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Geochemistry and Thermal analyses in subduction zone serpentine (SE Turkey)

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Abstract – This Studying serpentinites requires a thorough understanding of their original rock types and their geological history before undergoing serpentinization. The chemical composition analysis and TGA analysis of serpentinites indicates that certain elements tend to remain relatively stable in terms of distribution even as the serpentinites undergo serpentinization. This stability in elements like rare earth elements (REE) can serve as a valuable tool in determining both the original rock type and potential magmatic processes that occurred prior to serpentinization. However, interpreting trace element data from serpentinites that have been subducted presents challenges. This is primarily due to the presence of elevated levels of light rare earth elements (REE), which seem to be independent of the original rock type. In such cases, we suggest that these enrichments are likely not directly linked to the serpentinization process itself, but rather stem from interactions between fluids derived from sedimentary sources and the rock within the subduction environment after serpentinization has taken place. The trace element abundances, when normalized to chondrites, exhibit a range between 30-90 ppm. In relation to chondrites, there is a distinct decrease in elements such as Sr, Rb, K, and Y while there is an increase in elements like Ba and U (by a factor of 93). Minerals display a negative anomaly for elements P, K, Sr, Ti, Zr and Y, and a pronounced positive anomaly for Ta, Nd and U.

Keywords – Chondrite-Normalized, Depletion, Minerals, TGA Analyses, Ophiolite

I. INTRODUCTION

This Recently, there has been a proposal that the presence of serpentine's, particularly within subduction zones, could carry significant implications for the Earth's dynamic and global geochemical processes [1]. Nevertheless, unraveling the origins of serpentinites and understanding the underlying causes of serpentinization remains a formidable task, primarily because this unique process is primarily initiated on the ocean floor, often near mid-ocean ridge. Serpantinites then persists during the subduction of abyssal serpentinites and peridotites. Furthermore, serpentinites in the mantle wedge are a result of fluids being released from the descending slab. Fortunately, a substantial collection of high-quality bulk rock compositions, along with on-site geochemical data related to serpentine phases, has recently become accessible. These datasets now comprehensively represent serpentinite compositions worldwide, providing a comprehensive overview.

Being a mineral with low strength and buoyancy, and having a wide range of stability in terms of pressure and temperature, serpentine minerals can have a significant impact on the behavior of subduction zones. This impact is particularly noteworthy in relation to events such as the initiation of earthquakes, the process of bringing high-pressure to ultra-high-pressure rocks to the Earth's surface, and even potentially in the commencement of the subduction process itself [2]. Based on major and trace element chemistry, serpentines are typically composed of chrysotile and Mg-rich lizardite. The presence of these minerals and their rare earth element (REE) chondrite-normalized values distinctly indicate differentiation and point towards a similar parent rock origin.

The distribution of serpentinization and accompanying mineral formations in the ultramafics of the Guleman Ophiolite are intended to be determined through applied studies aiming to identify the mineralogical and chemical alterations due to the effects of the detachment zone.

II. Materials and Method

The materials employed in the conducted study and the applied methods were executed in two main phases: fieldwork and laboratory investigations.

In laboratory investigations, examinations were carried out using transmitted-light polarizing microscope, scanning electron microscope (SEM), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), DTA analyses and geochemical analyses, respectively, starting from thin sections. The mineralogical-petrographic examinations were exclusively conducted at the Research Laboratories of the Department of Geological Engineering at Fırat University.

III. Results

A. *Serpantinites*

The peridotite rocks forming the base of the Guleman ophiolitic unit have developed as a result of alteration under hydrothermal and surface condition.

In the microscopic examinations of serpentinites, Mesh/Network texture is dominant. Mineral composition includes olivine, pyroxene, and serpentine minerals. Serpentine minerals are observed within extensively fractured olivine minerals or in the surrounding areas. Pyroxene is present as vein-like structures transformed into serpentine, exhibiting parallel patterns, intersected by fibrous chrysotile cracks with silica fillings (Fig.1). In another group of samples, Holocrystalline and Mesh textures are evident. Serpentine, olivine, and pyroxene minerals float within a mesh-textured matrix. While olivine is highly fractured, pyroxene has completely serpentinized, with needle-like and platy chrysotile filling the cracks. Additionally, formless opaque chromites have been identified (Fig.1). Some serpentinites contain both glomero-porphyritic and mesh textures together. The mineral assemblage comprises olivine, serpentine, and pyroxenes. The mesh-textured structure, extensively fractured olivine minerals dispersed throughout the matrix, and entirely serpentinized pyroxenes with vivid alteration colors are easily distinguishable. Within the cracks, needle-like and occasionally platy chrysotile mineral formations are observed (Fig.1).

