

GEOCHEMICAL MODELLING OF FLUID – ROCK INTERACTIONS IN
AKKÖY AND EDREMIT GEOTHERMAL FIELDS (WESTERN ANATOLIA)
AS PROSPECTIVE CO₂ STORAGE SITES

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ABSTRACT

GEOCHEMICAL MODELLING OF FLUID – ROCK INTERACTIONS IN AKKÖY AND EDREMIT GEOTHERMAL FIELDS (WESTERN ANATOLIA) AS PROSPECTIVE CO₂ STORAGE SITES

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Lithogeochemical and hydrogeochemical characterizations of two geothermal fields located in western Anatolian region (Akköy – Denizli and Edremit – Balıkesir) are performed to simulate the CO₂-fluid-rock interactions in the systems through geochemical modelling studies.

Drill cuttings obtained from the fields are investigated in terms of their petrographic features, mineral compositions and elemental variations with depth. Calcareous rocks (marble/limestone/calcschist) and granitic rocks constitute the dominant rock fragments in the samples of Akköy and Edremit, respectively. Main mineral phases in Akköy include quartz, calcite and clay minerals whereas in Edremit, along with quartz, feldspars, micas, carbonates and amphiboles are the dominant phases. Hydrogeochemical analyses reveal that the hot waters are of Na+K-HCO₃-SO₄ type in Akköy and of Na+K-SO₄ type in Edremit field.

The results have led to the geochemical assessment of two fields as potential sites for CO₂ storage in the context of CO₂-fluid-rock interactions with the utilization of

geochemical simulations performed by PHREEQC software. Modelling studies of Akköy samples point to ankerite as the principal carbonate phase that can trap CO₂. In Edremit, mineral trapping mainly occurs through the precipitation of dolomite. Clay mineral abundance seems to prolong the reaction times and smectite presence, in particular, increases the propagation distance. Due to the mineralogical differences, the reactions in Edremit samples are shorter both temporally and spatially than in Akköy. The geochemical outcome of a CO₂ addition to a system (e.g. trapping mechanisms) seems to be closely interconnected to the composition and assemblage of minerals in the reservoir.

Keywords: CO₂ Storage, Fluid-Rock Interactions, Geochemical Modelling, Lithogeochemistry, Hydrogeochemistry

ÖZ

OLASI CO₂ DEPOLAMA ALANLARI OLARAK AKKÖY VE EDREMIT JEOTERMAL SAHALARINDAKİ (BATI ANADOLU) AKIŞKAN – KAYAÇ ETKİLEŞİMLERİNİN JEOKİMYASAL MODELLEMESİ

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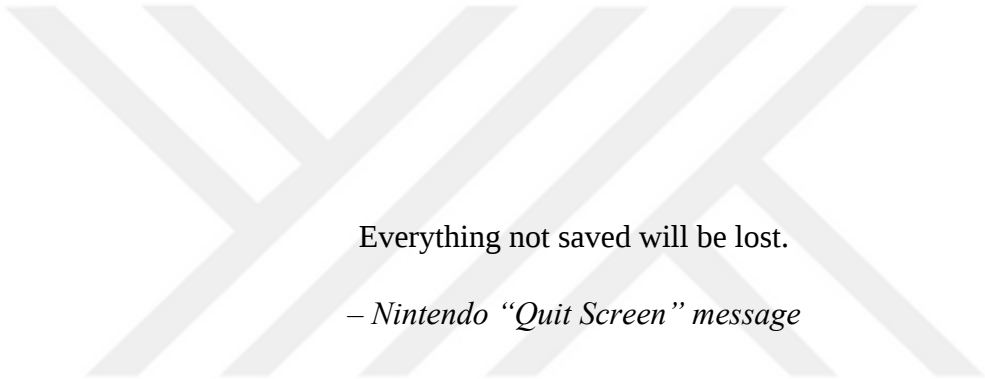
Batı Anadolu bölgesinde bulunan iki jeotermal saha (Akköy – Denizli ve Edremit – Balıkesir), jeokimyasal modelleme çalışmaları yoluyla CO₂-akışkan-kayaç etkileşimleri simüle edilmek üzere litojeokimyasal ve hidrojeokimyasal olarak karakterize edilmiştir.

Sahalardan elde edilen kırıntı kayaç örnekleri, petrografik özellikler, mineral bileşimleri ve elementlerin derinliğe göre değişimleri bakımından incelenmiştir. Kalkerli kayaçlar (mermer/kireçtaşı/kalkışist) ve granitik kayaçlar sırasıyla Akköy ve Edremit sahalarına ait örneklerde egemen kırıntıları oluşturmaktadır. Ana mineral fazları Akköy’de kuvars, kalsit ve kil mineralleri iken, Edremit’teki hakim fazlar kuvarsın yanı sıra feldispat, mika, karbonat ve amfibol mineralleridir. Hidrojeokimyasal çalışmalar sıcak suların Akköy’de Na+K-HCO₃-SO₄ tipinde, Edremit’te Na+K-SO₄ tipinde olduğunu ortaya koymuştur.

Elde edilen sonuçlar bu iki sahanın olası CO₂ depolama sahaları olarak, CO₂-akışkan-kayaç etkileşimleri kapsamında, PHREEQC yazılımı ile yapılan

jeokimyasal simülasyonlar aracılığıyla değerlendirilmelerini sağlamıştır. Akköy örnekleri üzerinde gerçekleştirilen modelleme çalışmaları, CO₂'nin tutulumunu sağlayan ana karbonat fazının ankerit olduğunu göstermiştir. Edremit'teki mineral kapanlanması ise başlıca dolomit çökmesi yoluyla gerçekleşmiştir. Kil minerallerinin oranlarının artmasıyla reaksiyon sürelerinin uzadığı gözlemlenmiş ve özellikle smektitin varlığı reaksiyonların ilerleme mesafesini arttırmıştır. Mineralojik farklılıklardan dolayı, Edremit örneklerindeki reaksiyonların Akköy'e göre daha kısa süre ve mesafede gerçekleştiği belirlenmiştir. Bir sisteme eklenen CO₂'nin jeokimyasal akıbetinin (örn. kapanlanma mekanizmaları), rezervuardaki minerallerin bileşimlerine ve birlikte bulundukları mineral grubuna yakından bağlı olduğu görülmüştür.

Anahtar Kelimeler: CO₂ Depolama, Akışkan-Kayaç Etkileşimleri, Jeokimyasal Modelleme, Litojeokimya, Hidrojeokimya



Everything not saved will be lost.

– *Nintendo “Quit Screen” message*

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CHAPTER 1

INTRODUCTION

CO₂ Capture and Storage (CCS) is proved to be one of the most effective measures for the mitigation of the destructive effects of anthropogenic CO₂ emissions on climate change. The implementation of CCS in geothermal fields as deep saline aquifers can contribute both to reduce the CO₂ emissions and to increase the energy production within the context of Enhanced Geothermal Systems (EGS). The understanding and application of this technology are particularly critical for Türkiye which has a substantial geothermal energy potential. Turkish geothermal systems which have considerably higher CO₂ emissions than the global average, include CO₂ as the dominant component of gas phases in many of the reservoirs, creating the necessity to tend towards CCS as a feasible solution.

Given the limitations of experimental studies regarding the time span and reservoir conditions, the geochemical modelling studies are highly important in the CCS projects. Equilibrium, kinetic and reactive transport modelling are the methods which are used to determine the potential CO₂-fluid-rock interactions, to interpret the temporal and spatial behaviour of CO₂ in the system and to predict the fate of CO₂. The necessary input parameters for these simulations are i) modal mineralogy of the reservoir rocks and ii) hydrogeochemistry of the reservoir fluid. The quality of the input data can determine the accuracy of a geochemical model. To be able to construct a dataset, two geothermal fields selected from Western Anatolia (Akköy – Denizli and Edremit – Balıkesir) are thoroughly assessed in terms of their lithologic and hydrogeochemical properties as potential sites for EGS.

Lithogeochemical analyses are focused on the drill cuttings obtained from PS-1, PS-2 (Akköy field) and EDJ-12 (Edremit field) wells. The samples that belong to the various depths of the wells are studied macroscopically and microscopically for their

mineralogic-petrographic properties, followed by the techniques of X-Ray Diffraction (XRD), Confocal Raman Spectroscopy (CRS) and Electron Probe Micro Analysis (EPMA) for detailed mineral characterizations. X-Ray Fluorescence (XRF) analyses are conducted for the examination of the elemental changes with depth. These analyses have led to the identification and quantification of mineral phases in the samples which distinctly affect the modelling results.

Hydrogeochemical characterization for Akköy geothermal field is performed through the analysis of two water samples collected from PS-1 well. The results provide an understanding regarding hydrogeochemical facies, hydrothermal effect of the water-rock interactions, possible reservoir temperature, source of fluids and scaling potential of the system. For Edremit geothermal field, on the other hand, since hydrogeochemical characterization of the field has been previously studied by Avşar et al. (2013), the results in their work are directly used in this thesis study.

In addition to the establishment of a complete dataset for relevant fields, lithogeochemical and hydrogeochemical studies complement each other by contributing to the knowledge on the systems with distinct information. The results are compiled to be used in geochemical modelling performed with PHREEQC software. Dominant reactions in each sample that occur with CO₂ addition to the system, are determined with equilibrium modelling results. These reactions are then investigated according to the temporal and spatial variations they may display and whether CO₂ is potentially stored in the reservoir by any of the trapping mechanisms. The results allow the interpretation of Akköy and Edremit geothermal fields in terms of CO₂-fluid-rock interactions.

1.1 Purpose and Scope

This thesis study is focused on the assessment of the fluid-rock interactions in two selected geothermal fields in the possible scenario of CO₂ injection to the systems. The main aim of this study is to geochemically characterize and model Akköy and

Edremit fields from Türkiye as potential sites for EGS. In this regard, rock and water samples are collected from the relevant fields. This approach is followed by the geochemical-mineralogical investigations on rock samples and hydrogeochemical and isotopic analyses of the water samples. Compiling the results of the analyses as input data, the potential geochemical reactions in the systems are identified and simulated in the context of CO₂-fluid-rock interactions with geochemical modelling studies which include batch model (equilibrium and kinetic modelling), integrated with reactive transport model.

1.2 Geographic Setting

Western Anatolia is the host for the numerous important geothermal fields of Türkiye which are distributed on the approximately E-W trending fault bounded basins (grabens). Two of these fields, Akköy and Edremit, are studied in this thesis.

Akköy geothermal field is situated in the relatively southern part of Western Anatolia and its location is in between Sarayköy and Akköy towns in Denizli province. Rock and water samples of two geothermal wells, PS-1 (676137 E, 4205869 N) and PS-2 (669046 E, 4196502 N), that have been drilled in the field are utilized for the lithochemical and hydrogeochemical characterization (Fig.1.1). Akköy field neighbours many well-known low to high temperature geothermal fields (e.g. Kızıldere, Tekkehamam, Yenice, Gölemezli, Karahayıt, Pamukkale) surrounding the Denizli Basin which are utilized for numerous purposes, including electricity generation and district heating for many years (Karakuş and Şimşek, 2013; Özgür and Çalışkan, 2014; Alçiçek et al., 2018; Alçiçek et al., 2019).

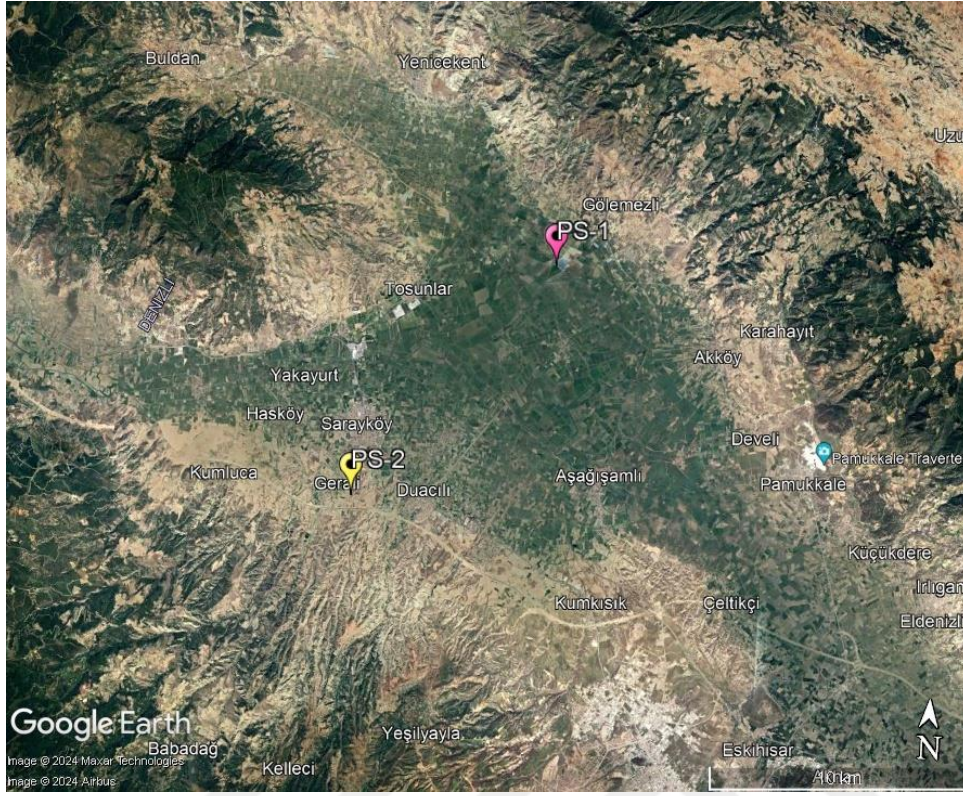


Figure 1.1. Google Earth view of PS-1 & PS-2 well locations

Edremit geothermal field is situated in northwest part of Western Anatolia, to the southwest of Edremit in Balıkesir province. In addition to the studied EDJ-12 well (503535 E, 4378962 N, Fig.1.2), a total of 27 wells have been drilled in the field. The field has been utilized productively over the last decades for district heating and irrigation purposes (Avşar et al., 2015; Edremit Jeotermal, 2018).

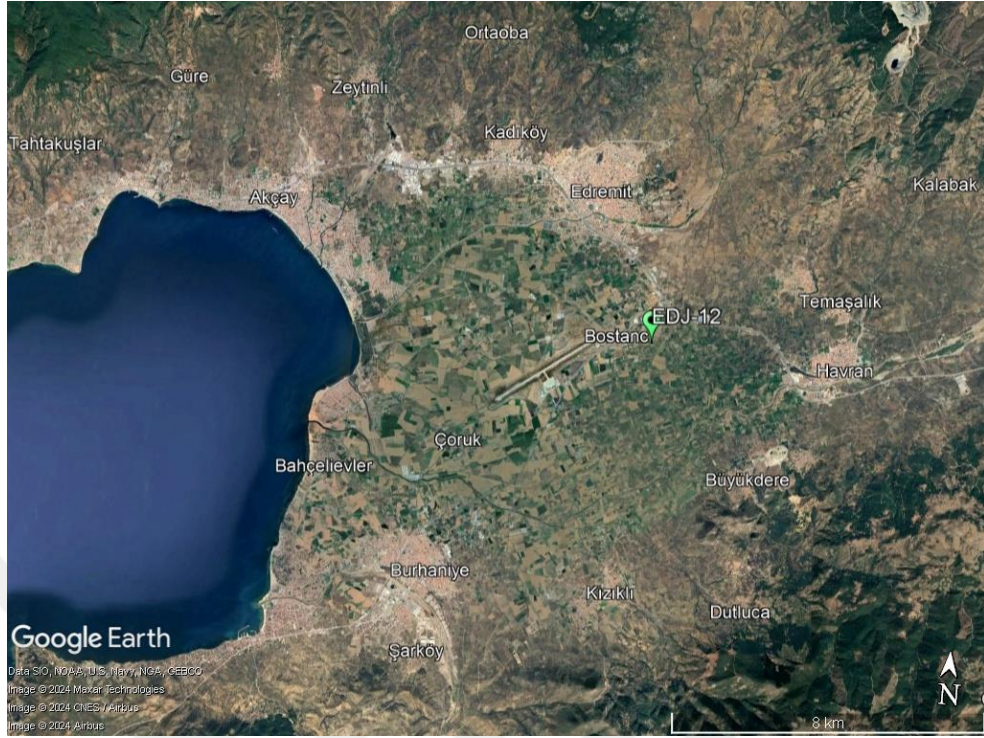


Figure 1.2. Google Earth view of EDJ-12 well location

1.3 Materials and Methods

The study was conducted in three main steps as i) sampling, ii) rock and water analyses, iii) data interpretation and modelling.

Drill cuttings were collected from Akköy and Edremit geothermal fields with a total of 109 and 70 samples, respectively. Two water samples were obtained from PS-1 well of Akköy field.

All the samples were geochemically analysed and examined for extensive lithogeochemical and hydrogeochemical characterizations. The analyses performed on the rock samples were macroscopic and microscopic examinations, X-Ray Diffraction (XRD), Confocal Raman Spectroscopy (CRS), Electron Probe Micro Analysis (EPMA) and X-Ray Fluorescence (XRF) techniques. The geochemical

content of the water samples were determined with wet chemical methods (ion chromatography, colorimetric analysis, titration) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Thermo Finnigan DeltaPlus XP Isotope Ratio Mass Spectrometer (IR-MS) was used for the determination of the isotopic composition. The results from the analyses were utilized as input data for the geochemical modelling studies in order to investigate CO₂-fluid-rock interactions in the case for a possible CO₂ addition to the system. The software program used in realization of the simulations was the PHREEQC code. Equilibrium, kinetic and reactive transport modelling studies were performed on the samples of both geothermal fields.

1.4 Layout of the Thesis

This thesis is divided into 9 chapters. Following this introduction chapter which is Chapter 1;

Chapter 2 is a literature review regarding the fundamental aspects of CO₂ storage process in a geochemical perspective.

Chapter 3 presents the geologic and hydrogeologic outline of the studied Akköy and Edremit geothermal fields.

Chapter 4 elaborates the methods used in this study.

Chapter 5 provides the results from the analyses performed for the lithogeochemical characterization of the fields.

Chapter 6 gives the results for hydrogeochemical analyses for Akköy field and the compiled hydrogeochemical information regarding Edremit field.

Chapter 7 is concerned with the investigation of samples and their dominant reactions in both fields in terms of CO₂-fluid-rock interactions through geochemical simulations.

Chapter 8 discusses dissolution-precipitation mechanisms and temporal as well as spatial evolutions of the reactions determined from the modelling studies and their significance in relation with CO₂ storage.

Chapter 9 summarizes the major conclusions derived from all the performed studies with the comparison of two fields.



CHAPTER 2

CO₂-FLUID-ROCK INTERACTIONS IN GEOTHERMAL FIELDS IN THE FRAMEWORK OF CO₂ STORAGE: A REVIEW

Over the past 250 years, burning of fossil fuels (coal, oil, gas) for power production, heating, industry and transportation has dramatically increased the amount of CO₂ emitted into the atmosphere. The atmospheric CO₂ concentration which has been reported as 280 ppm in the 19th century, increased up to 424 ppm as of March 2024 (Fig.2.1, Siegenthaler, 1984; Scripps Institution of Oceanography, 2024). This has resulted in the rise of the average global surface temperature by more than 1°C over this period (IPCC, 2018).

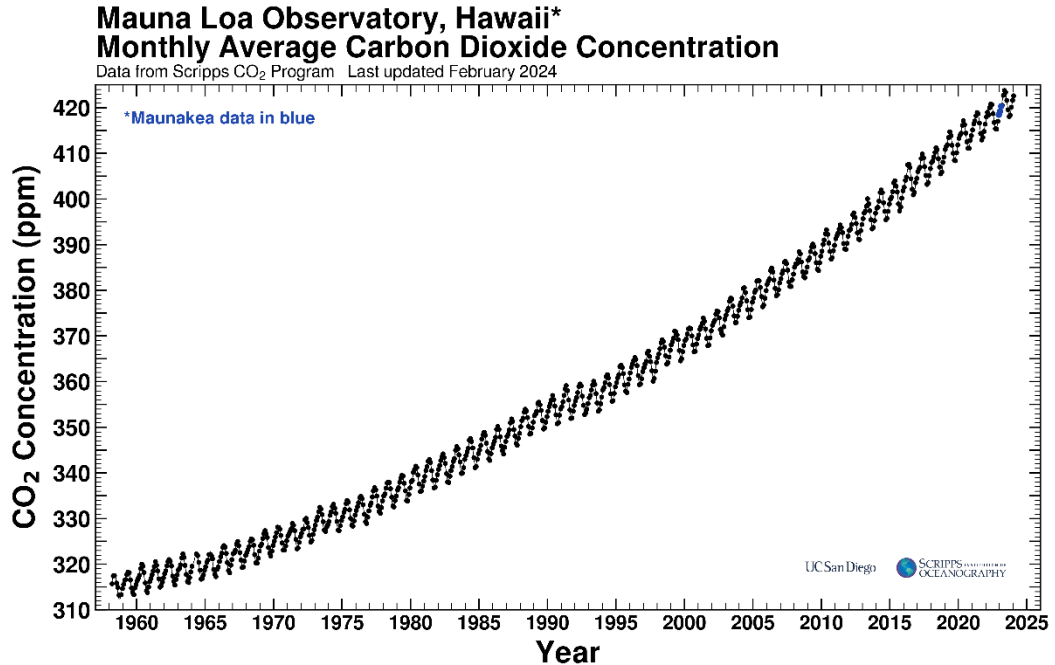


Figure 2.1. Monthly average atmospheric CO₂ concentration in time recorded at Mauna Loa Observatory (Scripps Institution of Oceanography, 2024)

2.1 Carbon Capture and Storage (CCS)

To reduce CO₂ emissions and to mitigate the effects of global warming and climate change, Carbon Capture and Storage (CCS) is considered to be one of the major strategies which is a process carried out in several stages: the separation of CO₂ from industrial and energy-related sources, the transportation to a storage location and the injection of CO₂ into deep geologic formations (such as deep saline aquifers, and depleted or active oil reservoirs) for long-term confinement from the atmosphere (Fig.2.2).

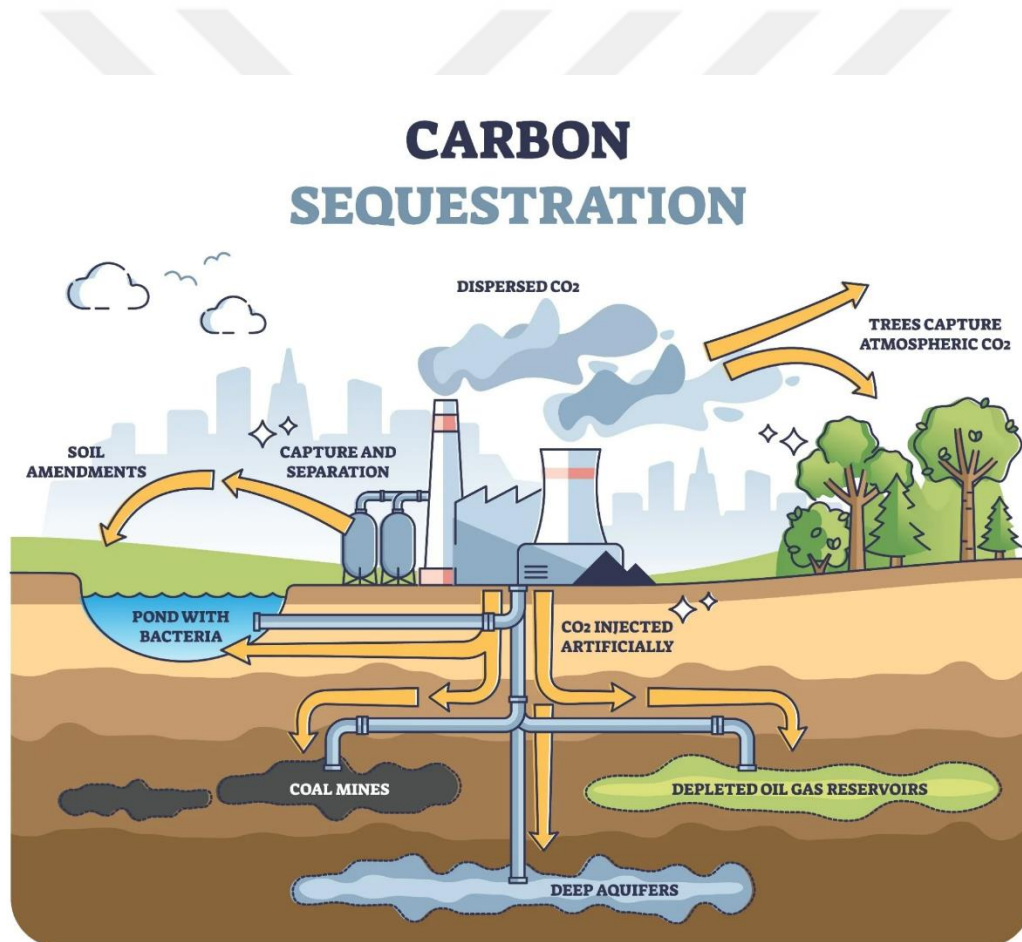


Figure 2.2. Schematic diagram of CO₂ storage processes (Wright, 2022)

Studies regarding CO₂ injection into subsurface formations started in the early 1970s in Texas, USA as a part of Enhanced Oil Recovery (EOR) project and many research projects have been performed since the 1990s in Europe, the United States, Canada, Australia and Japan. Some of the large-scale projects include, Norway – Sleipner (since 1996), Canada – Weyburn (since 2000), Algeria – In Salah (2004 – 2011), Norway – Snøhvit (2007 – 2011), Australia – Otway (since 2008), Germany – Ketzin (2008 – 2009), USA – Cranfield (2009 – 2015) and Canada – Alberta Carbon Trunk Line (since 2018) (IPCC, 2005; Shukla et al., 2010; MIT, 2016; Kalam et al., 2021; CO₂GeoNet, 2024). According to the 2016 report of the Global CCS Institute, 38 large-scale worldwide CCS projects have been recorded for that year while in their latest study, a total number of 119 CCS facilities across Europe which involve capture, storage, transport applications have revealed to be in different phases of development (Global CCS Institute, 2016; 2023). Sleipner which is the first commercial-scale storage project started in 1996, demonstrated that a rate of 1 Mt/yr storage of CO₂ in saline aquifers is viable and safe (Kelemen et al., 2019). In fact, in the study of Zhang et al. (2022), it is reported that in the years between 1996 and 2020 the estimated cumulative CO₂ storage in industrial-scale projects (including EOR and deep saline aquifer injection) is 197 Mt.

