diagram normalized by Chondrite (Sun and McDonald, 1989).

## Tectonic Environment

Additionally, on an AFM tectonic discriminant diagram, the Nahant dikes consistently plot in the tholeiitic field implying magmatism related to rifting or within-plate hotspot activity.

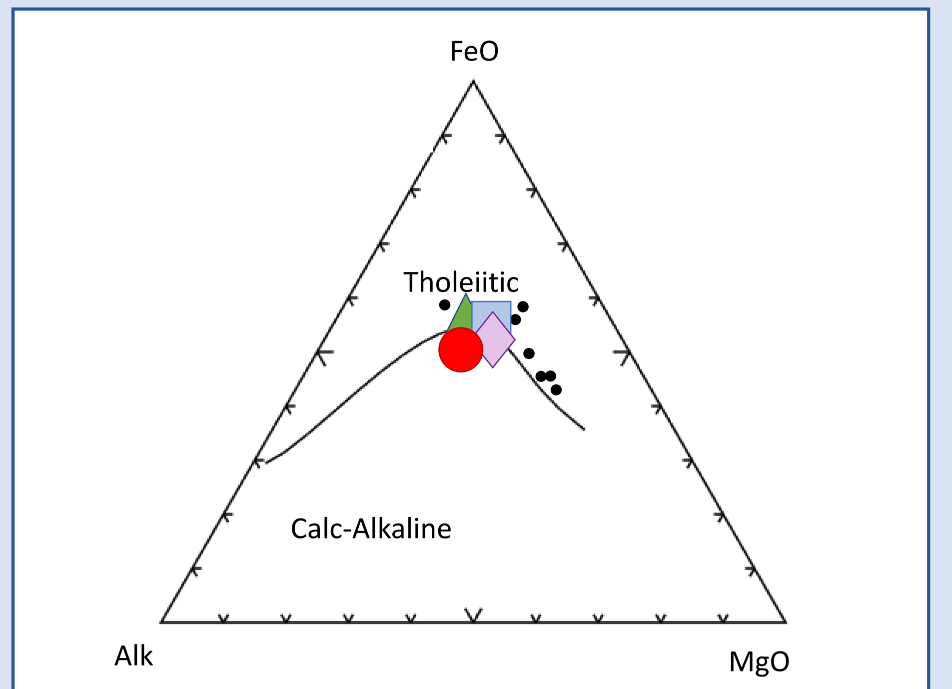


**Figure 7:** Tectonic Discrimination AFM diagram of different sampled dikes modified from Irvine and Baragar (1971).

## Discussion and Conclusion

- Dikes B, C and D are basalts while dike E is a trachybasalt. Dike D is more primitive but younger than dike B suggesting a complex magmatic history with multiple stages of magmatic recharge.
- Fractional crystallization is apparent with olivine and clinopyroxene affecting the concentration of MgO, CaO and FeO.
- The trace elements of these dikes are consistently similar to OIB and they plot within the tholeiitic field suggesting magmatism related to rifting or within-plate hotspot activity.

### References


Irvine and Barager (1971). AFM Diagram. Le Maitre et. Al (1989). TAS Diagram. Ross, Martin & Bailey, Richard. (2001). *Igneous and Sedimentary petrology of East Point, Nahant, Massachusetts* [Online]. Available at: https://www.researchgate.net/ publication/278848533_Igneous_and_ Sedimentary_petrology_of_East_ Point_Nahant_Massachusetts (Accessed: November 2021). Sun and McDonald (1989). Spider Diagram. Zen, E-an, et. al. (1983). *Bedrock Geologic Map of Massachusetts [Online]. Available at:* https://ngmdb.usgs.gov/Prodesc/proddesc_16357.htm (Accessed: March 2022).


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