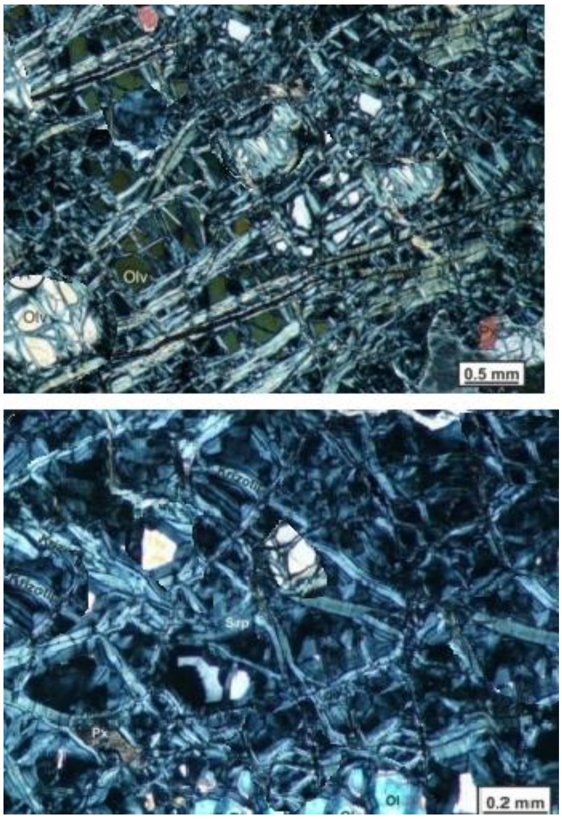

Fig. 1 The view of serpantinite

B. *Subduction and Geochemistry*

Chemical analyses (ICP-MS), along with the comprehensive evaluation of data obtained from DTA analysis of the samples, allowed for the determination trace and REE element analyses in a total of five samples, including serpentinite samples.

n relation to chondrites, there is a distinct depletion in elements like Sr, Rb, K, and Y, while elements like Ba and U show enrichment. there is a negative anomaly for elements K, Sr, P, Zr, Ti, and Y in all minerals; conversely, a strong positive anomaly is observed for U, Ta, and Nd. The total REE contents of serpentinites vary between 5-11 ppm. The chondrite-normalized REE patterns of serpentinites do not exhibit distinct differentiation, there is a weak negative anomaly observed for the Tb element. When evaluating the remaining compositions of serpentinite minerals, they display prominent depletion such as Dy, Ce, Er, and Yb show negative anomalies, whereas Nd, Ho, and Tm show positive anomalies. Eu, on the other hand, presents a very weak positive anomaly (Fig. 2).

The presence of these elements offers insights into the interactions between fluids and rocks during the process of serpentinization, as well as how Highly Incompatible Elements (HIE) behave, ranging from their integration into the system to their subsequent gradual liberation during the subduction process.

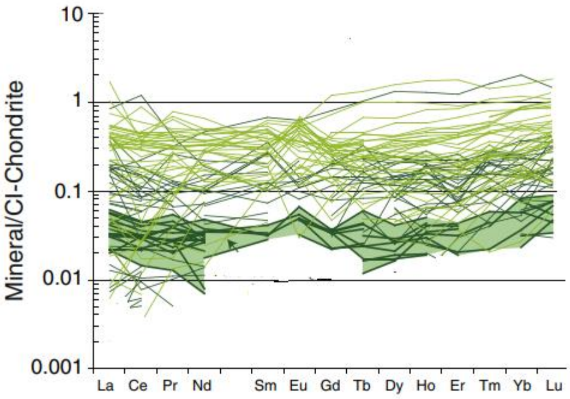

Fig. 2. REE and trace element of serpentine [3]

The outcomes of the differential thermal analysis and thermal analysis conducted on pre-heated serpentine are presented in Fig.3. Serpentinite underwent a thermal treatment at a temperature of 660 °C for a duration of 3 hours. The disintegration of the crystal lattice corresponds to a weight reduction of around 13%, which coincides with the elimination of chemically bonded water. The commencement of forsterite is signified by the appearance of an exothermic peak at 820°C.