Deep saline aquifers constitute one of the potential formations for geologic storage of CO₂. Having much larger storage capacity and being widespread than the alternatives, deep saline aquifers are considered to be an effective solution (Fig.2.3). In this regard, geothermal systems started to gain attention as prospective sites for CO₂ storage in recent years. CO₂ which constitutes the dominant gas phase in most of the geothermal systems, is injected into the reservoir not only to reduce the CO₂ emissions to the atmosphere but also to use CO₂ as working fluid to increase energy recovery (Enhanced Geothermal Systems, EGS). The potential synergy between CO₂ storage and geothermal energy utilization has been investigated in many studies (e.g. Randolph and Saar, 2011; Saar et al., 2015; Tutolo et al., 2015; Elidemir ve Güleç, 2018; Avanthi Isaka et al., 2019; Esteves et al., 2019).

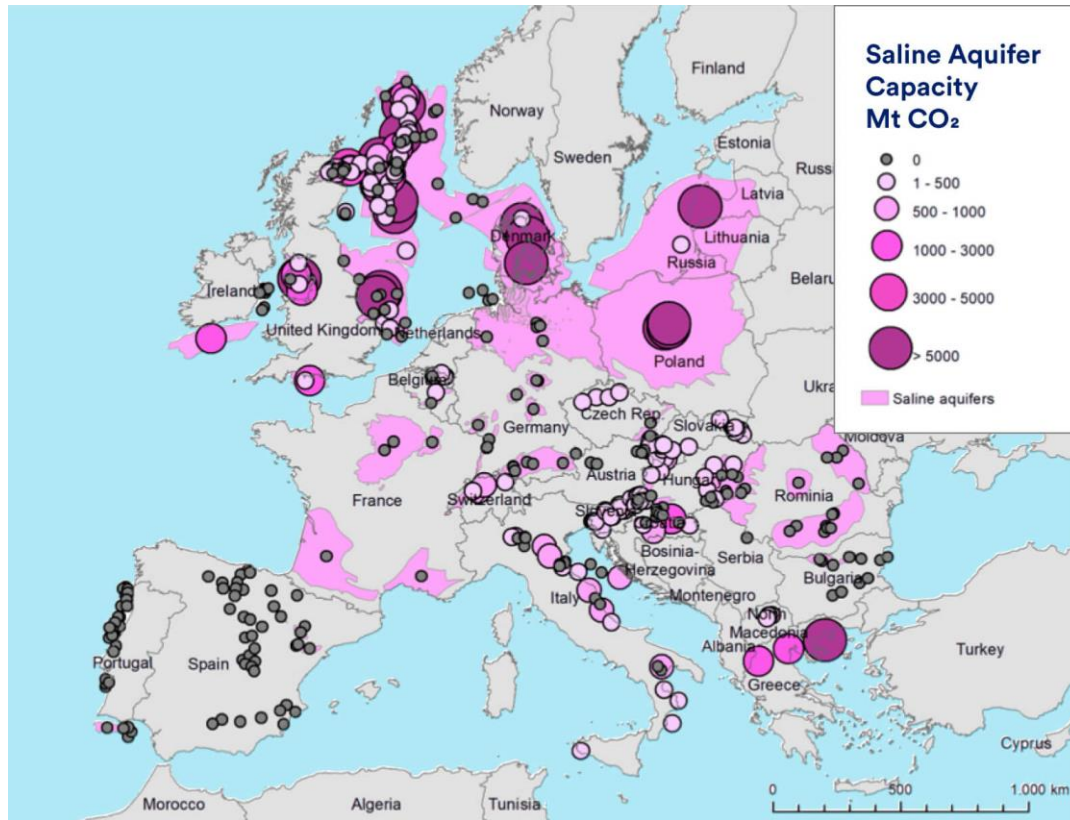


Figure 2.3. Locations of saline aquifers and associated storage capacities in Europe (Anthonsen and Christensen, 2021 in Grove, 2021)

2.2 The Fate of CO₂ in the Reservoir

The geochemical assessment of CO₂-fluid-rock interactions is an essential part of CCS, as both the movement and entrapment of CO₂ depend on the geochemical characteristics of the reservoir.

When CO₂ is injected into the reservoir, it initially fills the fractures and pore spaces of the permeable formation then, it slowly rises towards an impermeable layer (caprock). In time, CO₂ may dissolve into the reservoir fluid and/or may react with the host rocks leading to geochemical changes in the mineralogic as well as the

hydrologic properties of the reservoir. These changes take place heterogeneously and they may have either positive or negative impact on the storage operation due to the complex relationship of multitude factors such as aquifer characteristics (porosity, permeability, mineral reactive surface areas, areal extent and thickness of the reservoir), injection rate and duration, number of the injection wells, injection strategy (Lamy-Chappuis et al., 2014; Bachu, 2015; Bensinger and Beckingham, 2020; Al-Khdheawi et al., 2021; Wang et al., 2021; Gao et al., 2024).

The “storage” of CO₂ can be accomplished through various trapping mechanisms that would hold the injected CO₂ and prevent it from migrating upwards to the surface. These mechanisms depend on the local geology as well as the reservoir characteristics and may act together if more than one mechanism is present. The trapping mechanisms (Fig.2.4) include i) stratigraphic/structural trapping: traps in which CO₂ is trapped by impermeable rock, formed due to lithology change or shift of rocks by a fault, ii) residual trapping: CO₂ being stuck in pore spaces due to capillary forces, iii) solubility trapping: dissolution of CO₂ in groundwater, and iv) mineral trapping: precipitation of secondary carbonate minerals. Mineral trapping is considered to be the most secure mechanism for CO₂ storage (IPCC, 2005; IEAGHG, 2008; Pham et al., 2012; Lee et al., 2016; Zhang and Huisingh, 2017; Liu et al., 2019; Delerce et al., 2021; Mishra et al, 2021).

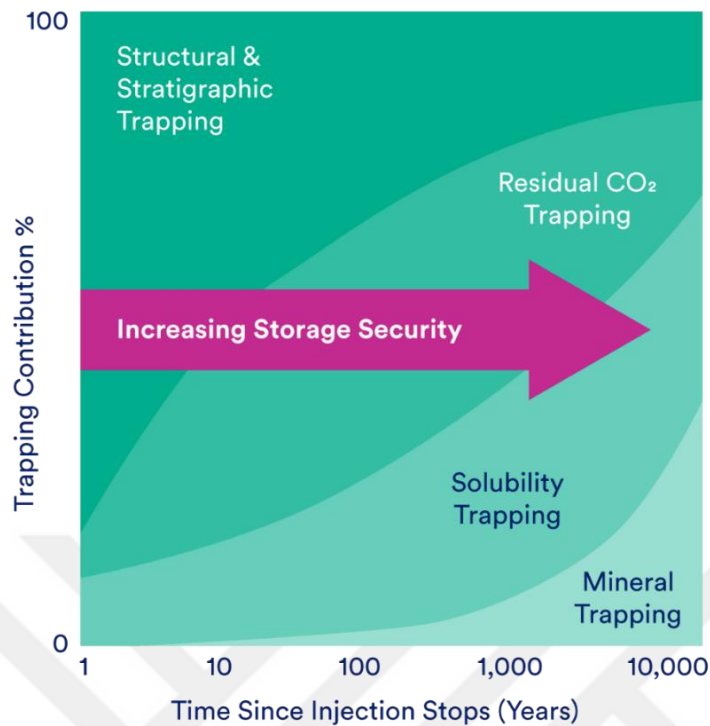
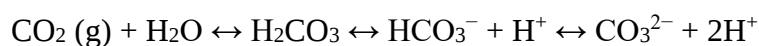


Figure 2.4. Development of trapping mechanisms over time in relation to storage safety (IPCC, 2005)

When CO₂ dissolves into the reservoir fluid, weak carbonic acid (H₂CO₃) is initially formed, followed by its dissociation to form bicarbonate (HCO₃⁻) and carbonate (CO₃²⁻) ions (solubility trapping) resulting in the instantaneous drop in pH. The increase in the acidity provokes the dissolution of the minerals in the reservoir (e.g. silicate minerals) which buffers low pH. The cations (e.g. Ca²⁺, Mg²⁺) released during the dissolution react with the dissolved bicarbonate species leading to the precipitation of stable secondary carbonate minerals such as calcite and magnesite (mineral trapping). These series of geochemical interactions of CO₂ with the reservoir fluid and rock can be expressed by the following reactions:



Alumino-silicate minerals play a crucial role in permanent trapping of CO₂ by supplying the cations required to form the secondary carbonates (Assayag et al., 2009; Matter and Kelemen, 2009; Gaus, 2010; Rackley, 2010; Pham et al., 2011; Hellevang et al., 2013; Kaszuba et al., 2013; Zhang and DePaolo, 2017; Snaebjörnsdóttir et al., 2020; Mishra et al., 2021 and the references therein). As an example, chlorite alteration may provide iron and/or magnesium cations for CO₂ to be locked up in the form of dolomite and/or siderite (Gaus, 2010). The post-injection monitoring studies of some of the CO₂ storage projects reveal that the minerals which trap the injected CO₂ in these applications are calcite (CarbFix – Iceland, Nagaoka – Japan), ankerite (Wallula Basalt – USA) and siderite (Otway – Australia) (Romanov et al., 2015 and the references therein; McGrail et al., 2017; Pogge von Strandmann et al., 2019; White et al., 2020; Ratouis, 2022; CO₂ Storage Research Group, 2024).

Although the general conception is that development of mineral trapping is relatively slow (potentially taking a thousand years or longer) since the process is usually limited by the low reactivity of silicate minerals and the lack of Ca-, Mg-, and Fe-bearing minerals to release the necessary cations for carbonation, rapid mineralization has been reported in recent studies (CarbFix2 project: mineralization within two to nine months (Gunnarsson et al., 2018; Clark et al., 2020; Snaebjörnsdóttir et al., 2020) and in experimental studies: time scales of weeks to months (Kampman et al., 2014) and within five months (Voigt et al., 2021)). It is even disclosed in the 2020 study of Snaebjörnsdóttir et al. regarding CarbFix project that, no decrease in system permeability or in carbonation rates was observed since the start of injection in 2014. Thus, combined with its permanence of storage, mineral trapping is the most desirable outcome for long-term CO₂ storage.

Monitoring the CCS system is essential to reduce the uncertainties, to maintain a safe storage and to give early warnings about the potential risks. An indispensable part of a monitoring program is *geochemical monitoring* providing detailed information about the reservoir character, and the predictions regarding CO₂ migration and potential leakage pathways. Moreover, geochemical monitoring reveals the geochemical interactions between the fluids and reservoir rocks that may lead to

either increased risks or entrapment of CO₂ (IPCC, 2005; Rütters et al., 2013; CO₂GeoNet, 2024). One of the phases of geochemical monitoring is the modelling studies performed using a software program (e.g. TOUGHREACT, PHREEQC or The Geochemist's Workbench), in which i) existing and potential geochemical reactions, ii) hydrogeochemical behaviour of the system, iii) temporal changes associated with CO₂ injection, iv) potential trapping mechanisms and v) long-term predictions about the fate of injected CO₂ can be investigated in detail.



CHAPTER 3

GEOLOGICAL BACKGROUND OF THE STUDIED GEOTHERMAL FIELDS

3.1 Tectonic Setting & Regional Geology

Situated in the tectonically active Alpine–Himalayan belt, Türkiye is continuously affected by the relative movements of the European and the Afro–Arabian plates. The northward subduction of the African plate in the west combined with the northward collision of the Arabian plate with Eurasia in the east, induce westward motion of the Anatolian plate bounded by the North Anatolian Fault Zone (NAFZ) and East Anatolian Fault Zone (EAFZ). Western Anatolia, a neotectonic province governed by active extension is characterized by dominantly E-W trending graben-horst structures formed as a result of active extension (Şengör et al., 1985; Taymaz et al., 2004; Bozkurt and Rojay, 2005). The widespread thermal manifestations (such as hot springs, fumaroles and hydrothermal alterations) are closely interrelated with the tectonics in this region and they are concentrated along within the major grabens (e.g. Büyük Menderes, Gediz grabens) or along their boundary faults (Şengör et al., 1985; Vengosh et al., 2002; Taymaz et al., 2004; Güleç and Hilton, 2006; de Leeuw et al., 2010; Baba and Sözbilir, 2012; Güleç and Hilton, 2016; Alçiçek et al., 2019; Karakuş et al., 2019). The studied Edremit (Balıkesir) and Akköy (Denizli) geothermal fields, are located in the northern and southern parts of western Anatolia, respectively (Fig.3.1).

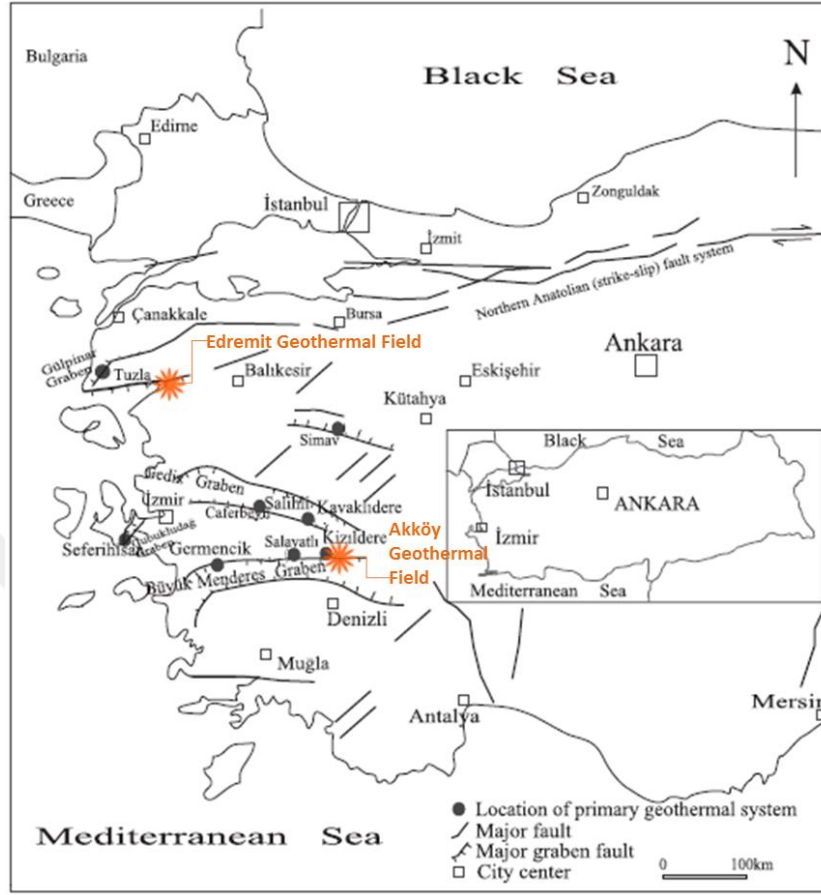


Figure 3.1. The location of Akköy and Edremit geothermal fields (shown with orange stars) along with some major geothermal fields (simplified geologic map is from Tarcan, 2005 and the references therein)

The studied Akköy geothermal field is situated in the Denizli Basin where two of the major grabens, namely E-trending Büyük Menderes and the NW-trending Gediz Graben intersect (Fig.3.1). Denizli Basin is 50 km wide and 70 km long bordered by NW- and SE-striking faults (Alçiçek et al., 2018; Alçiçek et al., 2019; Brogi et al., 2021 and the references therein).

Edremit geothermal field is located within the Edremit Graben. Tectonic position of the area corresponds to the western termination of the southern branch of the North Anatolian Fault Zone (NAFZ), controlled by dominantly NE–SW oriented right lateral strike slip and/or oblique faults (Herece, 1990; Avşar et al., 2013).

Akköy and Edremit geothermal fields are hosted by two major paleotectonic units of Türkiye, Menderes-Taurus Block and Sakarya Continent respectively which are separated by İzmir-Ankara suture (Fig.3.2). These units, along with other microcontinents bounded by suture zones and Tethyan oceans in between, are the products of the complex motions of Eurasia and the Afro-Arabian continents (Şengör and Yılmaz, 1981; Şengör, 1984).

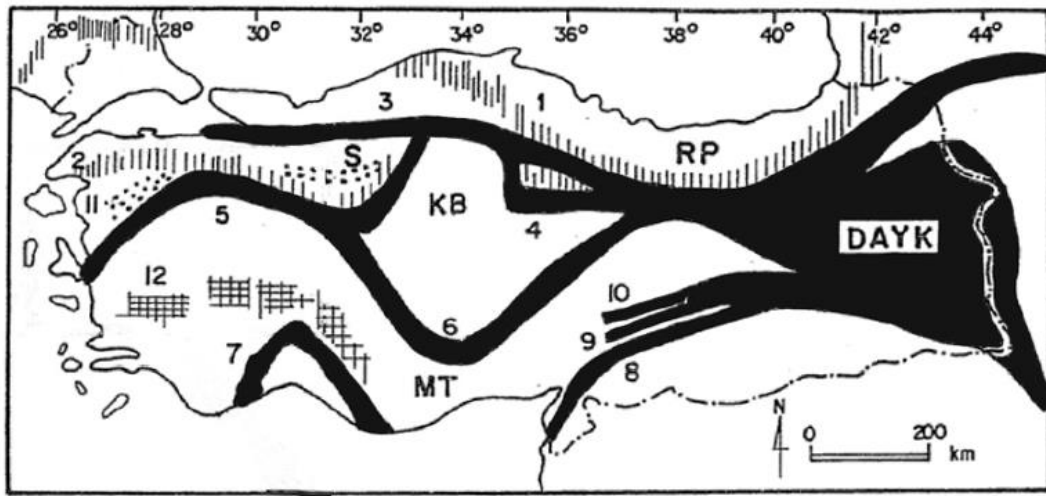


Figure 3.2. Paleotectonic provinces and the suture zones of Turkey. RP: Rodope-Pontide Fragment, KB: Kırşehir Block, S: Sakarya Continent, MT: Menderes-Taurus Block, DAYK: East Anatolian Accretionary Complex, 1: Main Palaeo-Tethys Suture, 2: Karakaya Suture, 3: Intra Pontide Suture, 4: Erzincan Suture, 5: İzmir-Ankara Suture, 6: Inner Tauride Suture, 7: Antalya Suture, 8: Asurid Suture, 9: Çüngüş Suture, 10: Maden Suture, 11: Hercinian Suture, 12: Pan-African Suture (Şengör, 1984)

Menderes-Taurus Block is composed of from basement to top, Menderes massif metamorphics which constitutes a gneiss core covered by schist and marble (Dürr, 1975; Şengör et al., 1984), Upper Cretaceous ophiolitic mélangé (conglomerate, sandstone–shale, limestone, serpentinite, mafic volcanics, chert (Şengör & Yılmaz, 1981) and Neogene terrestrial sediments. Menderes massif comprises one of the oldest basements of Türkiye.

The highly deformed basement of Sakarya Continent consists of Palaeozoic to Triassic aged metamorphic rocks of Kazdağ Massif (amphibolites, gnesisses, phyllites, marbles, metaperidotites) and Karakaya Complex (schists, phyllites, marbles, metabasites). Tertiary clastic and carbonate rocks overlie the metamorphic basement (Bingöl, 1969; Bingöl et al., 1973; Bozkurt and Mittwede, 2001).

Magmatic activities characterized by widespread volcanic products and granitic intrusions of Neogene-Quaternary age seem to have considerable effects on both the Sakarya Continent and the Menderes-Taurus Block.

3.2 Geology of the Fields

3.2.1 Akköy Field

Paleozoic metamorphic rocks of the Menderes Massif constitute the basement of the Akköy geothermal field (Fig.3.3). These rocks are composed, at the lower levels, of gneisses alternating with quartzites and schists (micaschist unit). The uppermost part of the metamorphics, known as İğdecik Formation, consists of marble, calcschist, quartzite and schist alternations (Şimşek, 1985). Menderes Massif is tectonically overlain by Mesozoic dolomitic limestones, marbles, sandstones and ophiolitic melange of the Lycian nappes (Okay, 1989; Alçiçek et al., 2007, and the references therein). Lacustrine sediments overlie the basement units with an angular unconformity. The succession starts with alternating conglomerates, sandstones, shales, and lignite layers of Kızılburun Formation. These rocks are overlain, from bottom to top, by intercalated limestones, marls, siltstones and lake deposits (mudstone, gypsum, halite) of Sazak Formation, marls, siltstones and sandstones of Kolonkaya Formation and alternating units of poorly-consolidated conglomerates, sandstones and mudstones of Tosunlar Formation. The youngest unit of the area is the Quaternary alluvium (Şimşek et al., 2005).

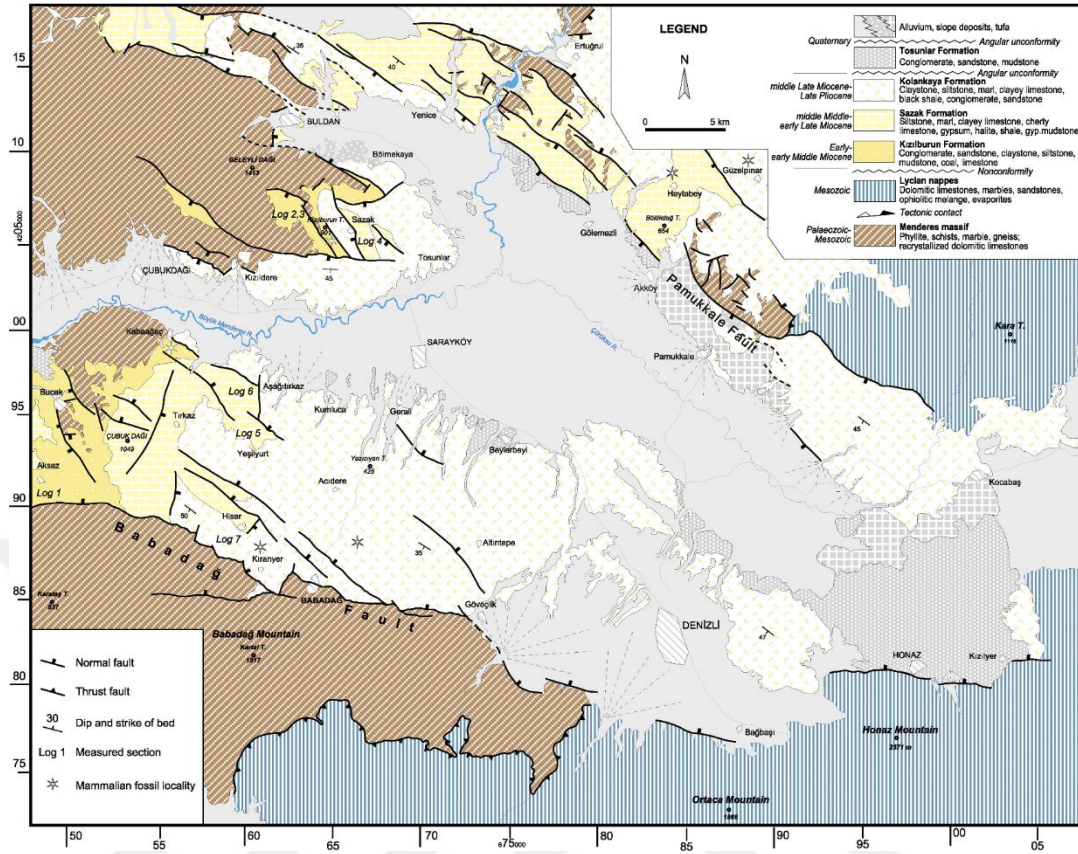


Figure 3.3. Geological map of Denizli Basin (Alçiçek et al., 2007 and the references therein)

3.2.2 Edremit Field

The basement of the region is represented by the Paleozoic aged metamorphic rocks of the Kazdağ Massif comprised of schists, gneisses, amphibolites, metadunites, migmatites and marbles (Fig.3.4). The basement is overlain by spilitic basalts, radiolarites and clastics of Karakaya Formation. Sandy limestones of Bilecik Formation overlies Karakaya Formation. These units are intruded by the Eybek Granodiorite which is reported to be genetically related to the overlying Upper Oligocene to Lower Miocene Hallaçlar volcanics. The youngest units in the field are the Ballica Formation and the Plio-Quaternary sediments, the former unconformably overlying the Hallaçlar Formation (Avşar et al., 2013, and the references therein).

