COMPARISON GEOCEHMISTRY OF THE IZU BONIN MARIANA (IBM) ARC WITH GEOCHEMISTRY OF THE TROODOS OPHIOLITE

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ABSTRACT

The Troodos Ophiolite is one of the best example of supra-subduction zone (SSZ) ophiolite that well studied by different researchers for many years. According to previous studies, Troodos ophiolite has similar geochemical affinities with the volcanic and mantle rocks from modern fore-arc and rear arc (back arc) intra-oceanic settings. Troodos ophiolite holds similar magmatic records of currently active Izu-Bonin-Mariana (IBM) arc-basin system. IBM arc is the best modern analogue for the supra-subduction zone (SSZ) evolution of Tethyan type ophiolites and has magmatic records of volcanism during subduction initiation.In this study, sixty whole rock and volcanic glass samples are collected from the dykes and pillow lavas of Troodos ophiolite . These collected samples were analyzed for their major and trace elements. Geochemical data from the samples were compared with geochemistry of samples from IBM arc and previous studies of the Troodos ophiolite. Some of the samples show similar trace elements patterns with the boninitic rocks from Troodos ophiolite. These rocks show enrichment in LILE compared to the HFSE (Ta, Nb, Hf) and show spoon-shaped REE pattern. Other samples which cross-cut boninites have similar trace element abundances with the fore-arc basalts (FABs) from the IBM. These FAB-like samples are depleted by all trace elements compared to boninite and basalt samples of Troodos ophiolite. Comparison between the major and trace element geochemistry of the IBM and the samples from this study reveal, for the first time, the presence of FAB-like samples in the Troodos ophiolite. Results of this study support recently proposed tectonic models that suggesting Troodos ophiolite may have formed in a subduction initiation setting .

1. Introduction

This study aims to understand the early magmatic evolution of the Troodos ophiolite and specifically to search for geochemical signatures that can be associated with the processes of subduction initiation. This study concentrates on the bulk rock and volcanic glass geochemistry of selected dykes and lava samples from the southern Troodos ophiolite. Major and trace element analyses of dykes (ten samples), and pillow lavas (fifty samples) have been obtained using inductively coupled plasma mass spectrometry (ICP-MS) and X-ray fluorescence spectrometer (XRF), and in-situ major element data has been obtained from mafic minerals of the samples using electron probe microanalysis (EPMA). **Testable hypothesis of this study** is that some of the early mafic volcanic rocks are forearc basalts (FAB), (Reagan et al., 2010), and in analogy to the IBM arc-basic system, this means that the volcanism is associated with subduction initiation.

2. Geological Background

The Troodos ophiolite is known as one of the best examples of ancient oceanic crust exposed on land. The Troodos ophiolite has been well-studied by different researchers for many years and described as one of the ophiolites formed at a spreading centre above a subduction zone SSZ ophiolites (Pearce,1984). Formation and alteration of Troodos Ophiolite material are suggested as Late Cretaceous. The Izu-Bonin-Mariana (IBM) arc is one of the most remarkable and well-studied examples of an intra-oceanic arc. The different components of the IBM such as arc, forearc, back-arcs show a continuous volcanic history from the early Eocene to the present. Studying the IBM system can provide clues regarding how subduction initiation occurs and how intra-oceanic arc volcanism developed through time. Having knowledge about the conditions of oceanic crust and upper mantle before subduction initiation and during the very early stages of subduction is very important for understanding the formation of the so-called supra-subduction zone (SSZ) ophiolites. Supra-subduction zone (SSZ) ophiolites like Troodos have similar geochemical affinities with the volcanic and mantle rocks recovered by IODP from modern forearc and rear arc intra-oceanic settings. Therefore, this study aims to early magmatic evolution of the Troodos ophiolite and specifically to search for geochemical signatures that can be associated with the processes of subduction initiation by using geochemistry of IBM arc and Troodos ophiolite.