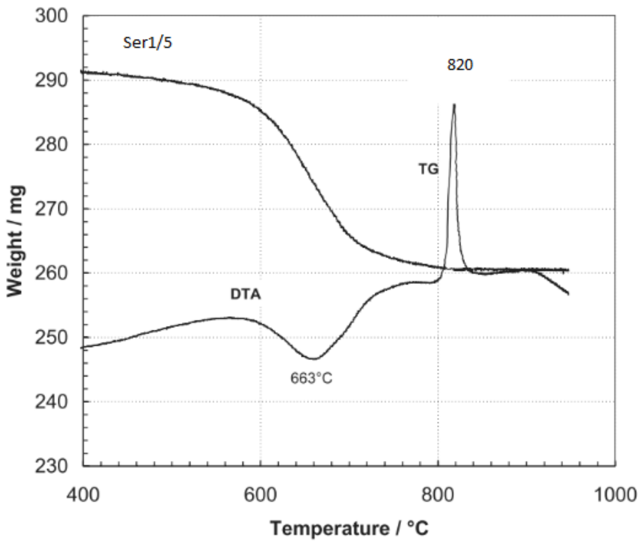

Fig. 3. DTA analysis of serpentine

V. DISCUSSION

The Upper Cretaceous Guleman Ophiolite consists of ultramafic serpentinized tectonites (harzburgite, dunite, pyroxenite), ultramafic-mafic sills and dykes in plagiogranite, basaltic and gabbroic forms, and at the top, sedimentary radiolarites. Despite the orderly arrangement of these units belonging to the Guleman Ophiolite, a complete ophiolitic sequence development has not taken place. All of the peridotites observed within the Ophiolite exhibit a tendency for serpentinization.

In rocks referred to as serpentinites, residual olivine minerals from the parent rock can be observed. These olivine minerals, extensively altered, have relatively high optical relief, are colorless under a single Nicol, and are distinguished by vivid alteration colors. Due to serpentinization, the primary characteristics of the minerals are lost, and a mesh and network texture has developed within the mineral.

The REE contents of serpentine minerals were normalized against chondrites [3] or elemental abundance comparisons. The REE contents of serpentines, are similar to each other. The values were reevaluated for comparison by incorporating for Ho and Tm. Chondrite-normalized total REE contents vary between 5-11 ppm. The chondrite-normalized REE patterns do not exhibit distinct differentiation, there is a weak negative anomaly observed for the Tb element. Serpentinites that have undergone subduction exhibit compositions that are less resistant and feature significant enhancements in REE content. These compositions might indicate the occurrence of a magmatic refertilization process or could be attributed to the inherent characteristics of the original rock type, such as the mantle at an ocean-continent transition zone [4]. Presently, limited research exists regarding the characteristics and geochemical compositions of fluids released during the dehydration process of serpentinites. Notable studies in this area include works by [5]), [6], [7] and [8]. Additionally, only a handful of field-based geological observations provide evidence of serpentinite dehydration, showcasing the transition from serpentine phases to anhydrous mantle minerals. These observations include instances such as the Cerro del Almirez massif in Spain [9], [10], [11] [12].

VI. CONCLUSION

Through macroscopic and microscopic observations, three distinct serpentine minerals (platy, columnar, and acicular-fibrous) have been identified based on their shapes and forms that exhibit variations from one another. The consideration of serpentinites is essential when interpreting the fluid-mobile element compositions (such as Li, B, Pb) of arc magmas. Serpentinites, regardless of their geological context, uniformly exhibit significant enrichments in fluid-mobile elements (B, Li, Sb, Pb As, Cs, Sr,, U, Ba) during the process of serpentinization. Specifically, the pronounced mobilized elements enrichments observed in subducted serpentinites predominantly arise from the impact of fluids originating from sediments. These enrichments are the outcome of subsequent chemical interactions that likely occur within the subduction channel.

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