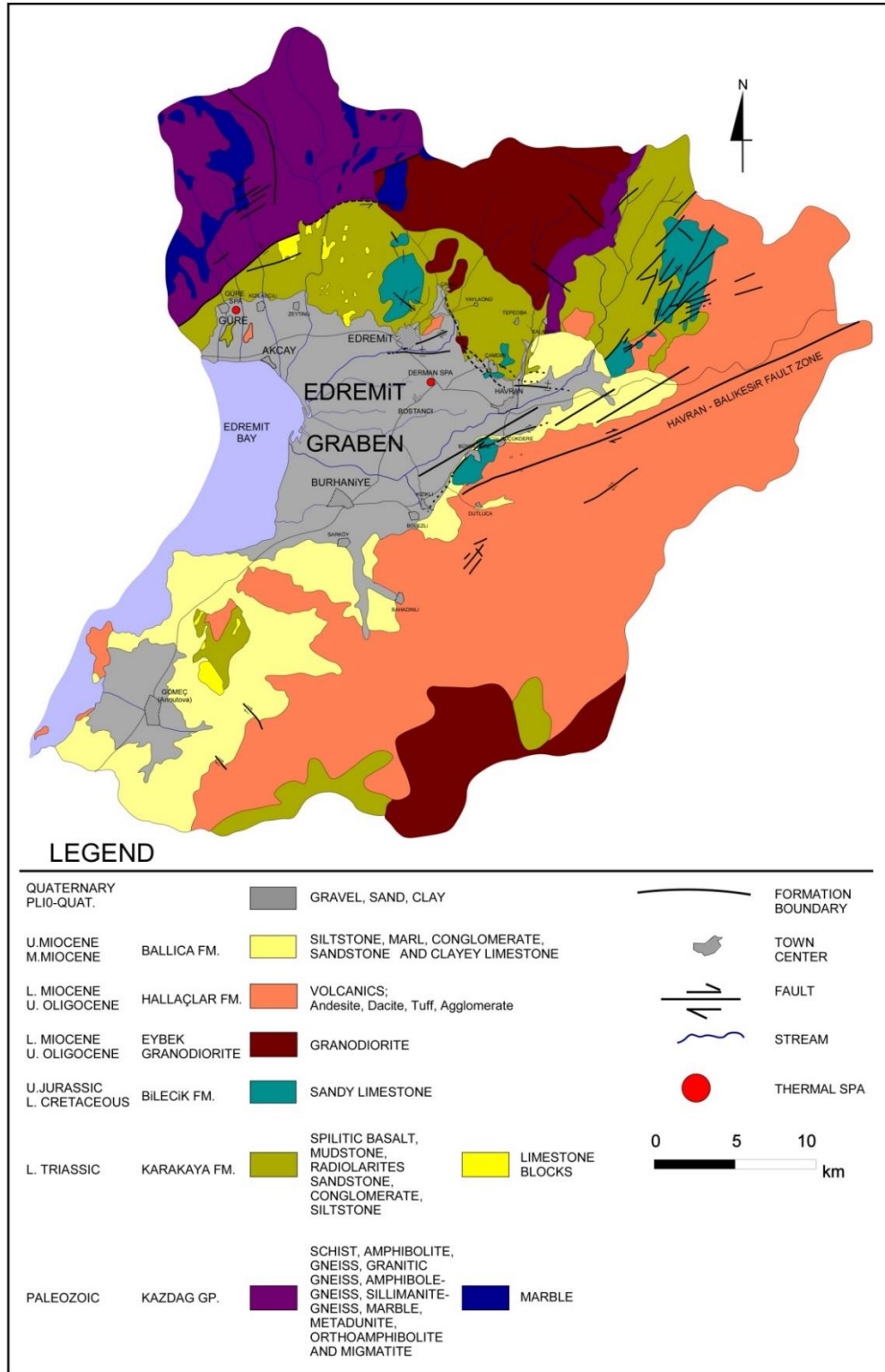


Figure 3.4. Geological map of the Edremit region (Avşar, 2011; Avşar et al., 2013 and the references therein)

3.3 Hydrogeologic Outline of the Fields

3.3.1 Akköy Field

Sazak Formation, İğdecik Formation and the lower levels of the Menderes Metamorphics are the three units identified as the reservoir rocks in the area, while relatively impermeable Kızılburun, Tosunlar, and Kolonkaya Formations act as the cap rocks (Şimşek, 1984; Şimşek et al., 2005; Tarcan et al., 2016). The reservoir and cap rocks of the Akköy field (schist-calcschist-marble-quartzite intercalations and the Neogene sedimentary units, respectively) are shown in well logs provided by Pekdemir Seracılık (Fig.3.5).

Two wells, PS-1 and PS-2, have been drilled in the field, among which PS-1 well is the production well and utilized in greenhouse heating.

Recharging of the system is sustained by the circulation of meteoric waters through the fault zones bounding the grabens, after being heated at depth. The rising hot water flows into the centre of the graben and subsequently, mixes with cold groundwater (Şimşek, 1985).

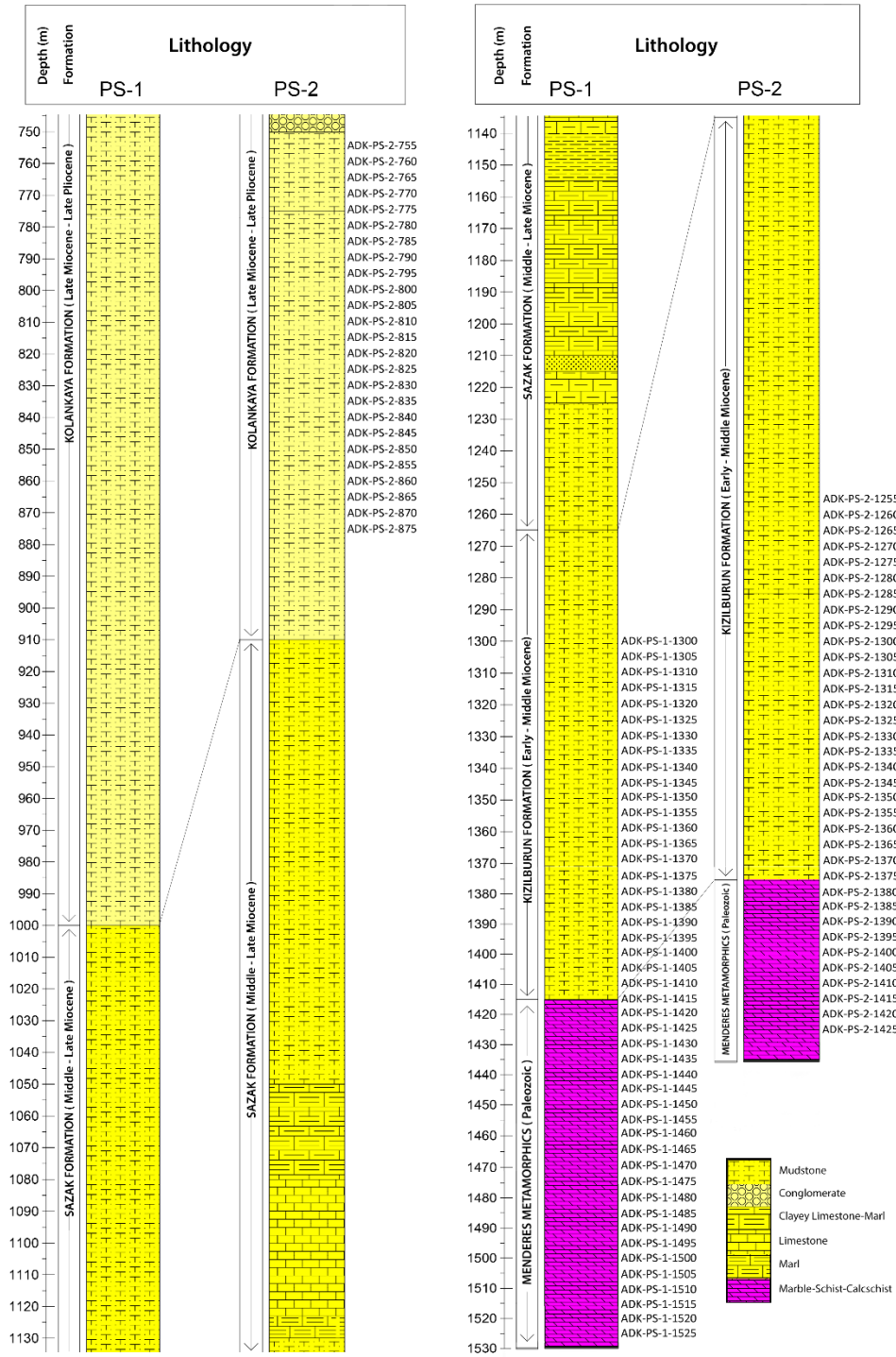


Figure 3.5. Well logs of PS-1 and PS-2 wells (Akköy field) with the sample numbers shown with respect to depth (the lithology after the depth of 1415 meter in PS-1 well was not shown in original document; this part was edited following the observations and analyses conducted in the thesis study)

3.3.2 Edremit Field

Based on the information obtained from the shallow and relatively deeper wells (with the depths of 30-496 m) drilled for irrigation purposes before 2013, the presence of two aquifers is identified around 0-90 m and 130-260 m levels in the Edremit field as reported by Avşar et al. (2013). For the second and relatively deeper aquifer, agglomerate and conglomerate units of Hallaçlar volcanics are determined to be the reservoir rocks while the cap rock is made up of siltstones, marls, conglomerates, sandstones and clayey limestones of Middle to Upper Miocene Ballica Formation. However, it is inferred from the conceptual model of Avşar et al. (2013) that the hot geothermal fluid seems to be ascending along the fault zones from much greater depths and the basement units of metamorphic and granitic rocks act as the deep reservoir levels of the field (Fig.3.6, well log taken from the 2019 report of Parlaktuna and Avşar). In fact, the later conducted drillings have shown that water leakage zones are present in deeper levels. A total of 27 wells have been drilled in the field, which are used for heating and irrigation purposes (Avşar et al., 2015; Edremit Jeotermal, 2018). The well, on which this study is focused, is EDJ-12 well with a 1038 m depth which was drilled in 2013 (Edremit Geothermal Inc., 2018), but it is not currently utilized in production. In the well log of EDJ-12, 657, 864, 930 and 1015 meters are marked as probable water leakage zones.

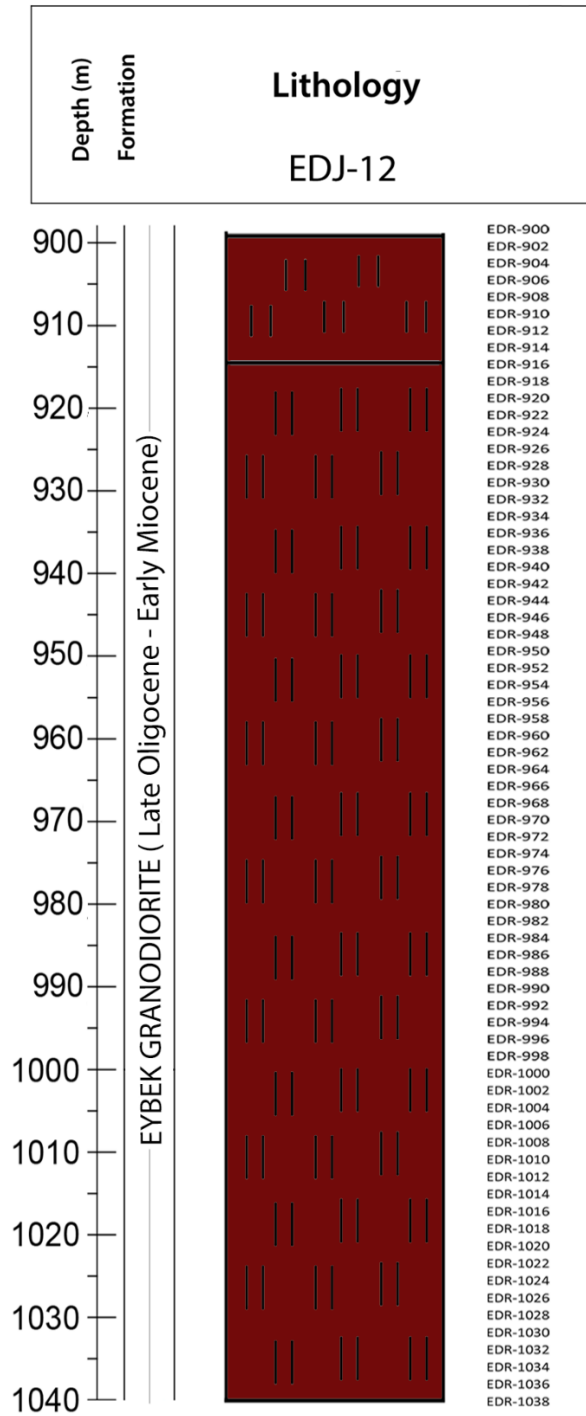


Figure 3.6. Well log of EDJ-12 well (Edremit field) with the sample numbers shown with respect to depth (modified from Parlaktuna and Avşar, 2019)

CHAPTER 4

METHODS OF STUDY

The construction of this thesis study is based on three main phases; i) sample acquisition, ii) analyses, iii) modelling. Rock and water samples are collected from Akköy (Denizli) and Edremit (Balıkesir) geothermal fields and the investigation of the samples is realized by means of mineralogic-petrographic and geochemical analyses. The results of the analyses are utilized as input data for the modelling studies in the context of CO₂-water-rock interactions.

4.1 Sampling

A field trip was conducted to Akköy geothermal field on 14 December 2018. Water sample from PS-1 well-head and drill cuttings that belong to various depths of both PS-1 and PS-2 wells were provided by Pekdemir Seracılık that owns the Akköy field (Fig.4.1). From a total of 109 rock samples, i) 46 samples collected in every five meters from 1300-1525 m depth belong to PS-1 well, ii) 60 samples collected in every five meters from 755-875 m and 1255-1425 m depth belong to PS-2 well, and iii) 3 samples collected from 1665, 2100 and 2195 m depth belong to PS-2 well. Another water sample taken from PS-1 well-head was obtained in January 2021.



Figure 4.1. PS-1 well and well discharge through pipe in Akköy geothermal field

For Edremit geothermal field, drill cuttings from different levels of EDJ-12 well were provided by Assoc. Prof. Dr. Özgür Avcı who conducted his PhD studies in the Edremit geothermal field. A total of 70 samples collected in every two meters between 900-1038 m depth were obtained for this study.

Sample numbers of the drill cuttings with respect to their depths are marked in the stratigraphic columnar sections of the PS-1, PS-2 and EDJ-12 wells (except the last three samples from PS-2 well, Fig.3.5 and 3.6).

4.2 Analyses

4.2.1 Rock Analyses

Cuttings that were obtained from drill wells from Akköy and Edremit geothermal fields were geochemically investigated in the laboratories of Ankara University – YEBİM (Earth Sciences Application and Research Centre). Additional microscopic examinations were performed in the Tectonic Laboratory of METU Geological

Engineering Department. The geochemical analyses, each of which providing a different scale of information, performed on the rock samples are:

- i. Examination of the samples under microscope to determine the mineralogical and petrographical characteristics,
- ii. Selection of representative samples from reservoir rocks, and from the selected samples, execution of the analyses of Confocal Raman Spectroscopy (CRS) and X-Ray Diffraction (XRD) for detailed mineral identifications (especially for the secondary minerals that cannot be identified through thin section studies),
- iii. EPMA (Electron Probe Microanalysis) for the determination of minerals of solid solution series,
- iv. XRF (X-Ray Fluorescence) technique for whole rock analysis.

4.2.1.1 Petrographic Techniques

All of the rock samples were initially examined macroscopically using Meiji Techno PKL-2+EMZ 5 TR reflected light microscope. Adequate amount of specimen placed on a small glass container with the addition of water was investigated in terms of colour, state of crystallinity and mineralogical composition. In order to distinguish carbonate minerals, 10% HCl solution was added to the studied sample.

Thin sections of drill cuttings were prepared for microscopic examinations. The rock and mineral compositions, the abundance of the fragments, grain sizes and textural features were determined by taking into account of the changes with depth. The instruments used in these studies were Zeiss Axio 100 (transmitted light) polarizing microscope in YEBİM and Leica Orthoplan-Pol (transmitted light) polarizing microscope in METU.

4.2.1.2 Mineralogical Techniques

For the minerals that could not be distinguished solely by microscopic observations, X-Ray Diffraction (XRD), Confocal Raman Spectroscopy (CRS), Electron Probe Micro Analysis (EPMA) techniques were performed.

XRD analysis was carried out on 17 and 10 selected samples from Akköy and Edremit fields, respectively, by Inel Equinox 1000 diffractometer with Co cathode in the X-ray tube. Samples were prepared for the analysis with fine grinding procedure. Approximately 4 gr sample was put into the grinding jar with 10 balls and grinded for 40 seconds in Retsch's Planetary Ball Mill PM 100 CM. Any remaining coarse grains were sorted out from the powdered sample before putting the sample into small plastic bag (Fig.4.2).



Figure 4.2. Fine grinding procedure for XRD and XRF analyses

Given the fact that drill cuttings are likely to be contaminated from overlying layers, the areas likely to represent reservoir rocks are marked on selected thin sections and CRS studies are performed on these areas with Thermo Scientific DXR Raman Microscopy equipped with 633 nm laser. For Akköy, 6 samples (2 samples from PS-1 and 4 samples from PS-2 well) were chosen, on which 62 points from 42 regions were analysed and for Edremit, on 6 selected samples, 110 different points from 41 regions were investigated. The Raman system included Olympus microscope, monochromator, filter and a charge coupled device (CCD) detector and the Raman measurements were excited at a resolution 2.4 cm^{-1} in the range between $100\text{-}1200\text{ cm}^{-1}$.

The fragments in the marked areas were also analysed using EPMA technique to determine the chemical compositions of minerals (especially the minerals from solid solution series). The studied thin sections were initially carbon coated with Quorum Q150T ES instrument and then, samples were analysed utilizing JEOL JXA 8230 Superprobe equipped with five Wavelength Dispersive Spectrometer (WDS) (Fig.4.3). The analyses were performed on a total of i) 183 spots from 11 samples (5 samples from PS-1 and 6 samples from PS-2 wells) of Akköy, ii) 284 spots from 6 samples of Edremit field. Compared to CRS analyses which was executed on randomly selected minerals, aside from similar results, different mineral compositions were also obtained in EPMA measurements for which fresh mineral grains were specifically selected.



Figure 4.3. a. Carbon coating procedure, b. EPMA system in YEBİM laboratories of Ankara University

4.2.1.3 Whole Rock Geochemistry

Polarized Energy Dispersive (PED) XRF technique with Spectro X-Lab Pro instrument was used to determine the changes in major and trace element concentrations of all the samples. For this analysis, pellets were prepared using previously powdered samples. In the pellet preparation procedure, 4 gr powdered sample was weighed and 0.9 gr wax binder was added and mixed. The mixed powder was placed in a steel sleeve (die) and pressed using an XRF Pellet Press (Fig.4.4).



Figure 4.4. Pellet preparation procedure for XRF analyses

4.2.2 Fluid Analyses

Two water samples collected from PS-1 well of Akköy field (first sample in December 2018 and second one in January 2021) were analysed. Anion and cation contents of the water samples were determined via wet chemical methods (ion chromatography, colorimetric analysis, titration) while Al, Fe element values of the sample collected in 2018 were detected by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). These analyses were performed in the Laboratories of General Directorate of State Hydraulic Works Technical Research and Quality Control Department (DSİ TAKK). The isotopic composition ($\delta^{18}\text{O}$, δD , $\delta^{13}\text{C}$) of the water sample collected in 2021 was determined with Thermo Finnigan DeltaPlus XP Isotope Ratio Mass Spectrometer (IR-MS) in Middle East Technical University (METU) Central Laboratory using Gas Bench-Continuous Flow technique.

For the Edremit field, the results of fluid analyses are taken directly from Avşar et al. (2013) where it is reported that the element concentrations (major anion-cation, trace elements) were analysed by wet chemical methods and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) instrument while stable isotope

concentrations were determined with Element Analyzer-Isotope Ratio Mass Spectrometer (EA-IRMS) in SRC Analytical and TUBITAK-MAM laboratories, respectively.

The calculations which are based on saturation index (SI) values, are performed at measured sampling temperature and pH by using the PHREEQC code (Parkhurst and Appelo, 2013).

4.3 Geochemical Modelling Setup

The assessment of Akköy and Edremit systems in the context of CO₂-water-rock interactions was realized through modelling studies performed with the software *PHREEQC* (version 3, Parkhurst and Appelo, 2013) which is extensively used in numerous geochemical modelling applications owing to its robust modelling of reactions. Equilibrium, kinetic and reactive transport modelling approaches were utilized in order to identify and interpret the potential reactions that govern the systems in the case of CO₂ addition and to predict the fate of CO₂. The necessary input parameters for these simulations were i) modal mineralogy of the reservoir rocks and ii) hydrogeochemistry of the reservoir fluid.

Given the relationship between the intensities of diffraction peaks of a known phase with its abundance in a mixture, the results from XRD analysis were used for the determination of modal mineralogy. The quantification calculations were performed using *Match!* software which implements “Reference Intensity Ratio - RIR” (de Woolf and Visser, 1988) method for a semi-quantitative analysis. The RIR method operates by scaling the diffraction data to a standard reference material. The intensity differences of reference and experimental peaks are minimized with a least-squares refinement in the calculations.

The thermodynamic database used in the simulations was *llnl.dat* (Lawrence Livermore National Laboratory database) due to the availability of more mineral phases and its wider range of temperatures for the equilibrium constants of reactions.

However, since `llnl.dat` uses the ideal gas law and the properties of real gases, including carbon dioxide, deviate from the ideal gas law at high pressures and low temperatures, CO₂ solubility correction was applied to the script. The correction was taken from `phreeqc.dat` in which the fugacity coefficient is calculated from the critical pressure and temperature with the Peng-Robinson equation of state (Peng and Robinson, 1976), better representing non-ideal gas behaviour and the dissolution in water (Klajmon et al., 2017). The thermodynamic parameters for minerals that were identified in the analyses but not present in the database, were also added (data for ankerite and plagioclase solid solution series, from Koenen et al., 2014 and from Arnorsson and Stefansson, 1999 in Zhang et al., 2019, respectively).

Assumptions made in the modelling were:

- i) CO₂ as gas phase is assumed to be in equilibrium with the aqueous phase (Gaus et al., 2005; Klajmon et al., 2017; Ma et al., 2020; Fatah et al., 2022), in this regard, only partial pressure value of CO₂ for the relevant depth of the sample (calculated as the hydrostatic pressure) is defined,
- ii) Pore space is assumed to be completely filled by 1 liter of solution and the weight fractions are scaled to the rock sample accordingly (e.g. if porosity equals 10% which corresponds to 1 liter of water, rock volume becomes 9 liters).

Molar values of minerals are calculated with the following equation:

$$n_i = \frac{m_i}{100} \times \frac{(V \times \rho)}{M_i} \quad (4.1)$$

where n_i is the molar amount (mol), m_i is the weight percentage (%), M_i is the molecular weight (g mol⁻¹) of mineral i and V is the total rock volume (m³), ρ is the rock density (kg/m³).

The modelling studies were conducted on the “representative” samples which were differentiated according to:

- i) mineral abundance (e.g. SiO₂ values of Akköy field are $\leq 50\%$ from XRF analysis; samples which contain Quartz values that are above 50%, considering there are also other silicates in the mineral assemblage, are decided as not representative) and
- ii) mineral assemblage (e.g. a sample containing only quartz and muscovite from Akköy and a sample with only quartz and orthoclase from Edremit are eliminated)

most likely for the relevant field.

Prior to the simulations, the secondary minerals that are likely to precipitate were determined with preliminary Saturation Index calculations for each sample and those minerals were also evaluated in the models. These calculations also revealed the CO₂ amount specific to each sample (since the abundance of minerals differs) to be used in the modelling, with the assumptions of i) abundant CO₂ is supplied to the aqueous system and ii) after the reactions, CO₂ does not remain as a free gas (i.e. becomes trapped either in mineral or in solution). Using the specified CO₂ amount added to the system, the percentages for mineral and/or solubility trapping were calculated from the changes in the mol values of carbonate species following the equilibrium modelling results.

Kinetic modelling studies were based on the equation (Eq.4.2) by Lasaga (1984) which describes the rate of dissolution and precipitation of minerals including several mechanisms (acid, neutral, base, carbonate) for the computation of pH dependence of the reaction rates (Palandri and Kharaka, 2004).

$$r_i = SSA_i M_i n_i \left(1 - \frac{Q_i}{K_i}\right) (k_{i(acid)} + k_{i(neutral)} + k_{i(base)} + k_{i(carbonate)}) \quad (4.2)$$

where for mineral i, r_i is the reaction rate (mol s⁻¹), SSA_i is the specific surface area (m² g⁻¹), M_i is the molecular weight (g mol⁻¹), n_i is the molar amount (mol), Q_i is activity product and K_i is equilibrium constant. The rate constant k_i (mol m⁻² s⁻¹) is computed with Arrhenius equation (Eq.4.3) which describes the dependence on temperature.

$$k = A e^{\frac{-E_a}{RT}} \quad (4.3)$$

where A denotes Arrhenius pre-exponential factor, E_a is activation energy of a reaction (kJ mol^{-1}), R is the universal gas constant ($8.314 \text{ J mol}^{-1} \text{ K}^{-1}$) and T is temperature (K) (Palandri and Kharaka, 2004; Zhang et al., 2019). These equations are defined in PHREEQC via Basic language scripts inserted into the input file (Fig.4.5).

```

Dolomite
-start
10 REM PARM(1) = MSA (molar surface area) [m^2/mol]
20 SI_Dol = SI("Dolomite")
30 if (M <= 0 and SI_Dol < 0) then goto 200
40 SA = PARM(1) * M
50 if (M = 0 and SI_Dol > 0) then SA = 1e-05 #nucleation
60 temp_diff = 1/TK-1/298.15
70 k_acid = 10^(-3.76)*EXP(-56.7E+03/8.3145*temp_diff)*ACT("H+")^(0.5)
80 k_neut = 10^(-8.60)*EXP(-95.3E+03/8.3145*temp_diff)
90 k_carb = 10^(-5.37)*EXP(-45.7E+03/8.3145*temp_diff)*PR_P("CO2(g)")^(0.5)
100 k = k_neut+k_acid+k_carb
110 rate = k*SA*(1-(10^SI_Dol))
120 moles = rate*TIME
200 SAVE moles
-end

```

Figure 4.5. An example segment from the code in Rates data block of PHREEQC program written in Basic language representing the rate equations for the modelling. PARM(1) is the expression for SSA_i (specific surface area) multiplied with M_i (molecular weight)

Kinetic rate parameters were compiled from 2004 report of Palandri and Kharaka (except dawsonite and siderite, Table 4.1). Mineral specific surface areas applied in the calculations are given in Table 4.1. Considering the rapid reaction rates of calcite (Balashov et al., 2013; Hellevang et al., 2013; Haase et al., 2014; Ma et al., 2020), it was integrated into the models as an equilibrium phase. Simulation time of the reactions for kinetic modelling was defined as ten thousand years.