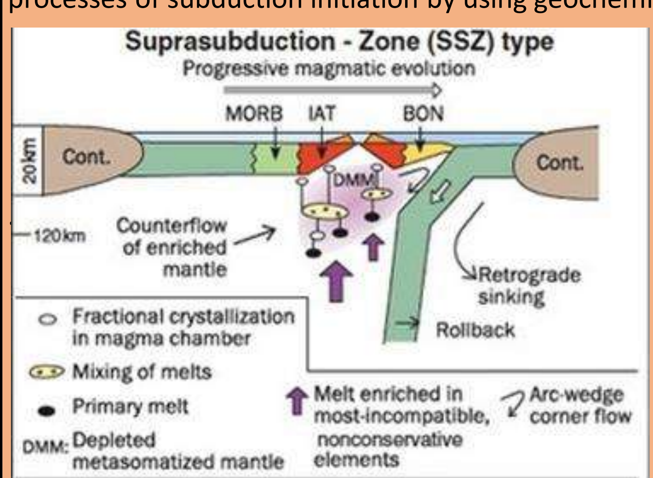


Fig 1. Formation Model of SSZ Type Ophiolites (Dilek and Furnes,2009)

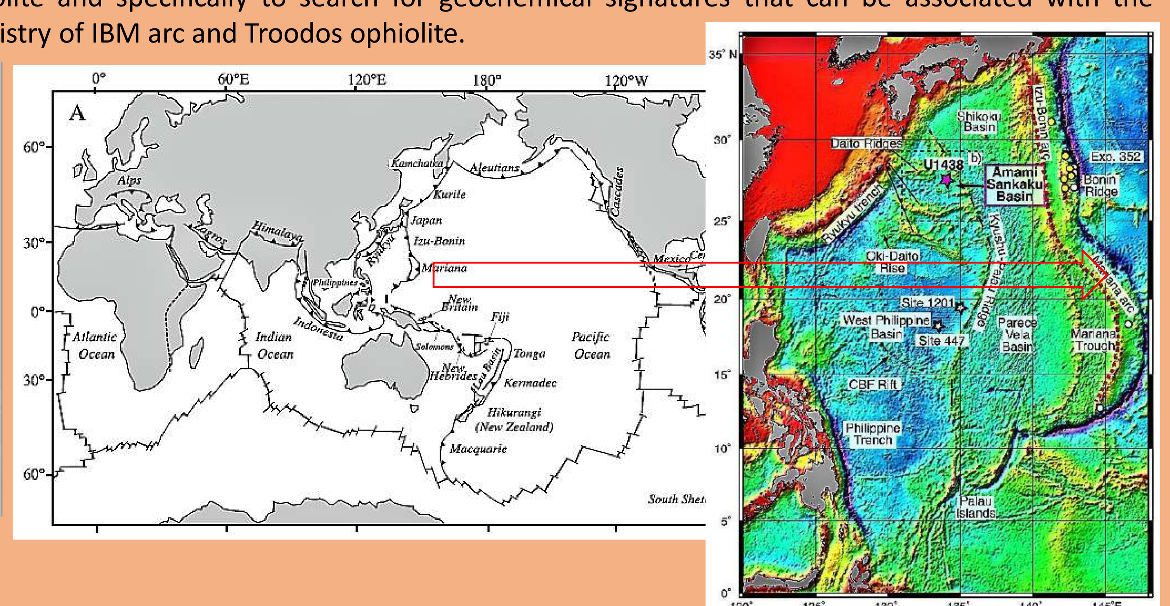
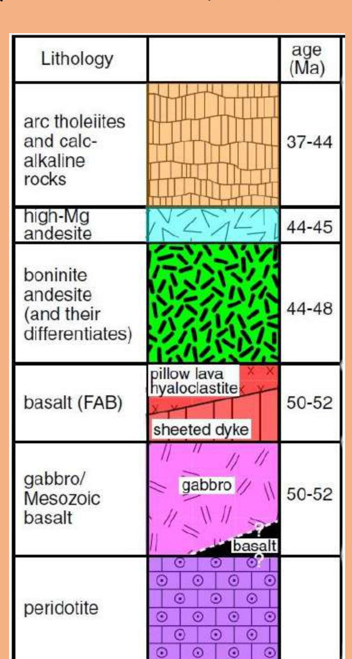


Fig. 2. Left side convergent margins and intra-oceanic arcs locations (Stern, 2010) and right side map of the western Pacific region show IBM arc and West Philippine Basin including previous drilling sites after (Yogodzinski et al., 2018).