Table 4.1 Kinetic rate parameters used in the modelling. If not otherwise specified, all data are taken from Palandri & Kharaka (2004). Parameters of hornblende and montmorillonite in Palandri & Kharaka (2004) are used for amphibole and illite, respectively (Prg: Pargasite, Ann: Annite, Phl: Phlogopite)

Mineral	Acid Mechanism			Neutral Mechanism		Base Mechanism			Carbonate Mechanism			SSA (m ² /g)
	log k (mol/m ² s)	E (kJ/mol)	n (H ⁺)	log k (mol/m ² s)	E (kJ/mol)	log k (mol/m ² s)	E (kJ/mol)	n (H ⁺)	log k (mol/m ² s)	E (kJ/mol)	n P(CO ₂)	
Albite	-10.16	65.0	0.457	-12.56	69.8	-15.60	71.0	-0.572	-	-	-	0.1 ^c
Amphibole (Prg)	-7.00	75.5	0.600	-10.30	94.4	-	-	-	-	-	-	0.6409 ^d
Ankerite	-3.76	56.7	0.500	-8.60	95.3	-	-	-	-5.37	45.7	0.500	0.15 ^e
Biotite (Ann)	-9.84	22.0	0.525	-12.55	22.0	-	-	-	-	-	-	1.23 ^f
Biotite (Phl)	-	-	-	-12.40	29.0	-	-	-	-	-	-	1.23 ^f
Bytownite	-5.85	29.3	1.018	-9.82	31.5	-	-	-	-	-	-	0.238 ^g
Calcite	Equilibrium											
Chlorite	-11.11	88.0	0.500	-12.52	88.0	-	-	-	-	-	-	1.14 ^h
Dawsonite ^a	-4.48	49.43	0.982	-6.89	63.82	-	-	-	-	-	-	9.8 ⁱ
Dolomite	-3.76	56.7	0.500	-8.60	95.3	-	-	-	-5.37	45.7	0.500	0.18 ^e
Illite	-12.71	48.0	0.220	-14.41	48.0	-14.41	48.0	-0.130	-	-	-	0.468 ^j
Kaolinite	-11.31	65.9	0.777	-13.18	22.2	-17.05	17.9	-0.472	-	-	-	10 ^k
Labradorite	-7.87	42.1	0.626	-10.91	45.2	-	-	-	-	-	-	0.219 ^g
Magnesite	-6.38	14.4	1.000	-9.34	23.5	-	-	-	-5.22	62.8	1.000	0.13 ^l
Muscovite	-11.85	22.0	0.370	-13.55	22.0	-14.55	22.0	-0.220	-	-	-	0.68 ^m
Orthoclase	-10.06	51.7	0.500	-12.41	38.0	-21.20	94.1	-0.823	-	-	-	0.11 ^c
Quartz	-	-	-	-13.40	90.9	-	-	-	-	-	-	0.02 ^l
Siderite ^b	-8.00	65	0.750	-	-	-	-	-	-	-	-	0.18 ⁱ
Smectite	-10.98	23.6	0.340	-12.78	35.0	-16.52	58.9	-0.400	-	-	-	0.11 ^j

^aHellevang et al. (2010)

^eKlajmon et al. (2017)

ⁱHellevang et al. (2013)

^mOelkers et al. (2008)

^bGolubev et al. (2009)

^fTaylor et al. (2000)

^jGaus et al. (2002)

^cBrantley (2008)

^gBrantley & Mellott (2000)

^kYang & Steefel (2008)

^dDiedrich et al. (2014)

^hJayasekara et al. (2020)

^lPokrovsky et al. (2009)

Following the implementation of equilibrium and kinetic modelling, reactive transport simulations were conducted. In this simplified 1-D reactive transport modelling performed with PHREEQC, CO₂ was equilibrated with the “reinjecting” reservoir fluid and representing the reservoir system, the minerals and the fluid were allowed to react kinetically throughout the simulation.

The mass of the transported chemical in a one dimensional column is calculated with the equation based on the Advection-Reaction-Dispersion Equation (ARD):

$$\frac{\partial c}{\partial t} = -v \frac{\partial c}{\partial x} + D_L \frac{\partial^2 c}{\partial x^2} - \frac{\partial q}{\partial t} \quad (4.4)$$

where C is the concentration in water (mol/kgw), t is the time (s), v is the flow velocity in the pores (m/s), x is the distance (m), D_L is the hydrodynamic dispersion coefficient [m^2/s , $D_L = D_e + \alpha_L v$, D_e is the effective diffusion coefficient, α_L is the dispersivity (m)] and q is the concentration in the solid phase (mol/kgw in pore space) (Parkhurst and Appelo, 1999; Hemme and van Berk, 2017).

The flow velocity for the CO_2 -charged solution was set as 10^{-7} m/s based on the reactive transport study in a hydrothermal setting by Yapparova et al. (2017). 10^{-9} m^2/s and 0.05 m were the values adopted as the diffusion coefficient and dispersivity, respectively, for aqueous phases in porous media (Parkhurst and Appelo, 2013 in Ma et al., 2020). A horizontal column of 100 m in length was simulated for a time period of 100 years with 100 cells of which each cell is 1 m long.

The geochemical models are based on the integration and/or derivation of algebraic equations. To evaluate the moles of reactions for a time subinterval in kinetic modelling, multiple rate expressions written in the Basic language are calculated with simultaneous integrations. 1-D advective-dispersive transport calculations are solved with an explicit finite difference algorithm. Since the calculations are iterative processes, computation time of the simulations directly depends on the physico-chemical properties of the system that is being modeled. Compared to equilibrium modelling, the calculation time for kinetic reactions is slower by a factor of six or more. Furthermore in transport modelling, the cell number and sizes affect the duration of the calculations. It is estimated that a 20-cell model takes 2.7 times, while a 200-cell model takes 600 times the CPU time of the 10-cell model since the increase in the grid size increases the solution calculations (e.g. doubling the grid size at least quadruples the number of calculations, Parkhurst and Appelo, 2013). Calculation of the chemical reactions take most of the computation time for the reactive transport modelling rather than the transport processes. The reasons include i) iterations performed in non-linear algebraic equations, ii) evaluation of thermodynamic properties at every iteration, such as activity coefficients, concentrations, activities and iii) the number of chemical species (Leal et al., 2017).

Calculation of very large molalities may also lead to convergence problems (Parkhurst and Appelo, 2013).



CHAPTER 5

LITHOGEOCHEMICAL CHARACTERIZATION

Drill cuttings obtained from Akköy and Edremit geothermal fields are investigated for the determination of mineralogical and petrographical features, mineral compositions and whole rock geochemistry. Variations in grain sizes and textural features with depth are additionally studied for Edremit samples.

The mineralogic-petrographic properties of rock samples are studied both macroscopically and microscopically. For detailed mineral identifications, Confocal Raman Spectroscopy (CRS), X-Ray Diffraction (XRD), Electron Probe Micro Analysis (EPMA) techniques and for the examination of elemental variations, X-Ray Fluorescence (XRF) analysis are conducted.

5.1 Petrographic Features

5.1.1 Akköy Field

Macroscopic and microscopic examinations are performed on all of the drill cuttings (46 samples from PS-1 and 63 samples from PS-2 wells). The photographs taken during these examinations are given in Figs. 5.1 to 5.3, and in Appendix A.

Abundant clay presence is observed on the spot for all the samples from both wells. Dominant rock fragments are identified as calcareous rocks (marble/limestone) in which marbles are generally micaceous (Figs.5.1a, 5.1b). Towards deeper levels (around 1375-1385 m, 1460-1465 m and >1500 m in PS-1 well, >1350 m in PS-2 well), schists composed mainly of calcschists (Figs.5.1c) and mica/chlorite schists (Figs.5.1b, 5.1d, 5.1e) start to increase in abundance.

Clay and clayey carbonate minerals (Figs.5.1f), quartz, calcite, micas (biotite and muscovite, Figs.5.1b, 5.1e) and hematite/limonite $\pm$ pyrite (Fig.5.1a) are the primary minerals observed in the cuttings from both PS-1 and PS-2 wells. Pyrite is generally present in PS-1 well at variable depths. In PS-2 well, although pyrite is observed at 1285, 1300, 1320, 1345 m depths, it is mainly abundant in the samples in depths shallower than 1000 m (755-875 m). The presence of Fe-bearing minerals (hematite/limonite $\pm$ pyrite) points to interaction of reservoir rocks with hydrothermal fluids.

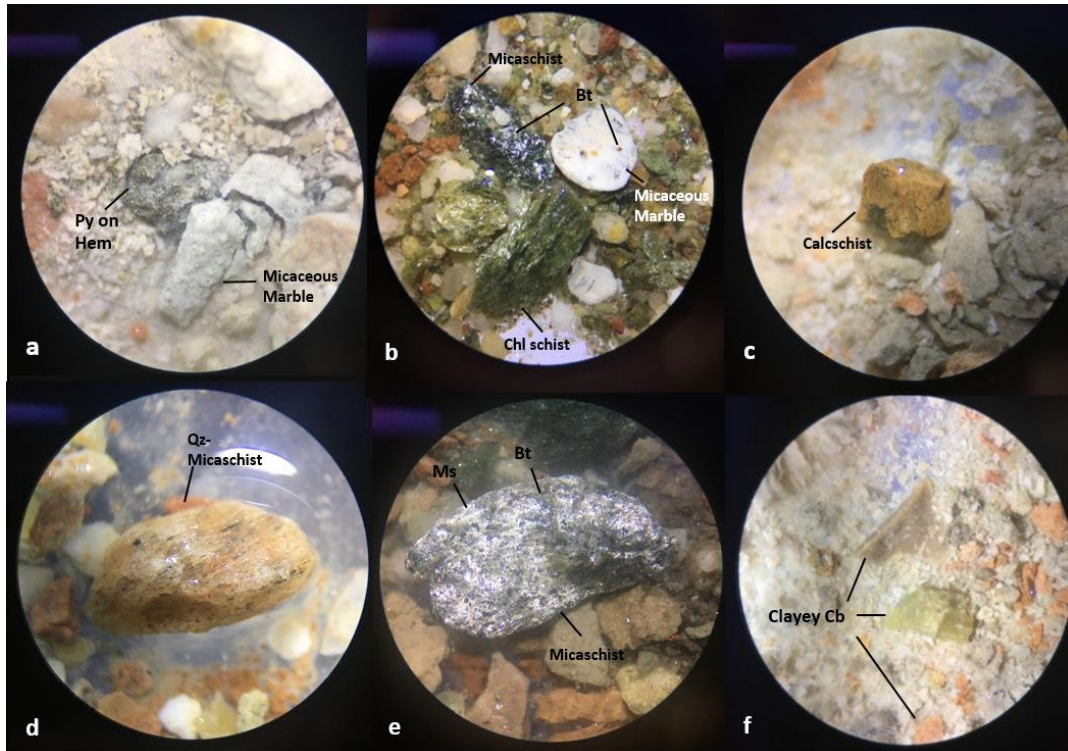


Figure 5.1. Macroscopic views of Akköy samples a. pyrite (Py) crystals on hematite (Hem) and argillized micaceous marble (sample no. ADK-PS-1-1330), b. micaschist, chlorite (Chl) schist and micaceous marble (sample no. ADK-PS-2-1380), c. calcschist (sample no. ADK-PS-1-1300), d. quartz (Qz) – micaschist (sample no. ADK-PS-2-1310), e. micaschist (sample no. ADK-PS-1-1525), f. clayey carbonate minerals (Cb) (sample no. ADK-PS-1-1300)

Microscopic examinations reveal the presence of sandstone, quartzite and chert fragments in the samples for both PS-1 and PS-2 wells, in addition to the macroscopically observed marble/limestone and schist (calcschist, micaschist, chlorite schist, amphibole schist) fragments (Figs.5.2a, 5.2b, 5.2c, 5.2d). Marble fragments are generally abundant at depths >1465 meters in PS-1 and >1295 meters in PS-2 well. As revealed by the macroscopic examinations, schist fragments are especially high in amount in deeper levels (e.g. >1485 m in PS-1, 1310-1330 m and 1345-1420 m in PS-2). In some levels (most of the samples in PS-1 well and between 1290-1305 m, 1360-1390 m and 1415 m in PS-2 well) serpentinite (Fig.5.2e) is found. These samples are likely to belong to the ophiolitic melange of the Lycian nappes of the region. These studies also confirm the abundance of clay minerals in all samples along with quartz and calcite (Figs.5.2a, 5.2b). Opaque minerals (Fig.5.2d) observed in the thin sections seem to be associated with the Fe-bearing minerals that are observed macroscopically. Further mineral observations lead to the identifications of feldspar, pyroxene, chlorite (Fig.5.2f) and amphibole minerals.

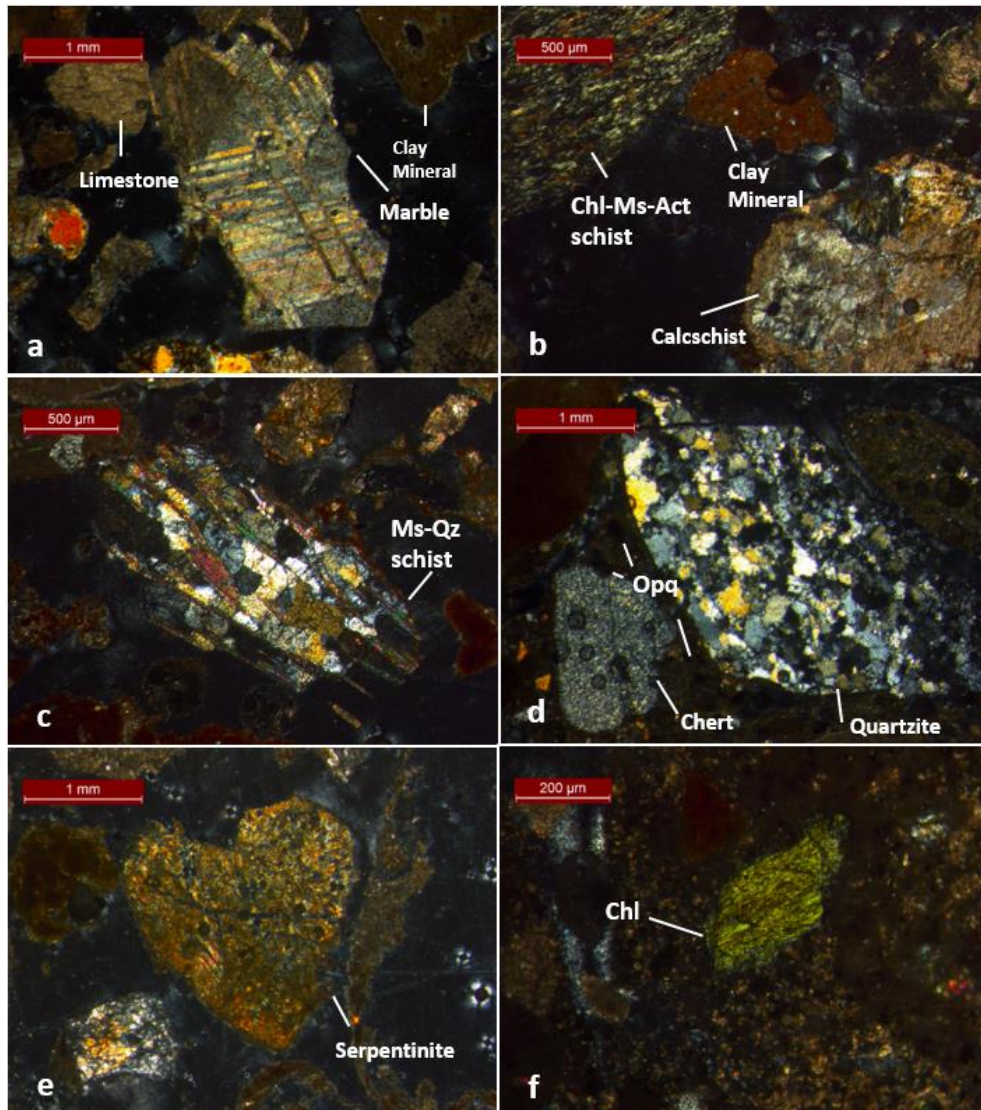


Figure 5.2. Microscopic views of Akköy samples a. marble with pressure twinning, limestone and clay mineral (sample no. ADK-PS-2-1410), b. chlorite (Chl)–muscovite (Ms)–actinolite (Act) schist, clay mineral and calcschist (sample no. ADK-PS-1-1515), c. muscovite (Ms)–quartz (Qz) schist (sample no. ADK-PS-2-1315), d. quartzite, chert and opaque minerals (Opq) (sample no. ADK-PS-1-1385), e. serpentinite (sample no. ADK-PS-1-1320), f. chlorite (Chl) (sample no. ADK-PS-2-1265)

Petrographic studies also reveal pressure twinning on marbles (Figs.5.2a, 5.3a) and the indications for the effects of hydrothermal fluid on mineral grains (Fig.5.3b).

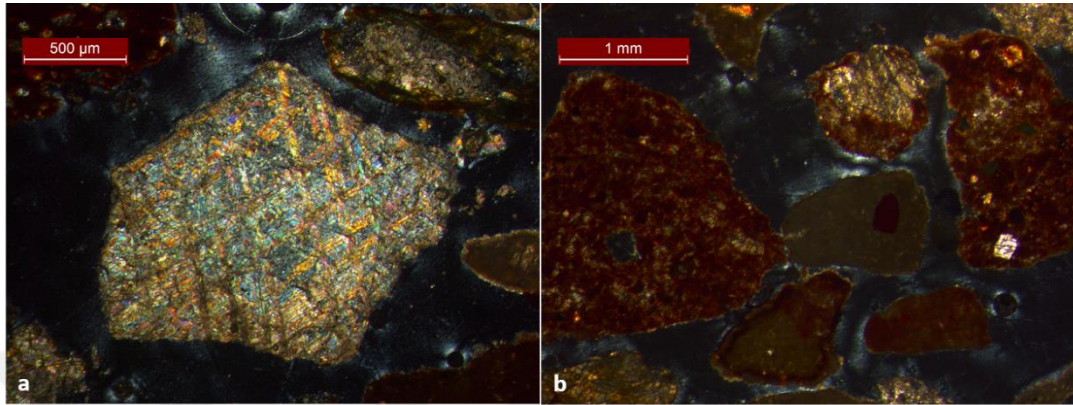


Figure 5.3. Microscopic views of a. marble with pressure twinning (sample no. ADK-PS-2-1390), b. effects of hydrothermal fluid (sample no. ADK-PS-2-1310)

5.1.2 Edremit Field

A total of 70 samples from the EDJ-12 well are studied macroscopically and microscopically. The photographs taken during these examinations are given in Figs. 5.4 to 5.7, and in Appendix A.

The macroscopic examinations display that rock fragments are dominated by granitic rocks (granite/granodiorite, Fig.5.4a). Metamorphic fragments (mainly marble, gneiss and calcschist) and fragments that belong to gabbroic (Fig.5.4b), volcanic and sedimentary rocks are also observed in some samples. The main minerals observed are quartz, biotite (Figs.5.4a, 5.4c), epidote (Fig.5.4d), calcite, amphibole, muscovite, chlorite, hematite/limonite (Fig.5.4e) and pyrite (Fig.5.4f). Although it is observed to be present in almost every sample, pyrite is found to be especially abundant in between 958-980 m levels. An apparent abundance of biotite is also noted in between 960-972 and 992-998 meters.

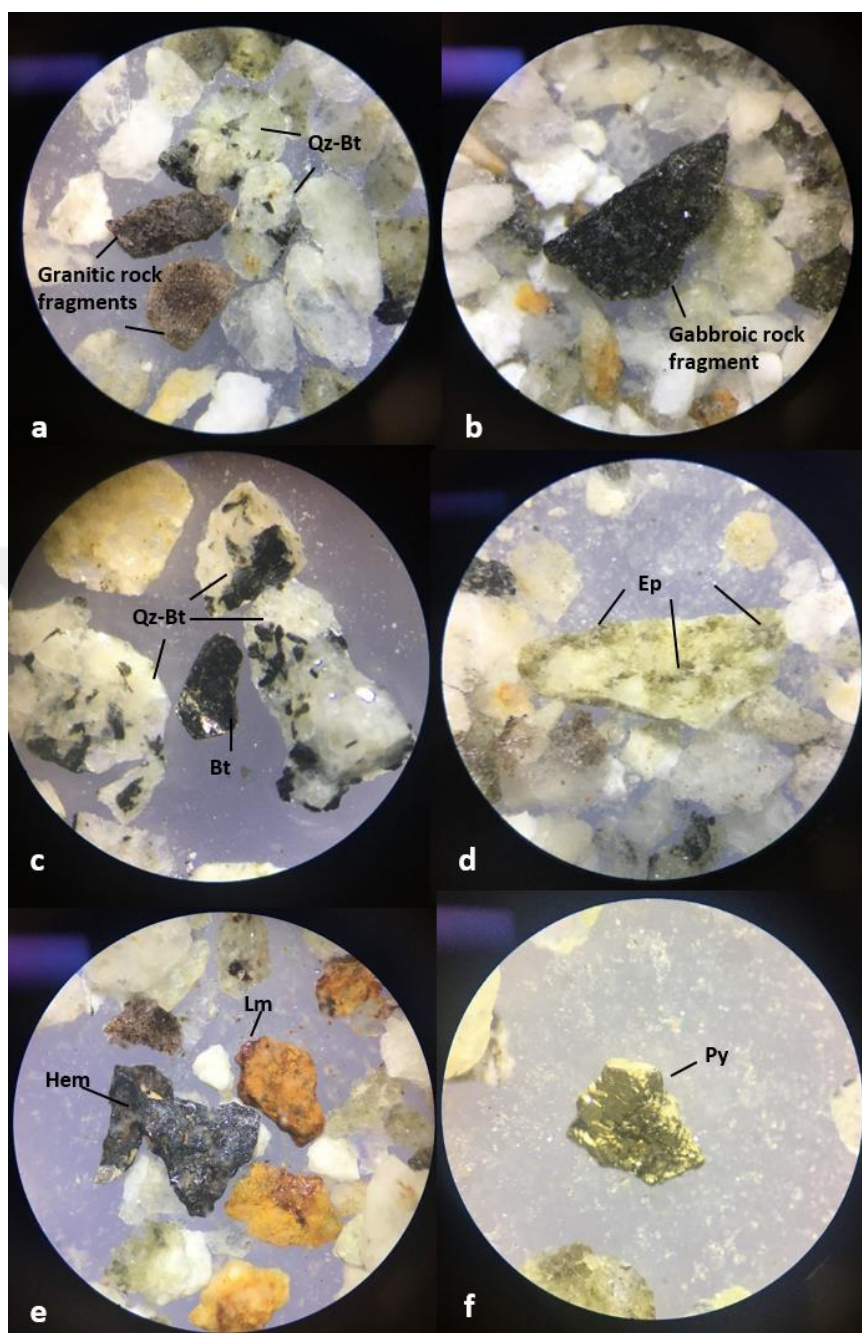


Figure 5.4. Macroscopic views of Edremit samples a. granitic rock fragments, quartz (Qz) and biotite (Bt) (sample no. EDR-912), b. gabbroic rock fragment (sample no. EDR-916), c. quartz (Qz) and biotite (Bt) (sample no. EDR-1026), d. epidotes (Ep) on a siliceous fragment (sample no. EDR-920), e. hematite (Hem) and limonite (Lm) (sample no. EDR-924), f. pyrite (Py) (sample no. EDR-968)

Cu-bearing minerals (chalcopyrite, azurite (Fig.5.5a), malachite), along with some grains containing native-Cu (Fig.5.5b) are recognized around 926-932, 942, 966, 984, 990-992, 1004 and 1024 m depths.

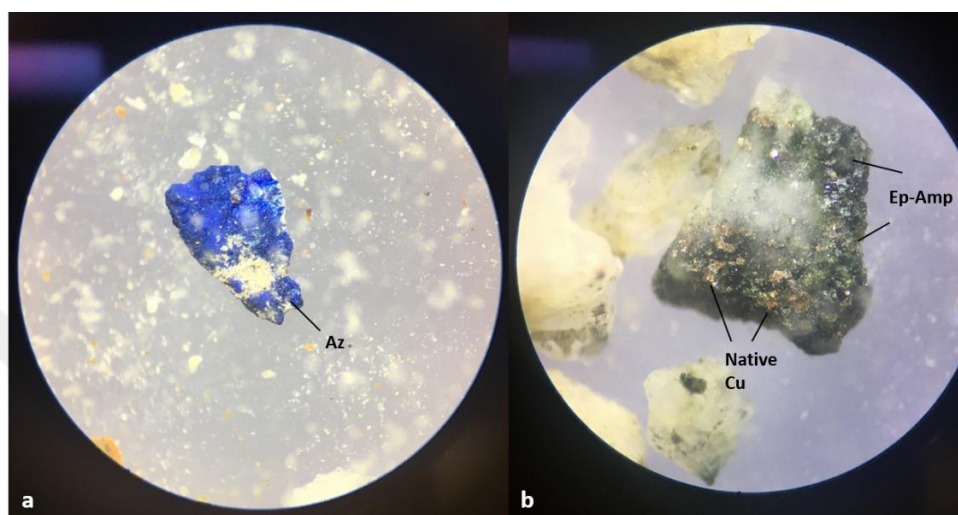


Figure 5.5. Macroscopic views of a. azurite (Az) (sample no. EDR-926), b. native Cu on a grain composed of epidote (Ep) and amphibole (Amp) (sample no. EDR-966)

The thin section examinations confirm the domination of granitic rocks (Fig.5.6a) with the average relative proportion of 80% followed by 17% for metamorphic, 2% for gabbroic (Fig.5.6b), 1% for sedimentary and 1% for volcanic rock fragments. Limestone (Fig.5.6a) is identified as a sedimentary rock fragment. Quartz, plagioclase (Fig.5.6c), calcite, biotite (Figs.5.6d, 5.6e, 5.6f), orthoclase, amphibole (Fig.5.6d), opaque minerals (Figs.5.6a, 5.6e, 5.6f), chlorite, pyroxene, epidote (Fig.5.6e) and muscovite (Fig.5.6f) are the minerals observed microscopically in the samples from Edremit field. The opaque minerals seem to be associated with the macroscopically observed Fe- and Cu-bearing minerals.

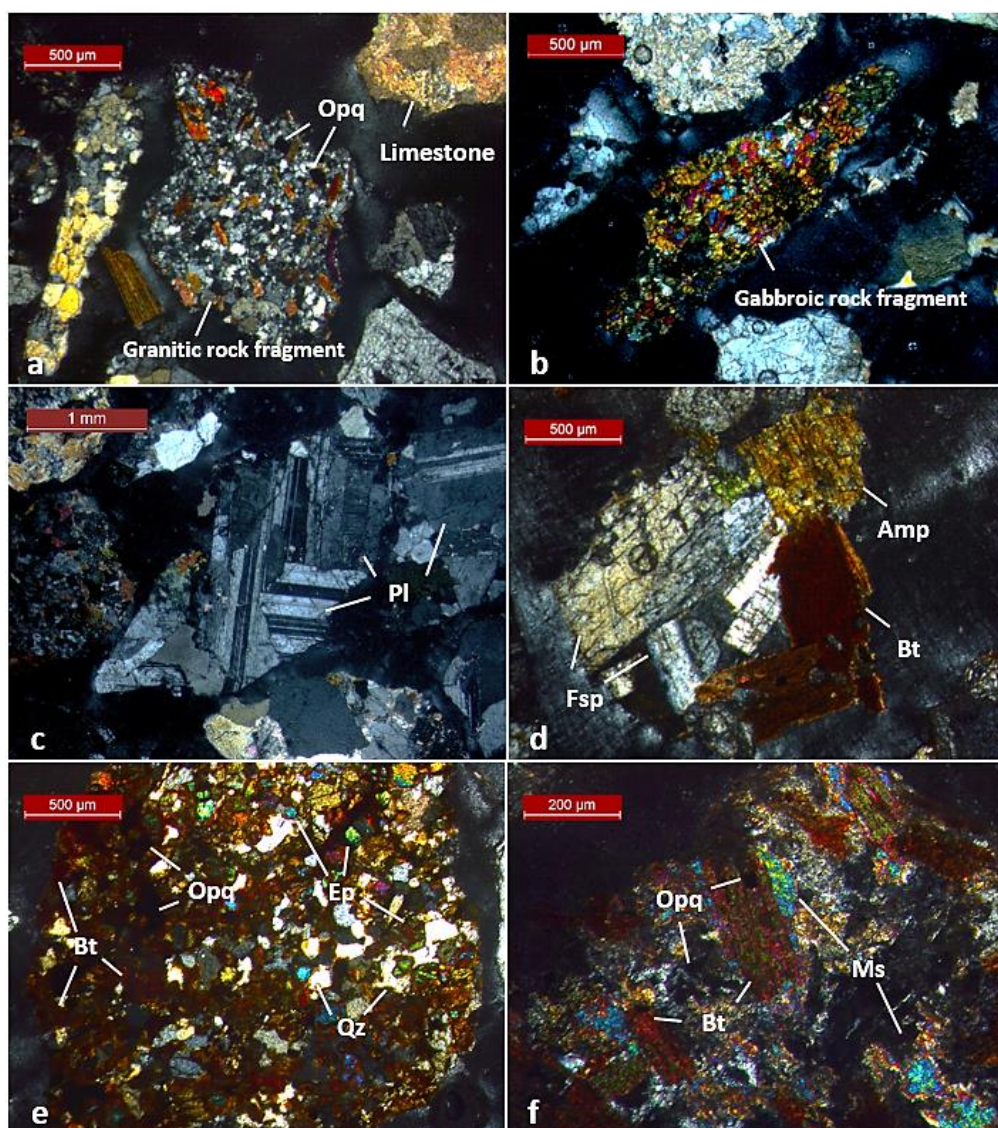


Figure 5.6. Microscopic views of Edremit samples a. granitic rock fragment, limestone and opaque minerals (Opq) (sample no. EDR-902), b. gabbroic rock fragment (sample no. EDR-944), c. plagioclase (Pl) minerals (sample no. EDR-986), d. biotite (Bt), amphibole (Amp) and feldspar (Fsp) minerals (sample no. EDR-998), e. biotite (Bt), epidote (Ep), quartz (Qz) and opaque minerals (Opq) (sample no. EDR-956), f. biotite (Bt), muscovite (Ms) and opaque minerals (Opq) (sample no. EDR-986)

The textures are heterogeneously distributed in each sample; there are holocrystalline fragments as well as the ones affected by cataclasis likely to be associated with a fault zone as revealed by the presence of cataclastic (Fig.5.7a), mylonitic (Fig.5.7b) and mortar (Fig.5.7c) textures. Furthermore, metasomatism (Fig.5.7d) and secondary uralitization (Figs.5.7e, 5.7f) are also observed in some fragments.

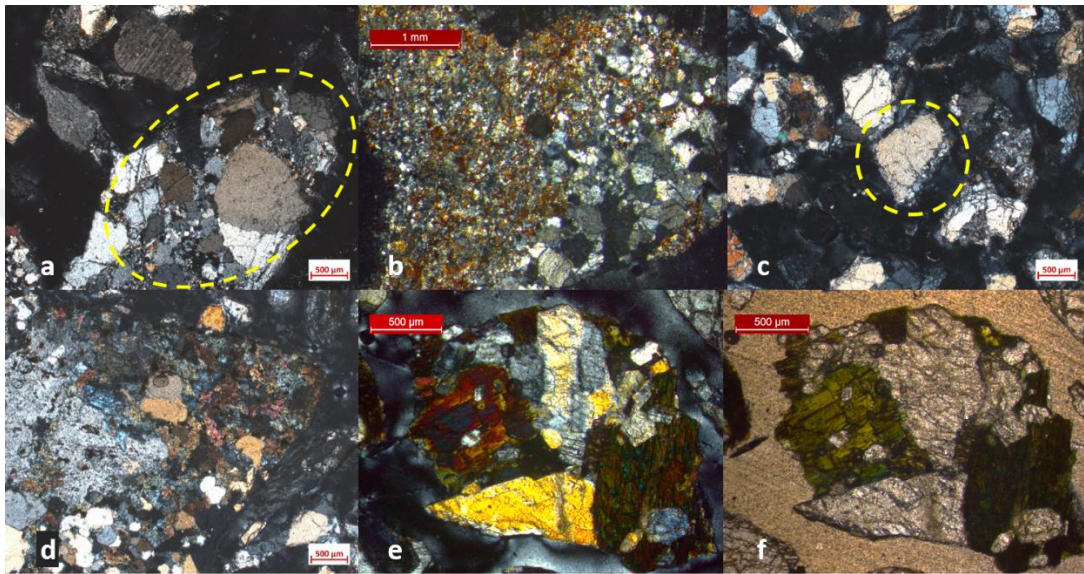


Figure 5.7. Microscopic views of textural features in Edremit samples a. cataclastic granite (shown in dashed line) with gneiss on top (sample no. EDR-912), b. mylonitic granite (sample no. EDR-966), c. mortar texture (shown in dashed line, sample no. EDR-932), d. metasomatism (sample no. EDR-954), e and f. gabbro rock fragment showing uralitization in cross-polarized light and plane-polarized light, respectively (sample no. EDR-1006)

The petrographic features of rock fragments from Edremit field are investigated in regard to the variations with depth along the wellbore (Fig.5.8). Grain sizes of granitic fragments change from coarse to fine at different depths: around the first 12 meters, the granitic fragments (mainly granite) are observed to be coarse grained and from 914 m to 984 m, the fragments become fine grained. After 986 meters to the deeper levels, relatively more granodiorite fragments are present, of which the grain sizes fluctuate from coarse to medium. The distribution of certain textural features

also seem to apply to similar depth levels: cataclastic (904-912 m and 994-1014 m, Fig.5.7a), mylonitic (912-986 m, Fig.5.7b) and mortar (932 m, Fig.5.7c) textures reflect the effects of cataclasis which is likely to be associated with a fault zone. Metasomatism (e.g. 954 m, Fig.5.7d) and secondary uraltization (e.g. 1006 m, Figs.5.7e, 5.7f) observed in some fragments point to the effects of hot fluids circulating via the fault/fracture zone(s) at the relevant depth(s).

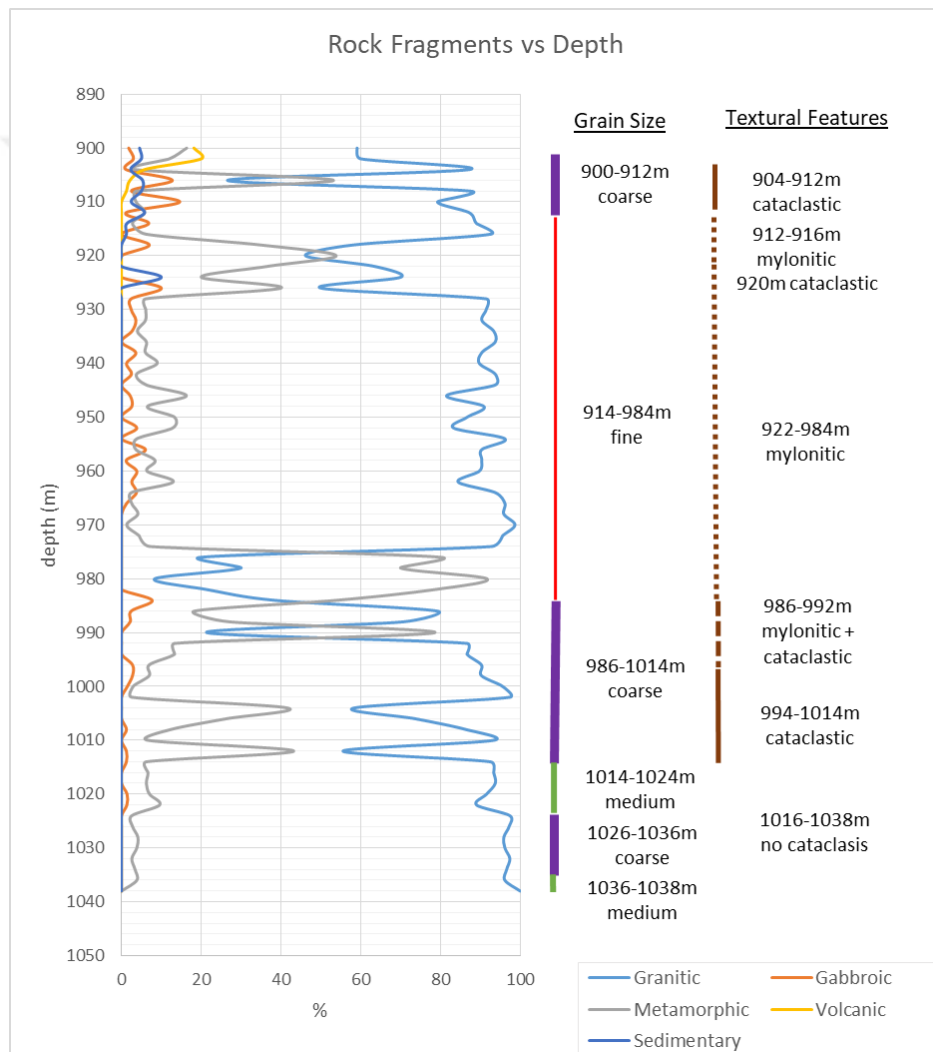


Figure 5.8. Analyses of rock fragments from Edremit field regarding their abundance, grain size and textural features with respect to depth

5.2 Identification of Mineral Phases

5.2.1 X-Ray Diffraction (XRD) Analysis Results

5.2.1.1 Akköy Field

XRD analyses of the selected 8 samples from PS-1 and 9 samples from PS-2 wells (Appendix B) confirm quartz, calcite and clay minerals as the dominant mineral phases and reveal the presence of dolomite, ankerite, orthoclase, albite, labradorite and talc. Kaolinite, illite and smectite are the determined clay minerals. Based on the abundance of minerals, all analysed samples contain quartz, 76% of them contain calcite and muscovite, followed by 53% dolomite.

XRD diffractograms of the samples against depth are examined for the mineralogical composition and the effects of possible alteration (Fig.5.9). The argillization effect decreases in deeper levels in the samples of both PS-1 and PS-2 wells. In PS-1 samples, kaolinite, feldspar and carbonate mineral proportions increase while in PS-2 samples, the proportions of calcite and ankerite increase and clay mineral content decreases with increasing depth. The presence and increasing proportion of ankerite point to increasing degree of hydrothermal alteration with depth.

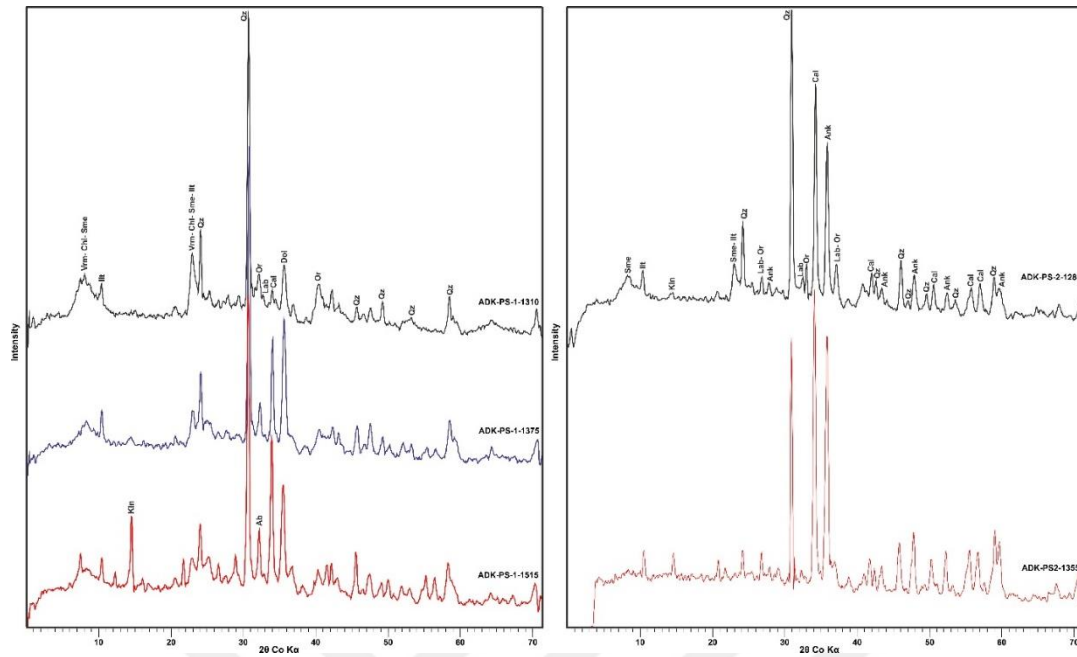


Figure 5.9. XRD patterns of the selected samples from different depths which belong to the PS-1 and PS-2 wells in Akköy field (Ab: Albite, Ank: Ankerite, Cal: Calcite, Chl: Chlorite, Ill: Illite, Kln: Kaolinite, Lab: Labradorite, Or: Orthoclase, Sme: Smectite, Qtz: Quartz, Vrm: Vermiculite)

5.2.1.2 Edremit Field

XRD analyses of 10 selected samples from the EDJ-12 well (Appendix B) reveal the presence of dolomite and actinolite in addition to the microscopically identified quartz, orthoclase, plagioclase, calcite, biotite, muscovite and chlorite (Fig.5.10). Designated plagioclase minerals include albite, labradorite, andesine and bytownite. Quartz and orthoclase comprise 90% and 80% of the analysed samples, respectively. The determined clay minerals are illite, kaolinite, smectite and vermiculite. Feldspar, mica and illite abundances seem to increase towards deeper levels.

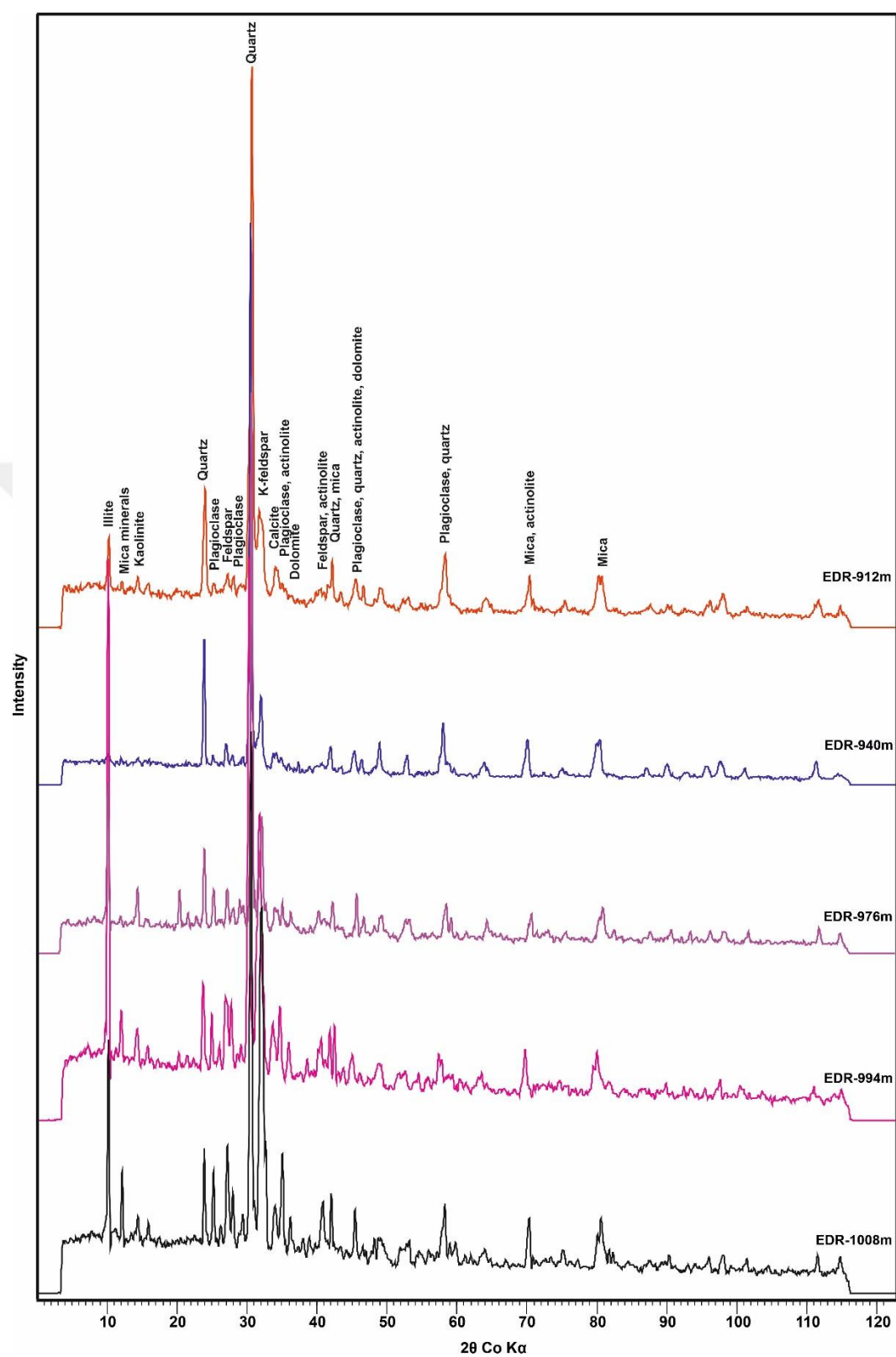


Figure 5.10. Example XRD patterns of Edremit samples from different depths

5.2.2 Confocal Raman Spectroscopy (CRS) Results

5.2.2.1 Akköy Field

The results of CRS studies which are performed on 62 distinct points from the 6 selected samples that generally display the characteristics of reservoir lithology (2 samples from PS-1, 4 samples from PS-2 well), are tabulated in Table 5.1. Raman spectrums of some of the analysed minerals are displayed in Appendix C. The minerals detected in the samples are carbonate minerals (calcite, dolomite, ankerite), quartz, chalcedony, albite, muscovite, clinocllore, talc, actinolite, hematite and marcasite among which chalcedony, actinolite and marcasite are distinguished with these analyses.

Table 5.1 Results of the Confocal Raman Spectroscopy (CRS) analyses for Akköy samples

Sample No.	Minerals											
	Calcite	Dolomite	Ankerite	Quartz	Chalcedony	Albite	Muscovite	Clinocllore	Talc	Actinolite	Hematite	Marcasite
ADK-PS-1-1495	•	•		•		•					•	
ADK-PS-1-1515	•	•	•		•			•		•	•	•
ADK-PS-2-1310	•	•									•	
ADK-PS-2-1355	•	•		•		•		•		•	•	
ADK-PS-2-1380	•						•		•		•	
ADK-PS-2-1415	•			•				•				

The results show that carbonate minerals are dominated by calcite. From all carbonate minerals that are analysed, 65.7% is recorded as calcite, 28.6% as dolomite and 5.7% as ankerite.

In order to investigate the changes in the physicochemical conditions of the reservoir lithology with depth, calcite which is the most abundant carbonate mineral in all

samples, is selected for the comparison of the CRS results. The Raman spectrums of calcite of the analysed samples against depth are shown in Figure 5.11. Calcite has strong Raman shift around 1080 cm^{-1} and weak peaks around 710 , 270 and 150 cm^{-1} . The sharp Raman shift around 1080 cm^{-1} is assigned to the $(\text{CO}_3)^{2-}$ symmetric stretching mode whereas the weak Raman shift around 710 cm^{-1} is resulted from the symmetric $(\text{CO}_3)^{2-}$ deformation. The Raman peaks around 270 and 150 cm^{-1} , which are in the low wavenumber region of the Raman spectrum, are related with the external vibrations of the $(\text{CO}_3)^{2-}$ (Sun et al., 2014). The examination of the Raman spectrums reveals that there is a shifting in the peak positions of calcite with depth in both PS-1 and PS-2 wells (Fig.5.11). The shifting in all sharp and weak peaks of calcite is related to the pressure increase with the increasing depth. This is also supported by the increasing degree of metamorphism with depth in the region (e.g. the basement lithology). This shifting in the peaks is compatible with the empirical studies (Fong and Nicol, 1971). According to calcite Raman data from the literature (Fong and Nicol, 1971), calcite minerals of the samples from Akköy field may be formed under 1 bar pressure.

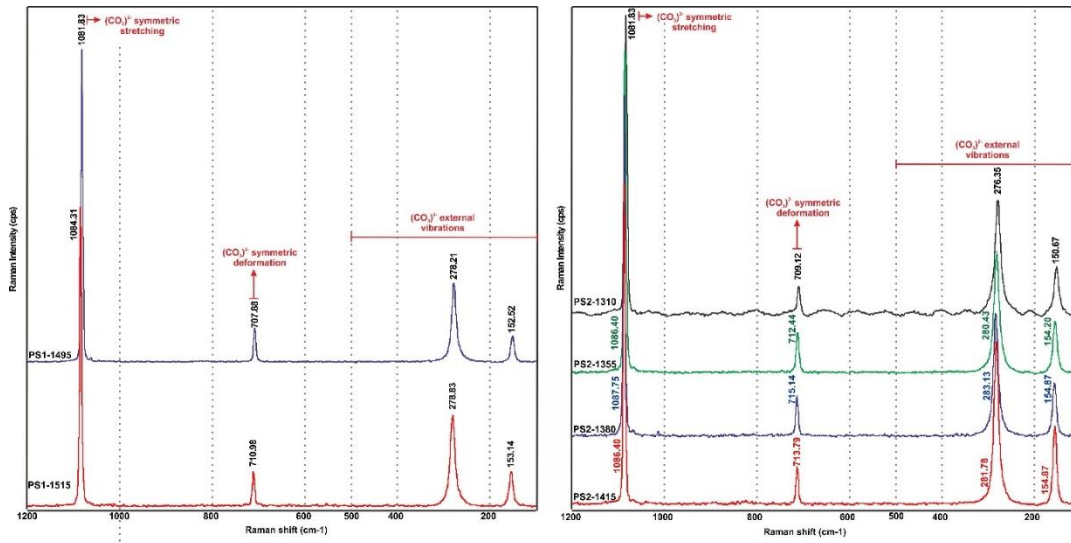


Figure 5.11. Calcite Raman spectrums of the analysed samples from PS-1 and PS-2 wells (Akköy field) against depth (The carbonate group minerals have characteristics with four distinct Raman shifts as the symmetric stretching, the asymmetric deformation, asymmetric stretching and symmetric deformation. The asymmetric stretching modes correspond to the 1700-1200 cm^{-1} Raman shift interval which is beyond the range of our measurements. The 1200-600 cm^{-1} region is due to the symmetric stretching whereas the 500-100 cm^{-1} region is assigned to the external vibrations of the carbonate group minerals (Rutt and Nicola, 1974; Sun et al., 2014))

5.2.2.2 Edremit Field

CRS analyses are performed for a total of 6 samples on 110 different points (Table 5.2). Raman spectrums of some of the analysed minerals are given in Appendix C. The results show that ankerite is also one of the carbonate mineral phases and calcite has the highest abundance. Plagioclase solid solution series are identified as bytownite (Ca-rich member), andesine and labradorite, with bytownite being the dominant mineral. Other minerals observed in the samples are phlogopite, clinocllore, richterite, pargasite and diopside. Magnetite, lepidocrocite and orpiment constitute the opaque minerals examined in the thin sections in addition to the ones identified microscopically. A notable observation for Edremit field is that

plagioclase minerals seem to become more calcic towards deeper levels (Table 5.2). Yet another observation is that in the sample taken from 1032 m depth, plagioclase composition changes from andesine in the core to bytownite on the rims indicating reverse zoning.