Forearc basalts or "FABs" were defined by Reagan et al. (2010), who named these basalts as "forearc" because they are found in modern forearc regions. FABs are basalts that have more depleted trace element abundances when compared with the mid-ocean ridge basalts (MORB) and less depleted trace element abundances when compared with those of boninites. Typically, these FABs are overlain by boninitic rocks and are thus considered to be **the first products of IBM type arc volcanism**. After the eruption of FABs, volcanism continues through the eruption of "transitional" lavas and then with boninites.

Fig. 3. Schematic Coloumn Section of IBM Arc is shown (Ishizuka et al.,2011).

As part of this study, 60 rock and volcanic glass samples that represented different parts of the Troodos ophiolite were collected.These different parts that represent sample locations decided by considering IBM arc column sections. Both the Troodos ophiolite and IBM arc have similar rock types and similar formation type. Most samples (CY17/7-12, CY24-30, and CY36-60) were collected from the Arakapas (Transform) Sequence Lava pile that described as olivine and pyroxene phyri and aphyric pillow lavas with hyaloclastites. These lavas also include sheet lava flows and dykes. The Arakapas Transform Fault is described as a fossil transform fault that divides the Troodos massif and Limassol Forest complex. Boninitic rocks are located at the southern margin of Troodos and Arakapas Transform Fault. These boninitic rocks that have high MgO, basaltic andesite range SiO2 and low TiO2 contents. Since boninites are considered as related to subduction and particularly related to forearcs, they play a significant role to understand supra-subduction zone settings. Samples CY17/1-6, 13-16 were taken from diabase dykes representing unit defined as aphyric diabase dykes that reach 3 m wide and include clinopyroxene and plagioclase crystals. The remaining samples CY17/31 to CY17/35 were collected from the UPL unit and have olivine and pyroxene phenocrysts. The LPL contain tholeiitic basalts, rhyolites and dacites, whereas the UPL is composed of picrites and boninites . UPL samples were collected from the vicinity of the village of Margi.

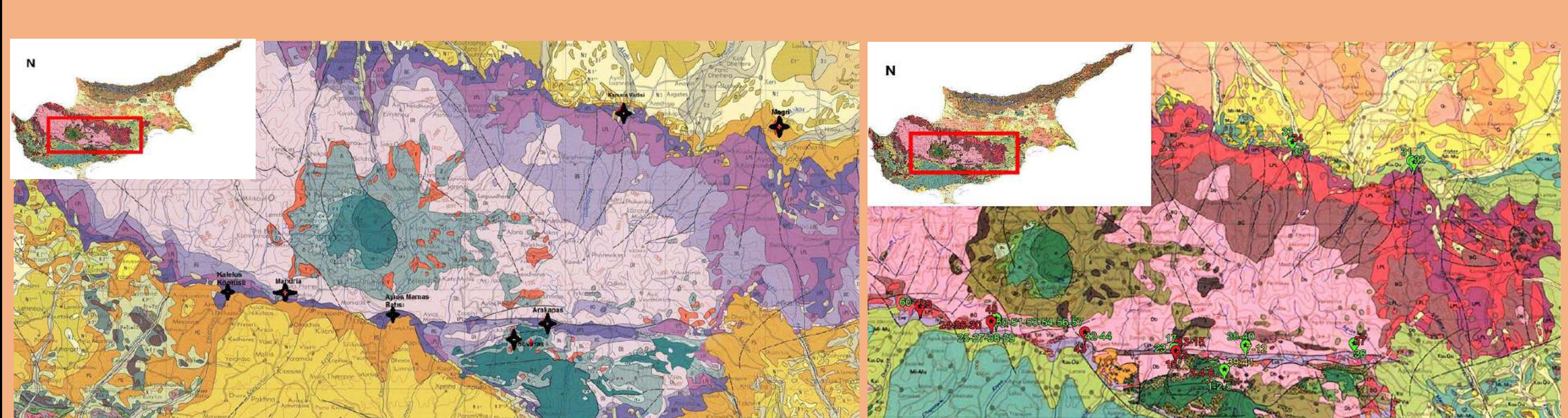


Fig. 3. Sample locations and geological map of Troodos Ophiolite are shown. Red shapes at right side figure represents FAB-like samples locations: pale green ones represent boninite samples location.

Fig. 4. Field photos are shown. From left side to right side, FAB samples, Arakapas boninites, Louvaras volcanic samples and Margi pyritic basalt samples respectively.