Table 5.2 Results of the Confocal Raman Spectroscopy (CRS) analyses for Edremit samples

Sample No.	Minerals																		
	Calcite	Dolomite	Ankerite	Quartz	Andesine	Labradorite	Bytownite	Orthoclase	Biotite	Phlogopite	Muscovite	Clinocllore	Actinolite	Richterite	Pargasite	Diopside	Epidote	Magnetite	Hematite
EDR-912	•			•	•	•		•	•		•		•						
EDR-958	•			•	•			•								•	•		•
EDR-964	•		•	•	•	•	•	•					•			•		•	•
EDR-994		•		•		•	•		•			•		•	•			•	
EDR-1008		•		•		•	•		•	•			•	•				•	
EDR-1032				•			•	•	•				•					•	

The Raman spectrums of plagioclase minerals against depth are examined for the effects of possible deformation and/or alteration (Fig.5.12). Following the grouping proposed by Freeman et al. (2008), the spectrums are investigated in five spectral regions each of which corresponds to five different modes as can be seen in Fig.5.12. The peak position of the strongest peak draws near the 500 cm^{-1} with increasing Ca content as observed at 958, 964 and 1032 m depths (Fig.5.12). This Ca increase is also reflected by the increase in the Group II and Group III features with depth from 912 to 1032 m levels. Furthermore, Group IV and V features of the plagioclases decrease towards deeper levels, with the loss of sharp bands in the spectral range from $700\text{ to }1200\text{ cm}^{-1}$ which might be related to the effects of an alteration pertinent to plagioclase minerals. It should also be noted that the width of the Raman peak in the $500\text{-}510\text{ cm}^{-1}$ becomes slightly wider with increasing depth from 912 m to 1032 m. This band broadening is related with the increased Al-Si disorder due to pressure induced deformation (Freeman et al., 2008) as can be expected from increasing lithostatic pressure with depth.

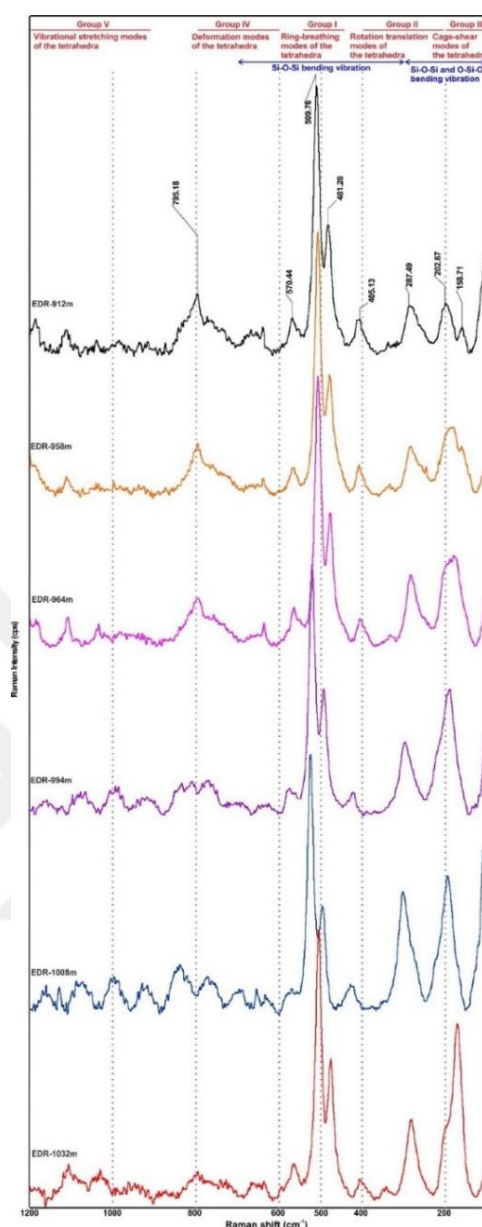


Figure 5.12. Raman spectra of plagioclase minerals of the analysed samples from EDJ-12 well (Edremit field) against depth (Group I: Raman spectra in the 450-520 cm^{-1} related with the ring-breathing modes of the tetrahedral. Group II: Raman spectra between 200-400 cm^{-1} corresponding to rotation-translation modes of the tetrahedral. Group III: Raman peaks below the 200 cm^{-1} representing the cage-shear modes of the tetrahedra. Group IV: Raman peaks in the 700-900 cm^{-1} representative for the deformation modes of the tetrahedra. Group V: Raman peaks in the 900-1200 cm^{-1} showing the vibrational stretching modes of the tetrahedra (Freeman et al., 2008). The Raman bands between 300-700 cm^{-1} are also known as Si-O-Si bending vibration modes and the spectrums between 300-0 cm^{-1} are a combination of Si-O-Si and O-Si-O bending vibrations (Lasaga and Gibbs, 1988))

5.3 Chemical Composition of Minerals

5.3.1 Akköy Field

Detailed characterization of minerals from solid solution series, feldspar, mica, amphibole and pyroxenes, is carried out utilizing EPMA technique. The results are tabulated in Appendix D and an example displaying the general view of the analysed sample is presented in Appendix E. Analyses are performed on a total of 183 points chosen from 11 thin sections (5 samples from PS-1, 6 samples from PS-2 well). The compositions of analysed feldspars resulted in 59% albite, 26% orthoclase and 15% oligoclase (Fig.5.13a). Regarding mica minerals, although the petrographic observations and XRD analyses point to biotite presence, results of selected samples which are deemed usable indicate muscovite composition (Fig.5.13b). Pyroxenes from the analysed spots are identified as augite (Fig.5.13c). Amphibole minerals, determined as Mg-hornblende, hastingsite and actinolite are calcic in composition (Fig.5.14). In addition to these observations, the presence of sulphur is detected in the compositions of feldspar and mica minerals pointing to hydrothermal fluid effect in the system (Appendix D).

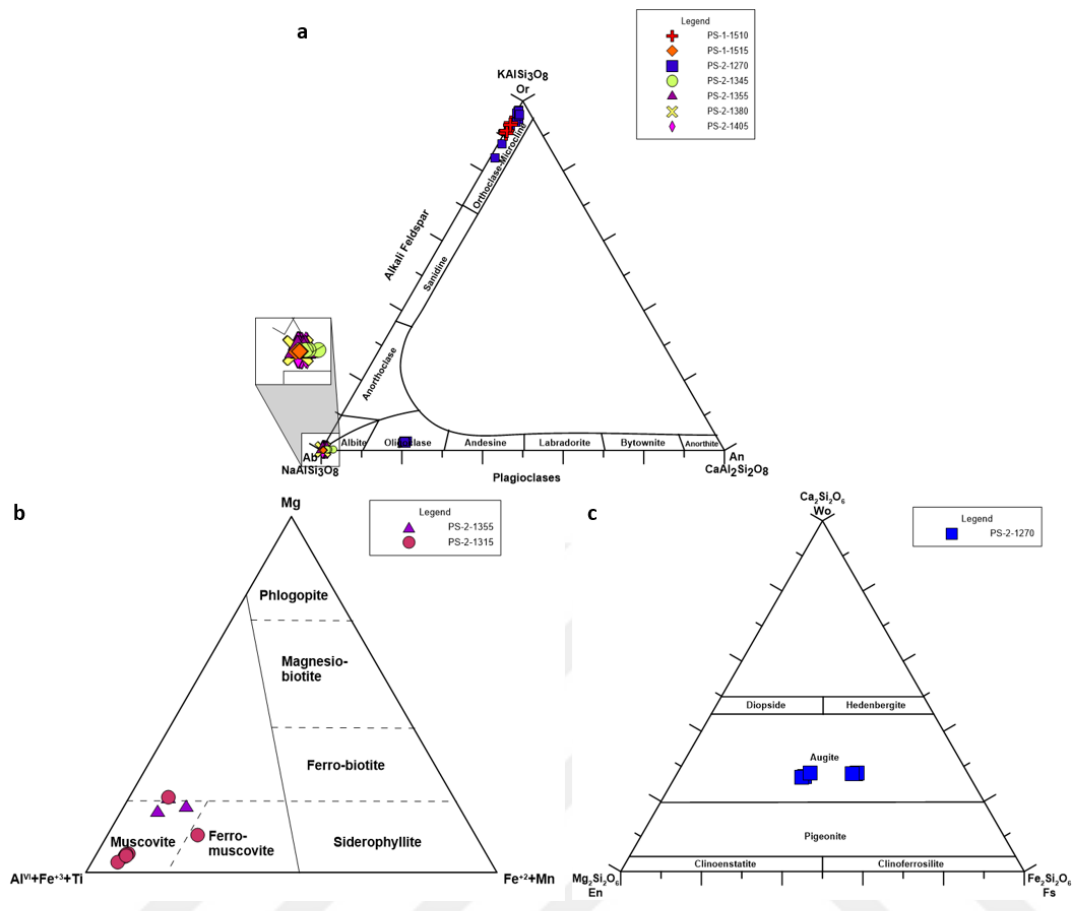


Figure 5.13. EPMA results of samples from Akköy field shown in ternary diagrams for a. feldspar minerals (Deer et al., 1992), b. mica minerals (Foster, 1960) and c. pyroxene minerals (Morimoto et al., 1988)

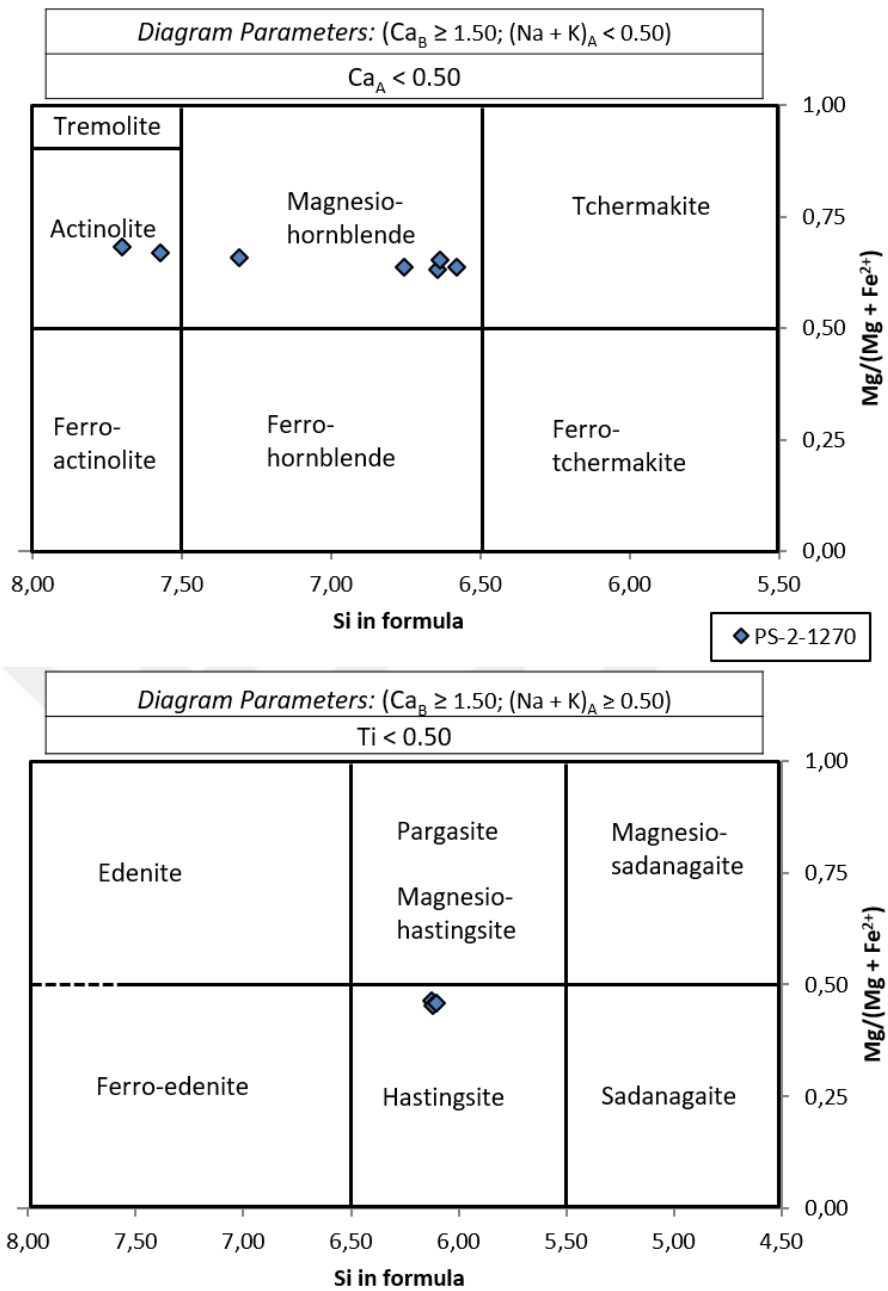


Figure 5.14. EPMA results of Akköy samples shown in classification diagrams of calcic amphiboles (Leake et al., 1997)

5.3.2 Edremit Field

EPMA studies are performed on a total of 284 spots for the 6 samples of EDJ-12 well (Appendix D). An example displaying the general view of the analysed sample is also presented in Appendix E. The results show that analyzed feldspars are 66% andesine, 19% orthoclase, 14% oligoclase and 1% sanidine in composition (Fig.5.15a). A detailed examination of sample from 1032 m depth reveals Na amount is relatively higher in the core whereas Ca has higher abundance in the rim (reverse zoning). The results of mica minerals point out Mg-Fe biotite composition (Fig.5.15b) and pyroxenes are found to be augite (Fig.5.15c). Some of the analyzed pyroxene grains are determined to be highly altered and they are not evaluated. Most of the amphibole minerals in the analyzed samples are calcic in composition and determined as Mg-hornblende, edenite and Mg-hastingsite (Figs.5.16a, 5.16b), while 3 points from two samples gave Fe-richterite composition (sodic-calcic, Fig.5.16c).

EPMA studies reveal the presence of sulphur in feldspar and mica minerals (Appendix D) pointing to hydrothermal fluid effect in the system, which may also stand for the SO₄-rich character of the geothermal waters (Avşar et al., 2013).

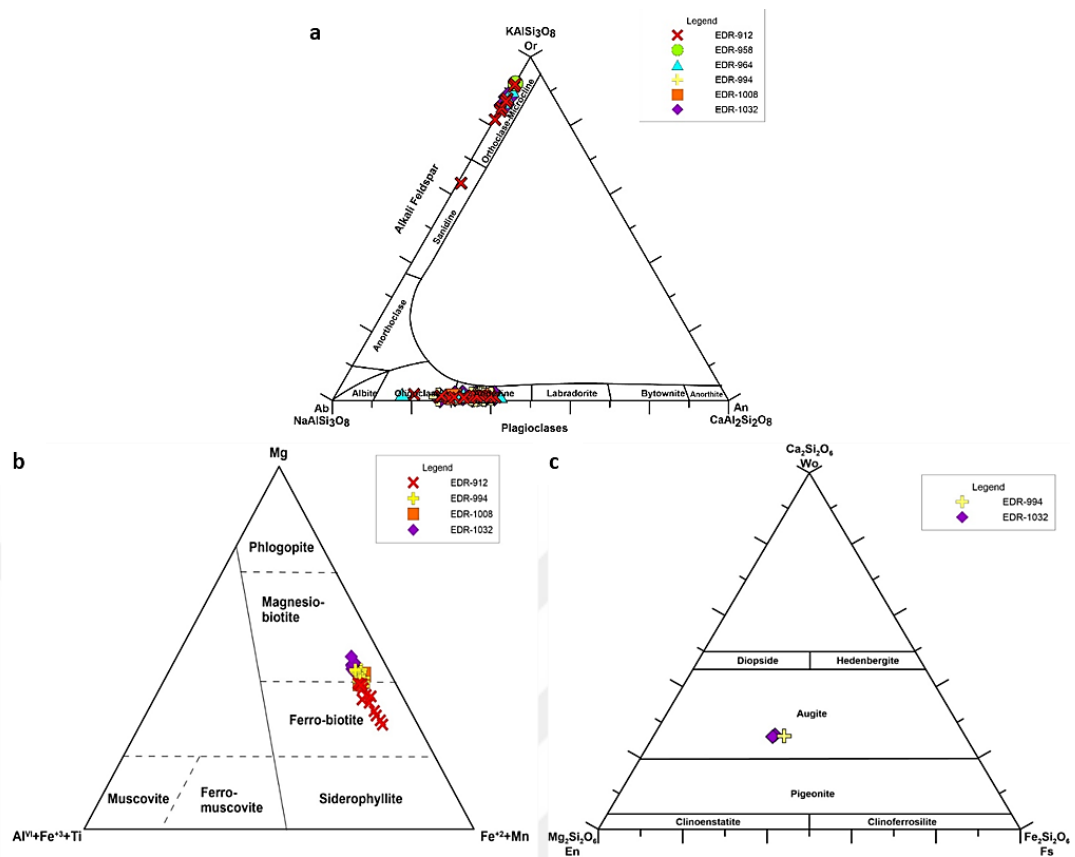


Figure 5.15. EPMA results of samples from Edremit field shown in ternary diagrams for a. feldspar minerals (Deer et al., 1992), b. mica minerals (Foster, 1960) and c. pyroxene minerals (Morimoto et al., 1988)

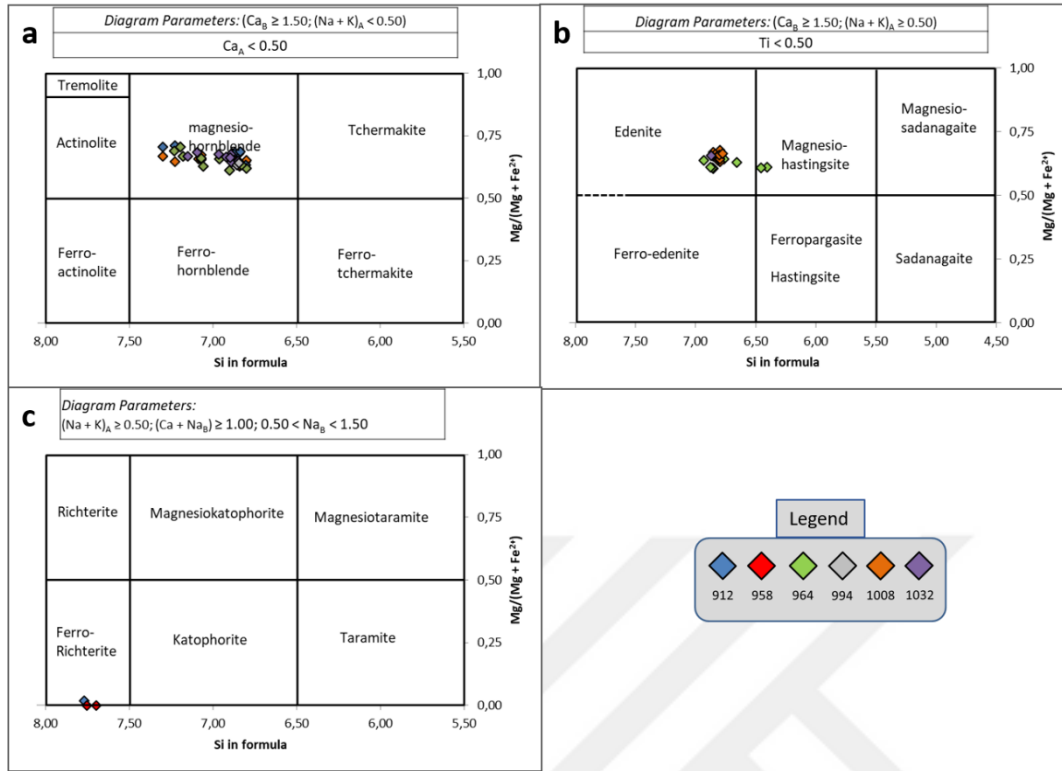


Figure 5.16. EPMA results of Edremit samples shown in classification diagrams of a, b, calcic and c. sodic-calcic amphiboles (Leake et al., 1997)

5.4 Whole Rock Geochemistry

5.4.1 Akköy Field

The XRF analysis results of both PS-1 and PS-2 wells of Akköy field are given as Appendix F. In both wells (PS-1 and PS-2), similar trends can be observed due to the lithological similarities (Figs.5.17 and 5.18). CaO values (although higher in PS-2) show increasing trends against depth for both of the wells (from ~5% to ~25% in PS-1 and from ~15% to ~60% in PS-2). On the other hand, SiO₂ values decrease towards the deeper levels in PS-2 (from ~40% to 10%), while in PS-1 there is no significant change (stays around 50%). The trends for CaO values imply the

increasing abundance of Ca-bearing rocks such as marbles and calcschists (reservoir rocks) as also observed in the microscopic examinations (Figs.5.1a, 5.1b, 5.1c, 5.2a, 5.2b).

Changes in the abundances of minerals such as clays and mica (biotites) +/- chlorite +/- amphibole in schist fragments are reflected in the XRF results. Decreasing trend of Al_2O_3 values coupled with K_2O values can be attributed to the decrease in clay mineral content from shallower to deeper levels in both wells. Enrichment displayed in the trends of Fe_2O_3 and MgO at depths around 1265-1275 m in PS-2 and ~1300 and ~1335 m in both wells, seem to be related to the abundance of schist fragments from these levels (Figs.5.1b, 5.1d, 5.1e). Given the similar geochemical behaviour as those of Fe_2O_3 and MgO , a correlative enrichment is observed for MnO , Cr_2O_3 , TiO_2 , Co and Ni values. The occurrence of relatively higher values of SO_3 coupled with Fe_2O_3 , is in conformity with the observed pyrite (Fig.5.1a) and marcasite minerals in the samples. Increases in the concentrations of elements which are commonly associated with sulphide minerals (e.g. As, Cu, Pb, Zn) are also detected around 1310-1320 m depths. This observation can be attributed to sulphide mineralization in these levels.

Regarding the Loss on Ignition (LOI) contents, the values in PS-1 well are generally lower than the ones in PS-2 (<20% in PS-1, between 10% - 45% in PS-2). The PS-1 well LOI values are also relatively lower between 1375-1465 m depth compared to the shallower and deeper levels of the same well. On the other hand, for PS-2 well, there seems to be an increase in the LOI values starting at about 1375 m towards deeper levels. This increase in LOI values can be correlated with an increase in the carbonate content of the respective levels. It should be noted here that the well log of PS-1 and PS-2 wells reveals a transition from Miocene shale-marl to Paleozoic schist-marble levels of Menderes Massif metamorphics at about 1415 m and 1375 m depths, respectively (Fig.3.5). For PS-1 well, the decrease in the LOI value in between 1375-1465 m levels can be attributed to a relative decrease in the abundance of carbonate rocks.

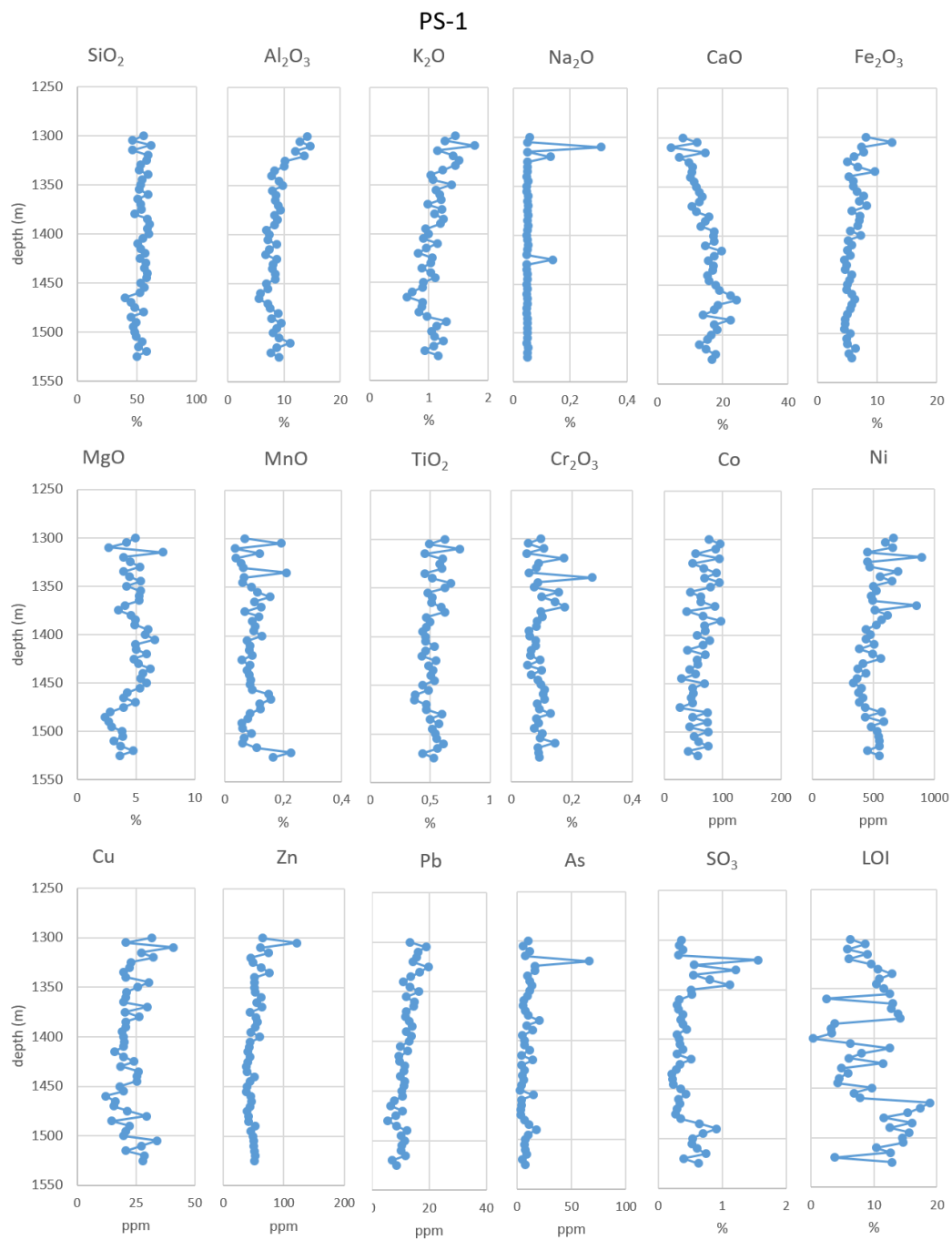


Figure 5.17. Major-minor oxide, trace element, loss on ignition (LOI) versus depth diagrams of the PS-1 well in Akköy field

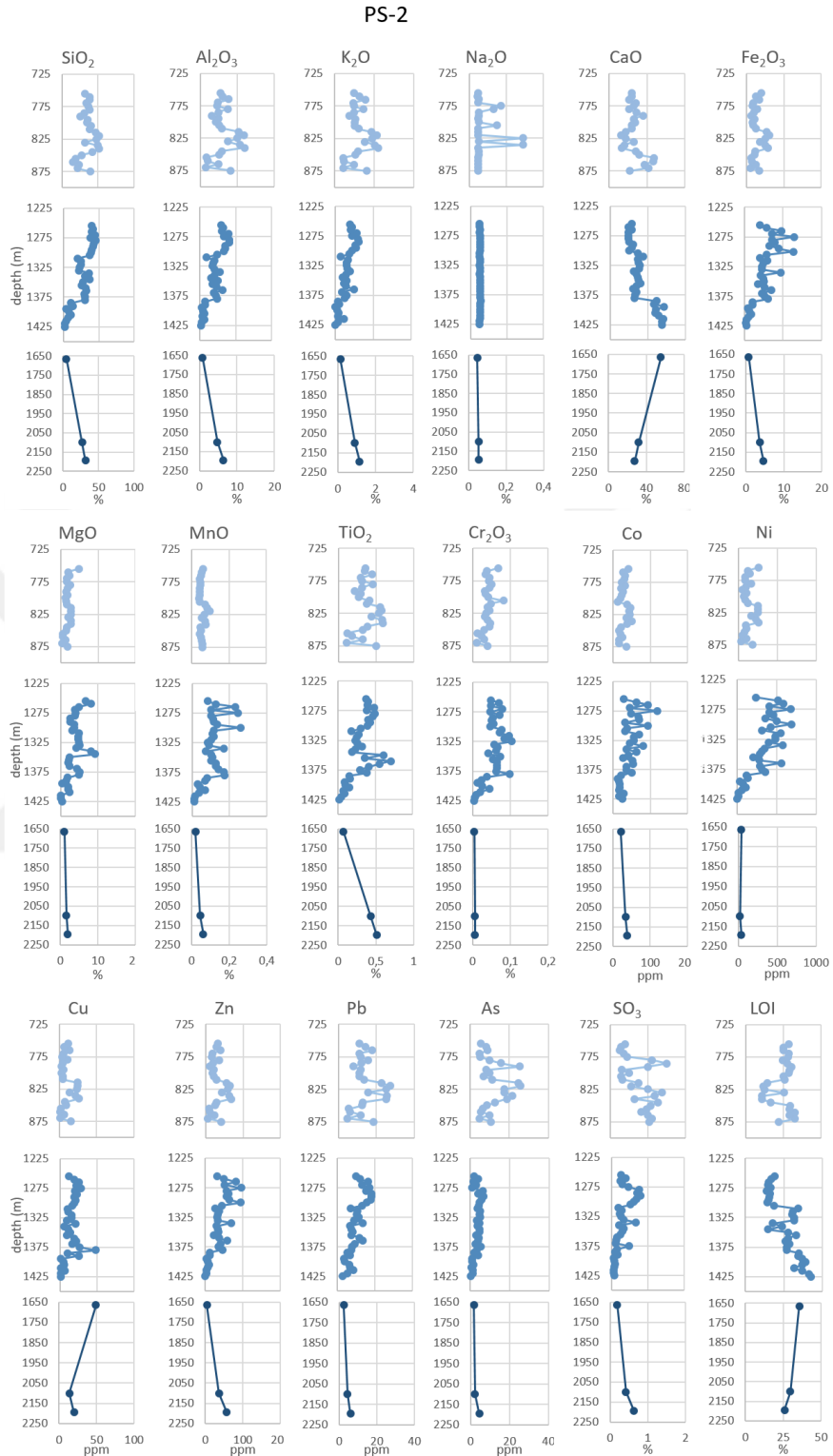


Figure 5.18. Major-minor oxide, trace element, loss on ignition (LOI) versus depth diagrams of the PS-2 well in Akköy field

5.4.2 Edremit Field

The XRF analysis results of EDJ-12 well of Edremit field are given in Appendix F. Three different concentration levels can be distinguished from the results of SiO₂, Al₂O₃, Fe₂O₃, MgO, MnO, TiO₂, Ni, Y, Zr, Pb, Th and SO₃ at depth intervals: 900-928 m, 930-974 m and 976-1038 m (Fig.5.19).

CaO values increase between 900-928 m, decrease between 930-984 m, start to increase again at 986 m. The increasing segments of the trend indicate the increasing abundance of Ca-bearing minerals (calcite and/or Ca-rich feldspar). On the other hand, SiO₂ and Al₂O₃ show inverse relation in terms of the trends they display against depth (e.g. results corresponding to 930-974 m depth interval yield relatively higher values for SiO₂ and lower values for Al₂O₃, with respect to the overlying and underlying levels). This observation might indicate the change in the relative abundances of quartz, feldspar and mica minerals.

MgO, Fe₂O₃, MnO, TiO₂ have higher values between 976-1038 m compared to the shallower levels. This increase can be attributed to the biotite abundance (coupled with Al₂O₃ content) observed in the samples, along with amphibole which is especially abundant between 990-1016 m, epidote and pyroxene (Figs.5.6d, 5.6e, 5.6f).

A conspicuous increase in SO₃ content at depths of ~966 and 980 m is also noted in XRF results which is coupled with an increase in the As content at 980 m (Fig.5.19). Given that the samples from these depths have highly fragmented appearance and abundant pyrite occurrence (Fig.5.4f), this increase points to sulphide mineralization possibly associated with hydrothermal brecciation.

A follow-up study for the paper (Elidemir et al., 2022) regarding the potential effect of alteration along the well bore in Edremit field is conducted with the CIA (Chemical Index of Alteration; Nesbitt and Young, 1982) and WIG (Weathering Index of Granite; Gong et al., 2013) indices which are used to describe the alteration and weathering intensities (Gong et al., 2016; Wu et al. 2021). The calculations are

performed with the utilization of major oxide contents and the results are qualitatively described according to the degree of alteration/weathering as incipient for $CIA < 60$ and $WIG > 60$, intermediate for $CIA = 60-80$ and $WIG = 20-60$, extreme for $CIA > 80$ and $WIG < 20$ (Wu et al. 2021 and the references therein). The calculated CIA and WIG values of the samples point to incipient and slightly intermediate degree of alteration (Fig.5.19). As the sensitivity of WIG is higher than CIA (Gong et al., 2013), more variations can be detected in WIG values and relatively notable decreases are observed around levels 930 and 976 m suggesting a hydrothermal activity.



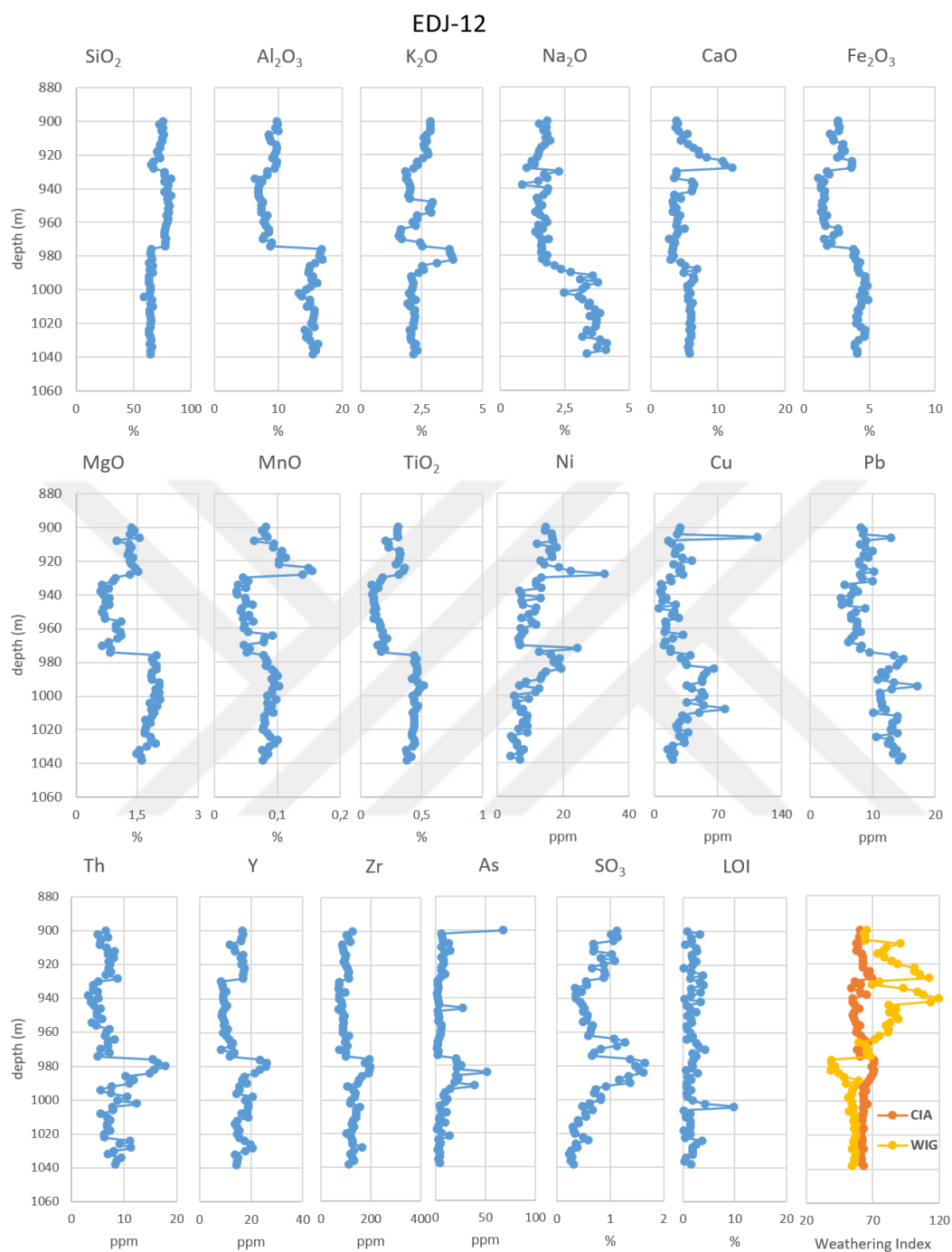


Figure 5.19. Major oxides, trace elements, loss on ignition (LOI) and the weathering indices of CIA and WIG variation diagrams with depth of the EDJ-12 well in Edremit field

5.5 Determination of the Modal Mineralogy

5.5.1 Akköy Field

Mineral percentages of the cutting samples from PS-1 and PS-2 wells are determined semi-quantitatively and selected results are visualised as pie charts (Figs.5.20, 5.21). The results indicate that silica and carbonate minerals are the main mineral phases in the rock samples. Mineral weight percentages of quartz and calcite are in the range of 27.6-52.9% and 0-26.6% in PS-1, 19.9-93.9% and 0-55.6% in PS-2, respectively. In average, clay minerals consist of approximately 16% in the samples of PS-1 while this ratio drops down to 8% in PS-2.

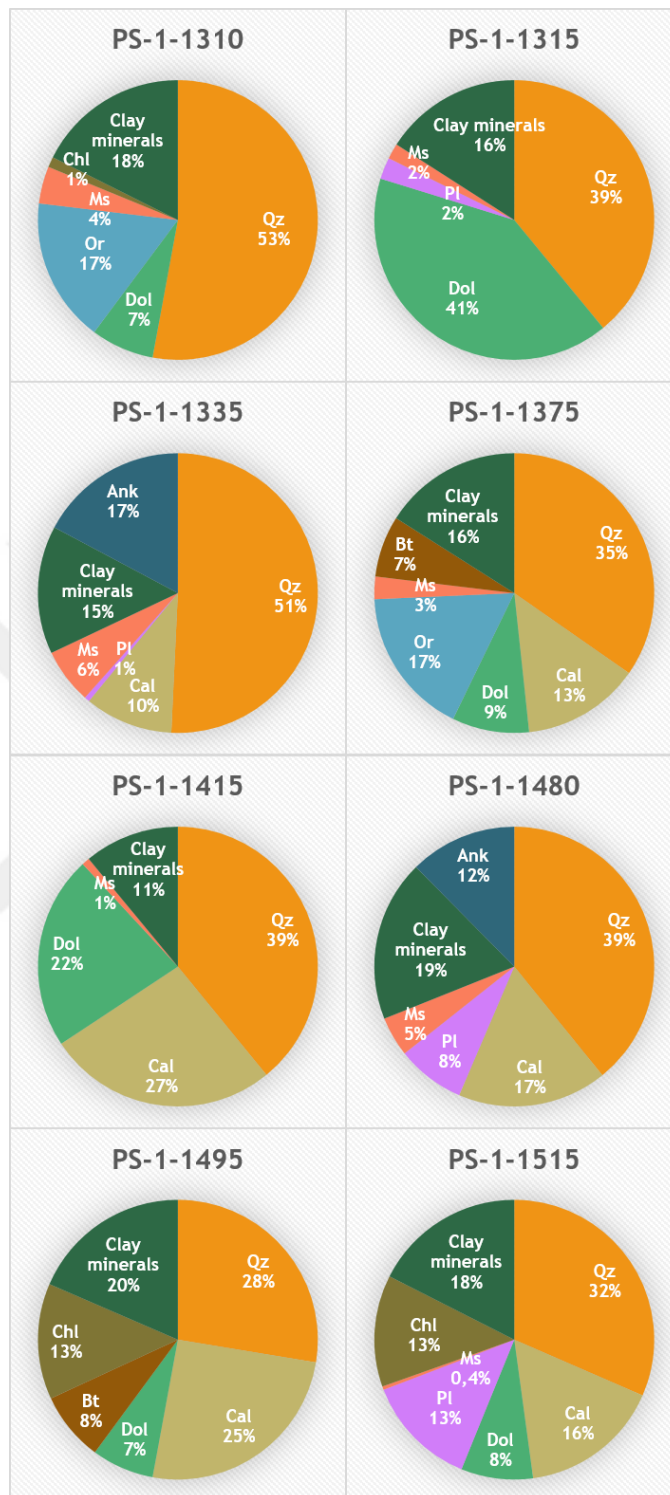


Figure 5.20. Mineral weight percentages of analysed samples from PS-1 well in Akköy field (Ank: ankerite, Bt: biotite, Cal: calcite, Chl: chlorite, Dol: dolomite, Ms: muscovite, Or: orthoclase, Pl: plagioclase, Qz: quartz)

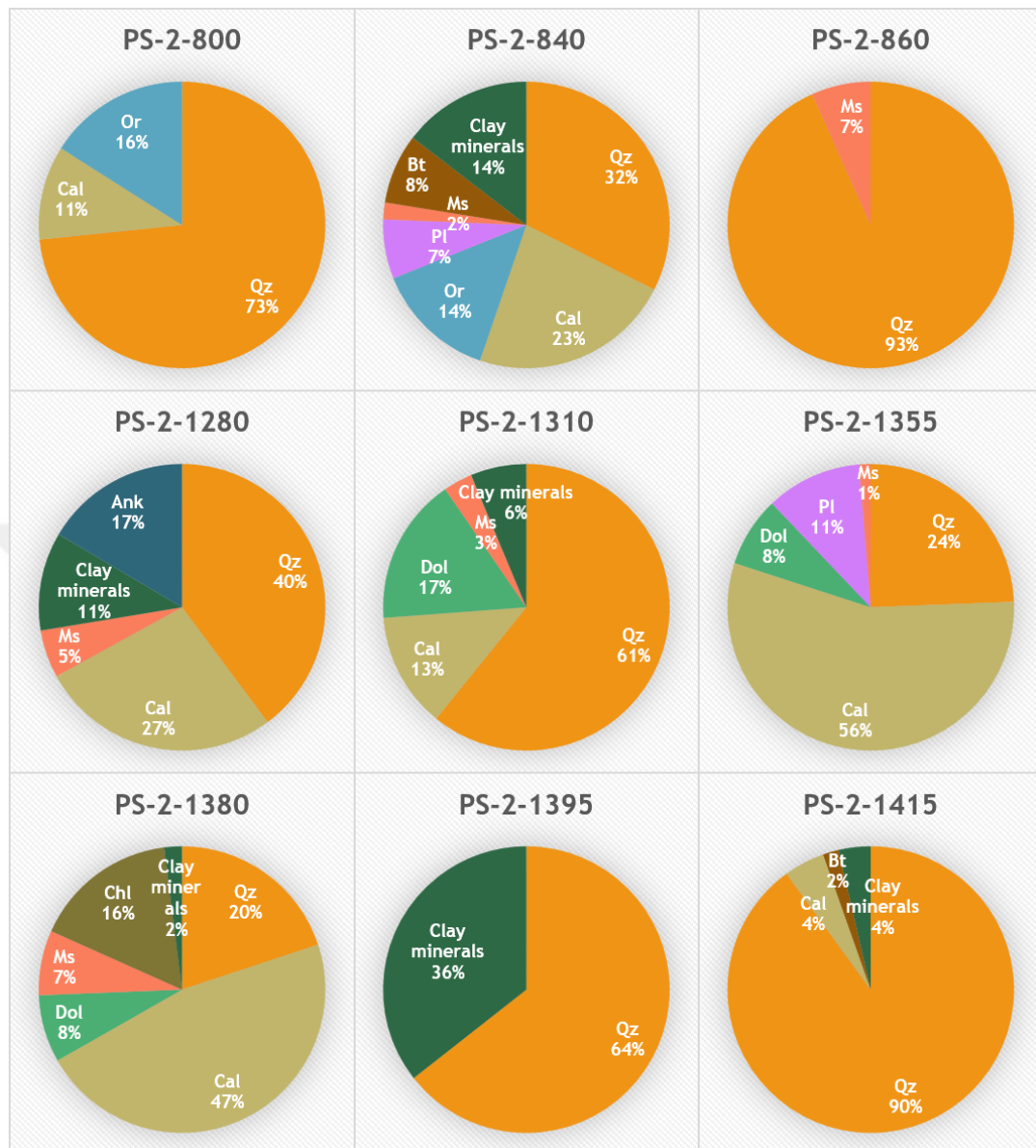


Figure 5.21. Mineral weight percentages of analysed samples from PS-2 well in Akköy field (Ank: ankerite, Bt: biotite, Cal: calcite, Chl: chlorite, Dol: dolomite, Ms: muscovite, Or: orthoclase, Pl: plagioclase, Qz: quartz)

5.5.2 Edremit Field

Pie charts depicting the weight percentages of minerals from EDJ-12 well samples determined from the XRD analyses' results are presented in Figure 5.22. The abundance of the primary minerals, quartz and orthoclase, ranges from 0-79.5% and 0-75.8%, respectively. Clay minerals constitute 8% of the samples in average.



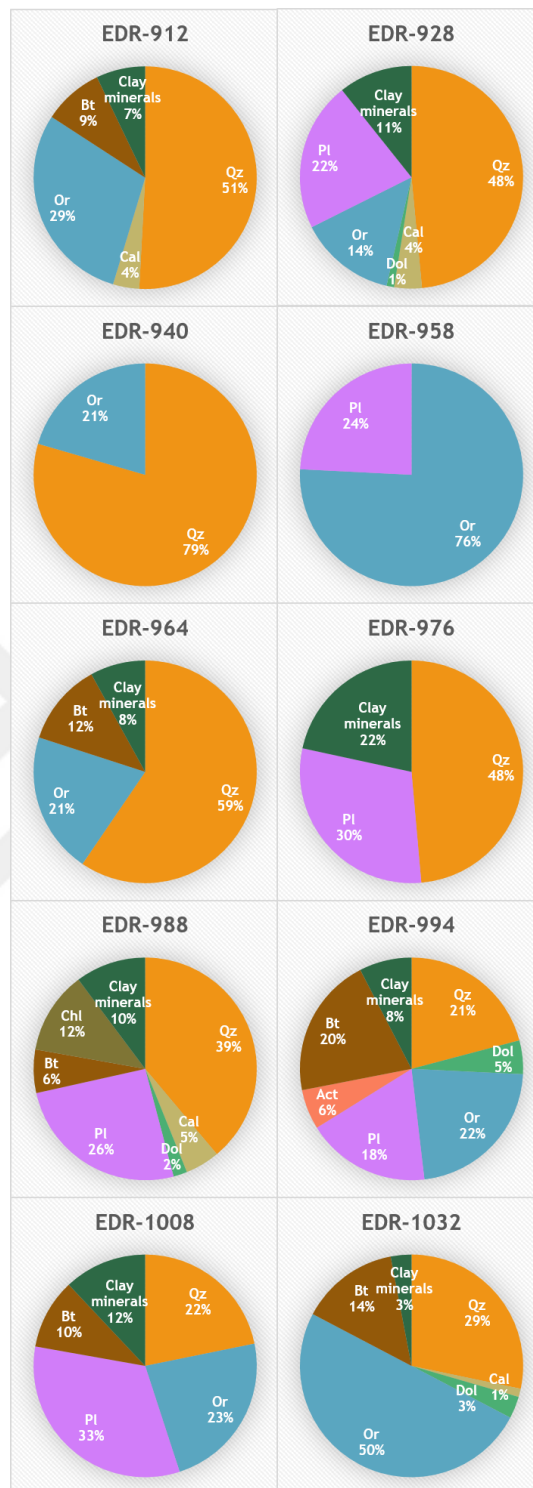


Figure 5.22. Mineral weight percentages of analysed samples from EDJ-12 well in Edremit field (Act: actinolite, Bt: biotite, Cal: calcite, Chl: chlorite, Dol: dolomite, Ms: muscovite, Or: orthoclase, Pl: plagioclase, Qz: quartz)

5.6 Comparison of the Lithogeochemical Results from Akköy & Edremit Fields

The investigations under microscope display that in the drill cuttings of Akköy field, dominant rock fragments are calcareous rocks (marble/limestone) and the main mineral phases include clayey carbonates and quartz. In Edremit samples, on the other hand, granitic rocks (granite/granodiorite) constitute the abundant fragments, while similar to Akköy field, quartz is the primary mineral. Fe-bearing minerals (hematite/limonite $\pm$ pyrite) present in both fields while pyrite is abundant in certain levels in both fields. XRD results are in favour of the previous findings regarding mineral species. CRS results of Edremit samples reveal more variety of silicate minerals (especially for feldspars and amphiboles) than in the samples of Akköy field. The feldspars of Akköy field seem to be more sodic in composition than the ones in Edremit.

Effects of the hydrothermal fluids on the samples and/or the indications for sulphide mineralization in Akköy and Edremit systems can be observed both in microscopic examinations and in the results of geochemical analyses (mainly EPMA and XRF).

In XRF results, SiO₂ values are higher in Edremit samples (>50%) while in Akköy, the amount is $\leq$ 50%. Edremit samples also have higher Na₂O (~1-4%, in Akköy <0.4%) values, the relatively higher results of these two elements (Si and Na) may be attributed to the abundance of feldspar minerals. On the other hand, CaO content seems to be higher in Akköy samples (~20% to 50% in some samples), than in Edremit samples (<~10%), pointing to the dominant carbonate lithology in Akköy, as observed in the lithogeochemical investigations. Although there are some exceptions, As and SO₃ values are similar in both fields which may indicate a similar intensity of hydrothermal fluid activity in these systems.

The averages of the mineral weight percentages as generally classified into mineral groups are calculated for both fields and tabulated in Table 5.3. Average calculations

are performed for 17 samples of Akköy and 10 samples of Edremit which are the samples studied for modal mineralogy.

Table 5.3 Comparison of the average modal mineralogy of the two fields

Field	Mineral Weight Percentage Averages (wt%)					
	Silica	Carbonates	Feldspars	Micas ^a	Clays	Other Minerals ^b
Akköy	47.84	27.23	6.18	4.22	11.95	2.58
Edremit	39.68	2.52	40.8	7.2	8.02	1.78

^amicas: muscovite+biotite for Akköy, only biotite for Edremit

^bother minerals: chlorite for Akköy, chlorite+actinolite for Edremit

Although quartz is the main mineral in both systems as also determined by previous studies, some differences in the modal mineralogies can be observed in Akköy and Edremit fields. In the samples of Akköy field, carbonate minerals have higher percentage than in Edremit samples, while in Edremit, feldspars are more abundant than in Akköy. The percentage of clay minerals is higher in the samples of Akköy field than the samples of Edremit.

These differences in mineralogy will potentially yield different modelling results in terms of CO₂-water-rock interactions.

5.7 Geochemical Implications for Possible Fault Zones of Edremit Field

Lithogeochemical characterization of Edremit geothermal field realized through the analyses of a total of 70 drill cuttings from EDJ-12 well in terms of their mineralogic-petrographic and geochemical properties against depth, has revealed three distinctive zones along the wellbore (Elidemir et al., 2022). The variations in rock fragments associated with chemical changes with increasing depth are visualized in Fig.5.23.