3. Methodology

To obtain geochemistry of selected regions based on previous studies in Troodos ophiolite, 60 rock and volcanic glass samples were collected from the southern part of Troodos ophiolite were prepared for analyses that EPMA and ICP-MS (trace elements), XRF (major oxides). Data corrections were made for getting precise results.

4. Results

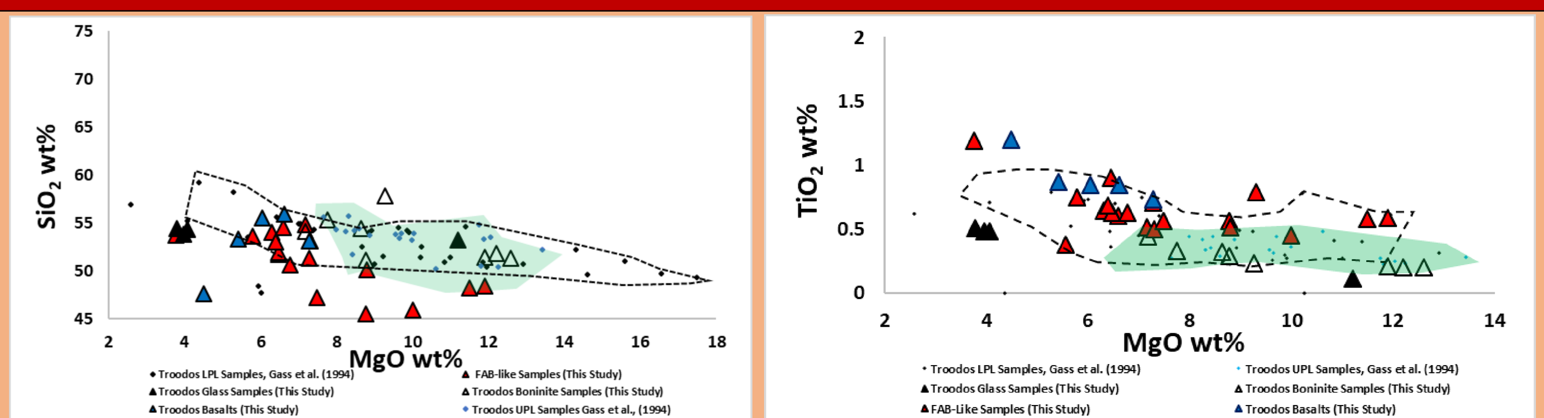


Fig. 6. Major element ratios for Troodos FAB-like samples, basalts, boninites and glass samples (this study) compared to Troodos lower pillow lava samples and Troodos upper pillow samples. Left: SiO_2 vs MgO Right: TiO_2 vs MgO. The area bordered with dash represents lower pillow lavas (LPL); green area represents upper pillow lavas (UPL) from Gass et al. (1994)

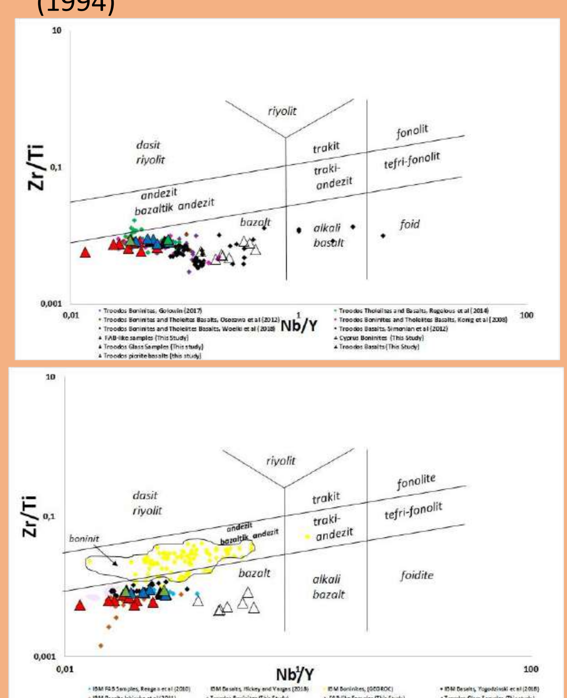


Fig. 7. Zr/Ti vs Nb/Y discrimination diagram for Troodos basalts, boninites, and FAB-like samples (this study). Upper: Zr/Ti vs Nb/Y diagram for Troodos basalts, boninites (this study) compared with Troodos basalts and boninites. bottom: Zr/Ti vs Nb/Y diagram for Troodos basalts, boninites (this study) and IBM basalts, boninites and FABs. IBM boninites data took from GEOROC, IBM basalts data.

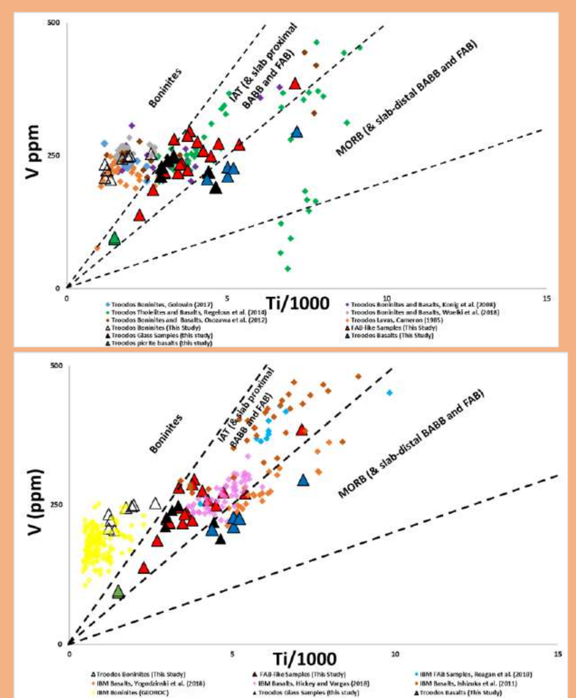


Fig. 8. From Shervais (1982) Ti/1000 vs V plot. Upper: Ti/1000 vs V plot for Troodos basalt and boninite Samples (this study) compared with Troodos basalts and boninites. Bottom: Ti/1000 vs V plot for Troodos basalts and boninite samples (this study) compared with IBM basalts, boninites and FABs.

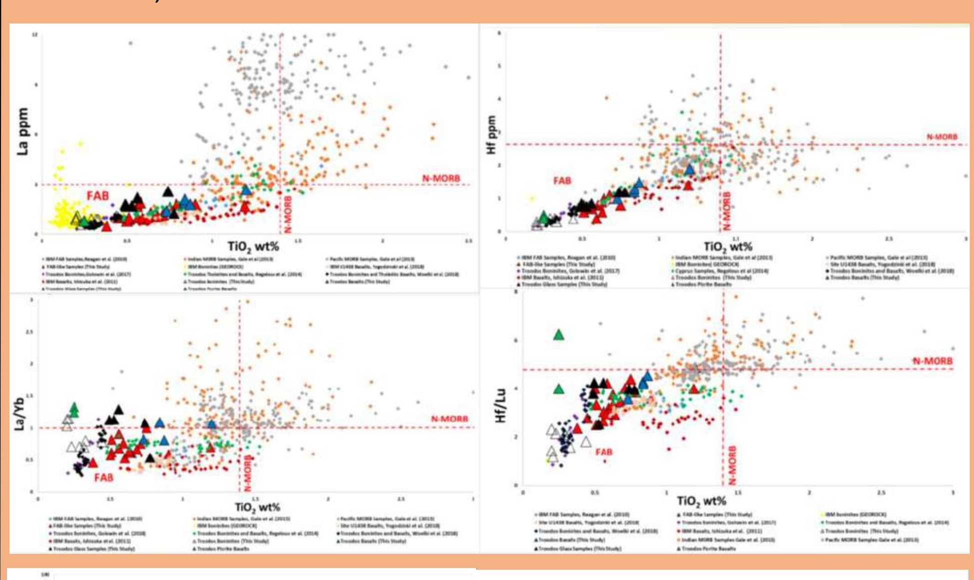


Fig. 9. From Yogodzinski et al. (2018) trace element concentrations vs TiO_2 for Troodos basalt and boninite samples (this study) and Troodos basalts, boninites and IBM basalts, basalts and FABs. a) La vs TiO_2 plot b) Hf vs TiO_2 plot c) La/Yb vs TiO_2 plot d) Hf/Lu vs TiO_2 plot.

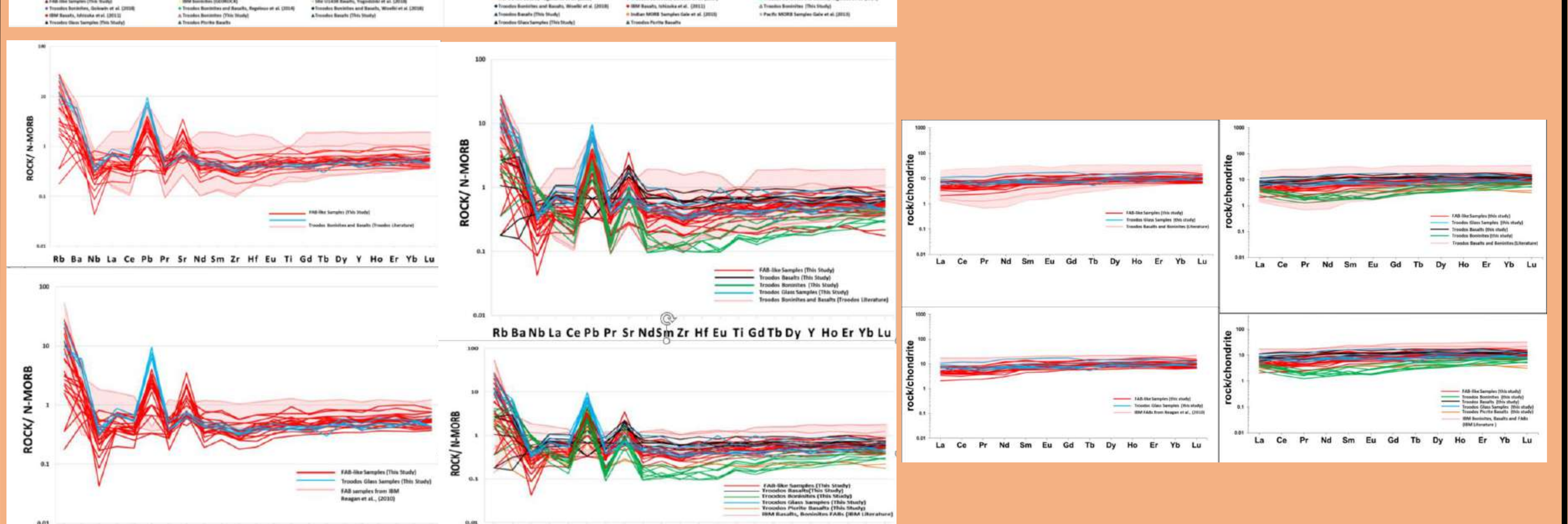


Fig.10. Left side: Trace element plots normalised to N-MORB for Troodos basalts, boninites, glass samples and FAB-like samples (this study) and Troodos and IBM samples from previous studies. Right side: Chondrite-normalised rare earth elements plots for FAB-like samples, basalts and boninites (this study) and Troodos and IBM Literature. The pink area represents previous studies on Troodos and IBM. This area plotted by using maximum and minimum REE values from each literature data.

5. Discussion and Conclusion

-Within the scope of the study, samples were divided into three groups as FAB-like, MOR-like basalts and boninites, according to the results obtained using the ICP MS, XRF and EPMA methods. All samples taken from Arakapas are in the upper pillow lava group and contain more than 52% SiO2, more than 8% MgO and less than 0.5% TiO2, and are compatible with previous studies. According to the results obtained from the study, there are both high and low Ca boninites, indicating a different type of mantle source. The results obtained from volcanic glass samples are basaltic in character and resemble lower pillow lavas. The trace elements of boninites are similar to previous studies, indicating that they came from a more depleted source. Samples that are in the IAT area are named as FAB-like examples. These samples show ultra depletion by REE, they indicate ultra depleted mantle source.

-Samples classified as boninites show a rich (LILE: Rb, Sr) and spoon-shaped LREE (LREE) trend and show a similar pattern to the Trodoos Ophiolite Boninites. Samples classified as basalts show a flatter HREE pattern than MORB. FAB-like examples are similar to IBM FABs, showing a rich LILE pattern that Show depletion of HREE.

- **The presence of FAB-like rocks in the Troodos Ophiolite, which was presented for the first time in this study**, is compatible with the model (Pearce,2010) that indicates that the Trodoos Ophiolite was formed in related to subduction iniation.

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