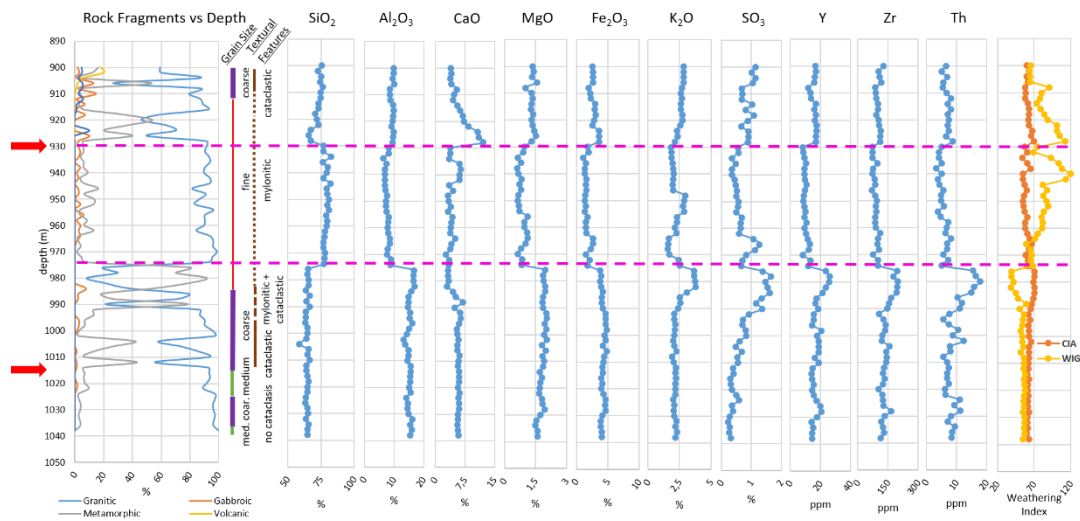


Figure 5.23. Correlation of variations in rock fragment percentages, grain sizes and element concentrations (SiO_2 , Al_2O_3 , CaO , MgO , Fe_2O_3 , K_2O , SO_3 , Y, Zr and Th) and the weathering indices of CIA and WIG of samples with depth in Edremit field (red arrows represent reported water leakage zones)

The effect of alteration which occurs as a result of fluid-rock interactions, changes proportionally with respect to the distance from the flow paths of hydrothermal fluid in a geothermal system (Warren et al., 2007). Variations in concentrations of both mobile and immobile elements with increasing depth, provide valuable information regarding fluid flow zones and lithologic correlations, respectively (Gifkins et al., 2005; Mauriohooho et al., 2016). The elements which are relatively mobile and can be easily transported in migrating fluids during hydrothermal activity are Si, Fe, Mg, Ca, Na, in addition to the large ion lithophile elements of Sr, K, Rb and Ba (and sometimes Th) due to their low ionic potential (Pearce, 1982; Gifkins et al., 2005; Franzson et al., 2008). Al and high field strength elements such as Ti, Zr and Y constitute the elements which remain relatively immobile and therefore, unlikely to undergo geochemical changes during hydrothermal alteration (Wagner and Jochum, 2002; Gifkins et al., 2005; Franzson et al., 2008; Mauriohooho et al., 2016). Consequently, whole rock geochemistry results which correlate well with the petrographical changes and bring out three distinctive zones (Fig.5.23), can be used

to elaborate on the hydrothermal fluid pathways. Since the reported leakage is from 930 m depth, the part in between 928-976 meters is likely to belong to the fluid path of the system. Moreover, the results show inverse relationship of SiO_2 with other major elements (Figs.5.19, 5.23) which may indicate the presence of a Si-rich hydrothermal fluid. This can also explain the slightly silica-oversaturated nature of the geothermal waters in the field as reported by Avşar et al. (2013). Earlier alteration studies explain that as a result of Si-rich fluid input to a system, the precipitation of silica within the pore spaces leads to the loss of FeO, MgO, CaO, K_2O , MnO and other metals from the rocks (Gifkins et al., 2005 and the references therein). The chemical variations identified with whole rock geochemistry results are also supported by the textural features which imply metasomatism (Fig.5.7d) and secondary uranization (Figs.5.7e, 5.7f).

Another indication of a flow path being present in the middle section of the downhole well plot, is the textural properties of the samples (Fig.5.23). The changes from cataclastic texture around the levels of 910 m to mylonitic texture towards 920 m, point to the proximity of the fault zone. From mortar texture to cataclastic texture, these features implicate areas that are at the edge of a fault. Mylonitic texture associated with fine grained rock fragments showing increased degree of deformation (Rankin, 1982) corresponds to the core of the fault zone. Therefore, textural features are in agreement with the geochemical observations regarding the location of hydrothermal fluid path and fault zone.

WIG calculations (Figs.5.19, 5.23) also point to the presence of a hydrothermal activity in various levels. A slightly increased degree of alteration is observed especially around 930 and 976 m depths. Although WIG values increase around 940 m (indicating decreasing alteration), this increase can be attributed to higher carbonate content (Gong et al., 2015) which is coupled with a small increase in CaO values in these levels (which is also the case in 928 m depth). After 942 m, the intensity of alteration starts increasing towards deeper levels. Moreover, the part from 976 to 1038 m displays an increased alteration effect in comparison with shallower levels.

The presence of fault zones and fluid paths inferred from this study are likely to correspond to the deep buried fault zones previously mentioned in Avşar (2011) and Avşar et al. (2013). The piezometric surface contour maps reported in these studies (and the references therein), point to two buried faults, the intersection of which shows a potentiometric (piezometric) high. The intersection is also revealed in the electrical resistivity surveys displaying low resistivity anomalies. It was reported that geothermal fluid ascends towards upper levels through this intersection of the buried faults.

A notable remark is that CRS and EPMA results suggest that towards deeper levels, the abundance of Ca-bearing minerals (feldspars and amphiboles) increases. This observation is in agreement with the remark of Avşar et al. (2013) that hydrogeochemistry of geothermal waters suggests increase in the calcite saturation index with increasing temperature (corresponding to increasing depth) in the field. Moreover, in the sample EDR-1032 from 1032 m depth, the plagioclase grains are characterized by reverse zoning, coupled with the increased Ca content as determined from the Raman spectrums of plagioclase minerals. Calculated WIG index values also suggest a change in the alteration degree towards deeper levels. These observations, combined with the information regarding a water leakage zone at 1015 m depth, might point to the presence of another fluid path around these levels.

CHAPTER 6

HYDROGEOCHEMICAL CHARACTERIZATION

Geochemical studies are performed on two water samples collected from PS-1 well-head in Akköy geothermal field. The results of the analyses lead up to i) the assessment of hydrogeochemical facies of the geothermal waters, ii) the estimation of possible reservoir temperature with geothermometry applications, iii) the evaluation of minerals for the potential of scaling with speciation–solubility calculations and iv) insight regarding the origin of fluids. While geochemical properties of Akköy water samples are personally investigated, for Edremit, the findings from the 2013 study of Avşar et al. are compiled in this chapter.

6.1 Geochemical Composition & Water Types

6.1.1 Akköy Field

The hydrochemical analyses results of the water samples collected in 2018 and 2021 from PS-1 well in Akköy field, are presented in Table 6.1 and major anion-cation concentrations are illustrated as Schoeller diagram in Figure 6.1. The waters are of alkaline-bicarbonate-sulphate ($\text{Na}+\text{K}-\text{HCO}_3-\text{SO}_4$) type and in three years although an increase in Ca and SO_4 contents is observed, there is no significant change in the hydrogeochemical facies of the thermal waters.

Table 6.1 Chemical analyses' results of the water samples from PS-1 well in Akköy field

PS-1	2018	2021
T (°C)*	81	-
pH*	7.6	-
EC (µS/cm)*	4371	-
Na (mg/l)	703	642
NH ₄ (mg/l)	24	<0.064
K (mg/l)	135	91
Mg (mg/l)	60	41
Ca (mg/l)	265	354
CO ₃ (mg/l)	0	0
HCO ₃ (mg/l)	1789	1679
F (mg/l)	3.3	4.1
Cl (mg/l)	73	72
NO ₂ (mg/l)	<0.05	0.55
NO ₃ (mg/l)	6.9	10.6
PO ₄ (mg/l)	295	-
SO ₄ (mg/l)	894	1295
Fe (µg/l)	349	-
Al (µg/l)	20.11	-
SiO ₂ (mg/l)	69	75
CBE	2.11	-4.79

*Well-head measurements (on-site)

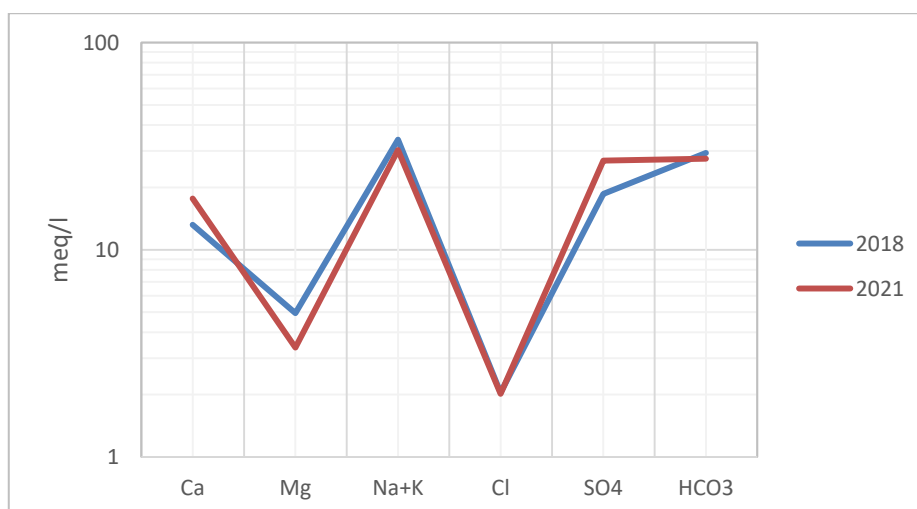


Figure 6.1. Schoeller diagram of waters from PS-1 well in Akköy field

The compositions of the waters are likely to be affected by water-rock interactions. Metamorphics (schist-calcschist-marble-quartzite) which comprise the reservoir rocks of the system provide the calcium, sodium and bicarbonate ions to the waters while S-bearing minerals are the potential source for SO₄ contents. High sodium values can also be attributed to the dissolution of Na-plagioclases (Fig.5.13a).

6.1.2 Edremit Field

There was no water data available for the studied EDJ-12 well and hence, previously published data of water samples from different wells in Edremit field (Avşar 2011; Avşar et al. 2013) are used in this study. As determined from major anion-cation contents of the waters of Edremit field (Avşar et al., 2013), hydrogeochemical facies are divided into three types according to the temperature ranges of the samples. The waters with measured temperature values are higher than 40°C are of Na + K – SO₄ type, the ones in between 30-40°C are of Ca – SO₄ type and relatively colder waters (<30°C) are of Ca – HCO₃ type (Fig.6.2). Possible processes that govern the system are identified as mixing and water-rock interactions.

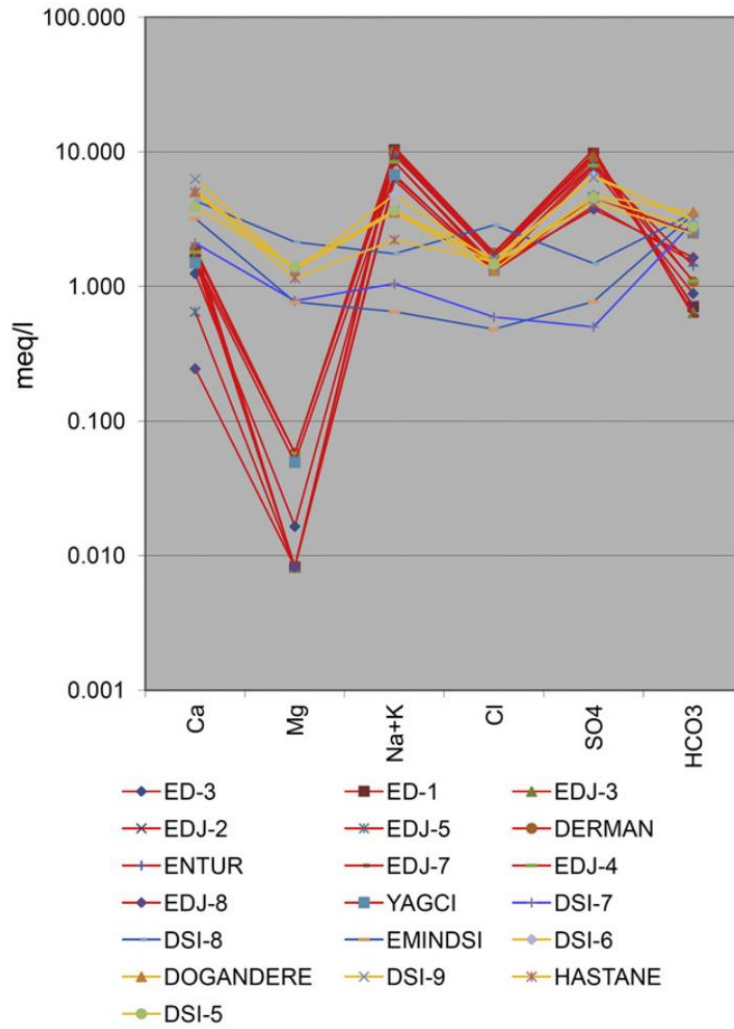


Figure 6.2. Schoeller diagram of waters from Edremit geothermal field (red: >40°C, orange: 30–40°C, blue: <30°C) (from Avşar et al., 2013)

6.2 Isotopic Compositions

6.2.1 Akköy Field

Stable isotope composition of the water sample collected in 2021 from PS-1 well is presented in Table 6.2 and plotted in $\delta^{18}\text{O}$ - δD diagram (Fig.6.3). The position of the

sample with respect to the Global Meteoric Water Line (GMWL) points to a meteoric source. C-isotope composition indicates that carbon content of the water originates from the dissolution of carbonate rocks ($\delta^{13}\text{C} = 0\text{‰}$; Sano and Marty, 1995). The determination of the original C-isotope composition of the system is of critical importance with regard to the monitoring of injected CO_2 in a possible carbon storage project.

Table 6.2 Stable isotope analysis results of the water sample from PS-1 well in Akköy field

Sample	$\delta^{18}\text{O}\text{‰}$ (VSMOW)	$\delta^2\text{H}\text{‰}$ (VSMOW)	$\delta^{13}\text{C-DIC}\text{‰}$ (VPDB)
PS-1.2021	-9.04	-67.51	1.07

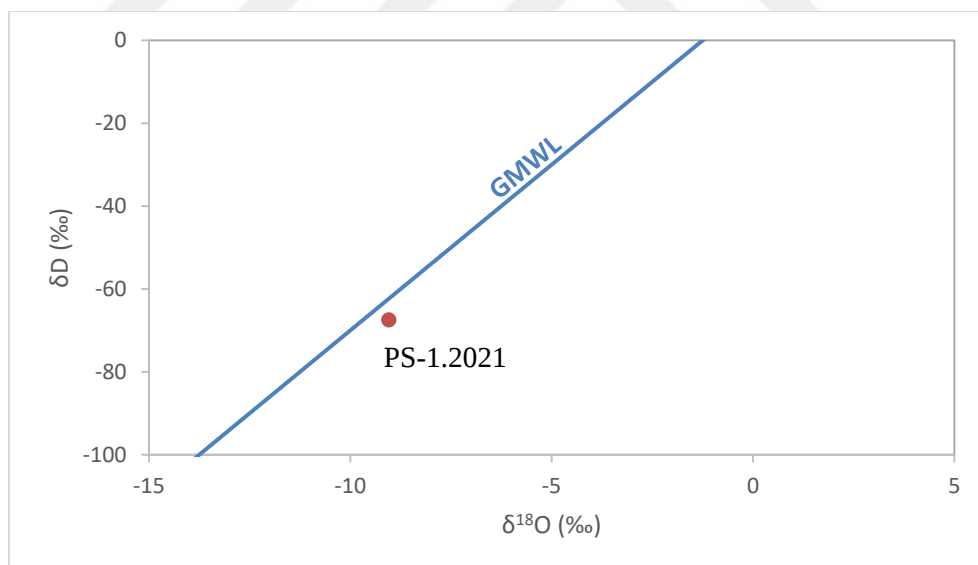


Figure 6.3. $\delta^{18}\text{O}$ - δD diagram for the water sample from PS-1 well in Akköy field (GMWL: Global Meteoric Water Line ($\delta\text{D} = 8 \delta^{18}\text{O} + 10$) (Craig, 1961))

Since only one production well is present in the field, the estimation of recharge altitude with $\delta^{18}\text{O}$ and δD isotopes is performed using the equations that are previously determined for Gölemezli and Pamukkale areas (Yıldırım and Güner, 2002; Alçiçek et al., 2019). The calculations result in between 1524 to 1543 m indicating that the possible recharge source of the waters is Babadağ Mountain (Fig.3.3). This implication is in accordance with the fluid circulation pathways depicted in conceptual models of the area (Şimşek, 1985; Alçiçek et al., 2019).

6.2.2 Edremit Field

Stable isotope compositions of Edremit waters display a range of -9.47‰ to -6.71‰ for $\delta^{18}\text{O}$, and -52.22‰ to -38.72‰ for δD values (Avşar et al., 2013), indicating a meteoric source according to the Global Meteoric Water Line (GMWL) plot of the samples (Fig.6.4). It is reported in Avşar et al. (2013) that relatively hot waters have lower $\delta^{18}\text{O}$ and δD values than colder waters, pointing to higher and lower recharge altitudes, respectively. The distribution of the waters also indicates mixing as a possible subsurface process. C-isotope values of the samples range between -14.4‰ to -9.1‰ (Avşar et al., 2013), indicating an organic source (Sano and Marty, 1995).

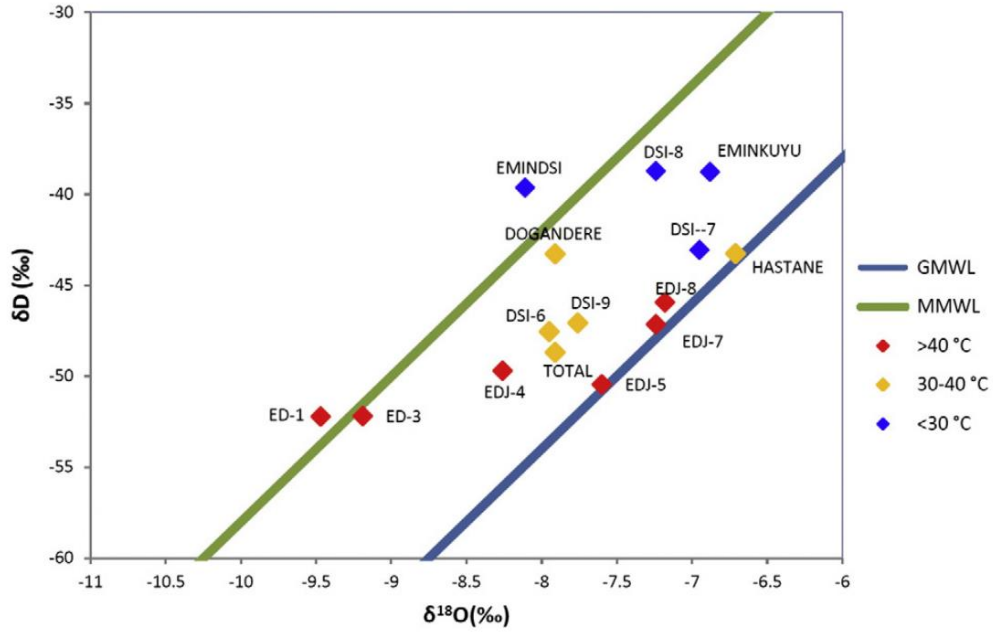


Figure 6.4. $\delta^{18}\text{O}$ - δD diagram for the water samples of Edremit field (MMWL: Mediterranean Meteoric Water Line (IAEA, 1981); GMWL: Global Meteoric Water Line ($\delta\text{D} = 8 \delta^{18}\text{O} + 10$) (Craig, 1961); red: $>40^\circ\text{C}$, orange: $30\text{--}40^\circ\text{C}$, blue: $<30^\circ\text{C}$) (from Avşar et al., 2013)

6.3 Geothermometry Applications

6.3.1 Akköy Field

Reservoir temperature estimations are carried out through the use of silica and cation geothermometers (Table 6.3). The maturity of the waters that reflects the physical-chemical balance between the fluid and the host rock is evaluated with Na-K-Mg ternary diagram developed by Giggenbach (1988) for the determination of the applicability of geothermometers (Fig.6.5). The samples plot into immature water zone indicating ongoing water-rock interactions.

Table 6.3 Chemical geothermometer results of Akköy samples (values in °C)

PS-1	Quartz ^a	Quartz-max. steam loss ^a	Chalcedony ^a	Na/K ^b	Na/K ^c	Na/K ^d	Na/K ^e	Na/K ^f	Na-K-Ca ^g	K-Mg ^e
2018	117	116	88	280	270	273	290	283	222	110
2021	122	120	94	249	228	233	262	238	198	104

^aFournier, 1977

^eGiggenbach, 1988

^bFournier, 1979

^fTonani, 1980

^cTruesdell, 1976

^gFournier & Truesdell, 1973

^dArnorsson et al., 1983

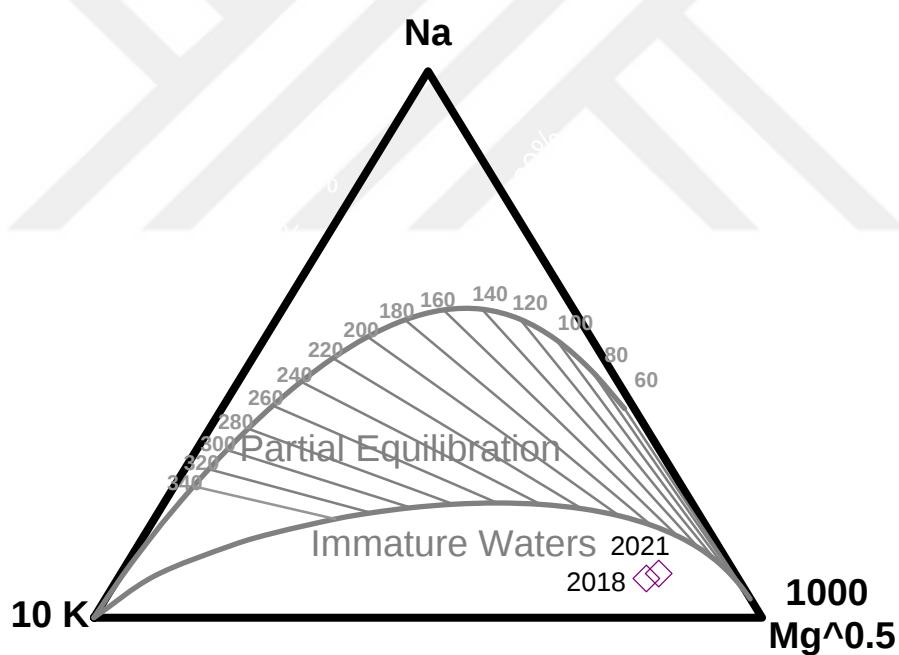


Figure 6.5. Na-K-Mg ternary diagram of Akköy water samples (Giggenbach, 1988)

Temperatures calculated with silica geothermometers vary between 88-122°C, while cation geothermometer estimations (except K-Mg) result in the range of 198-290°C. Given that the samples are classified as immature waters, silica geothermometers are considered to yield more reliable results and hence, the estimated reservoir temperature is in the 88-122°C range.

6.3.2 Edremit Field

Silica (quartz) and cation geothermometers (Na/K) are used for the calculation of the possible reservoir temperature in Edremit field (Avşar et al., 2013). The results produce a temperature range of 92-211°C.

6.4 Mineral Saturation States

6.4.1 Akköy Field

Saturation index (SI) calculations are performed for the minerals that are likely to be present in a carbonate dominated system at discharge temperature and pH conditions measured on-site (81°C and 7.6, respectively, Table 6.1). The Akköy water samples are undersaturated with anhydrite, dawsonite, gypsum, kaolinite and siderite, oversaturated with albite, aragonite, calcite, chalcedony, diopside, dolomite, illite, orthoclase, magnesite, quartz and smectite. The results point to the likely precipitation of most of the carbonate and silicate minerals in the system which is also in line with the travertine deposition observed extensively in the surrounding geothermal systems (e.g. Pamukkale, Karahayit, Gölemezli and Yenice, Şimşek, 2003; Tarcan et al., 2016; Alçiçek et al., 2016, 2018, 2019; Brogi et al., 2021).

Given the assumption that minerals and fluid in the reservoir are in a temperature-dependent chemical equilibrium, the temperatures at which the mineral saturation indices equal to zero (i.e. $SI = 0$, the fluid and mineral are at chemical equilibrium) are considered to reflect the reservoir temperatures. In this regard, the saturation

states of minerals are also investigated at different temperatures in the range of 60-150°C including the discharge temperature ($T = 81^{\circ}\text{C}$) and temperature range obtained from silica geothermometers (88-122°C, Table 6.3). The results display that the SI values generally intersect with the equilibrium line in the range of 88-116°C (Fig.6.6). The comparison of the temperature estimations obtained from chemical geothermometers with the ones calculated by fluid mineral equilibria reveals a zone of overlap. Therefore, the most likely reservoir temperature for Akköy geothermal field is considered to be in the range of 88-116°C. In this range, the SI values of albite, chalcedony and illite minerals which point to oversaturation at discharge temperature, indicate undersaturation in the estimated reservoir conditions. Below 88°C the waters are undersaturated with anhydrite, dawsonite, gypsum, siderite, close to equilibrium and oversaturated with albite, aragonite, calcite, chalcedony, diopside, dolomite, illite, orthoclase, kaolinite, magnesite, quartz, smectite, while above 116°C the waters become undersaturated with albite, chalcedony, illite, orthoclase, kaolinite, quartz and close to equilibrium and oversaturated with anhydrite, siderite. On the other hand, at all temperatures the waters are oversaturated with carbonate minerals aragonite, calcite, dolomite and magnesite and the degree of oversaturation increases with increasing temperature.

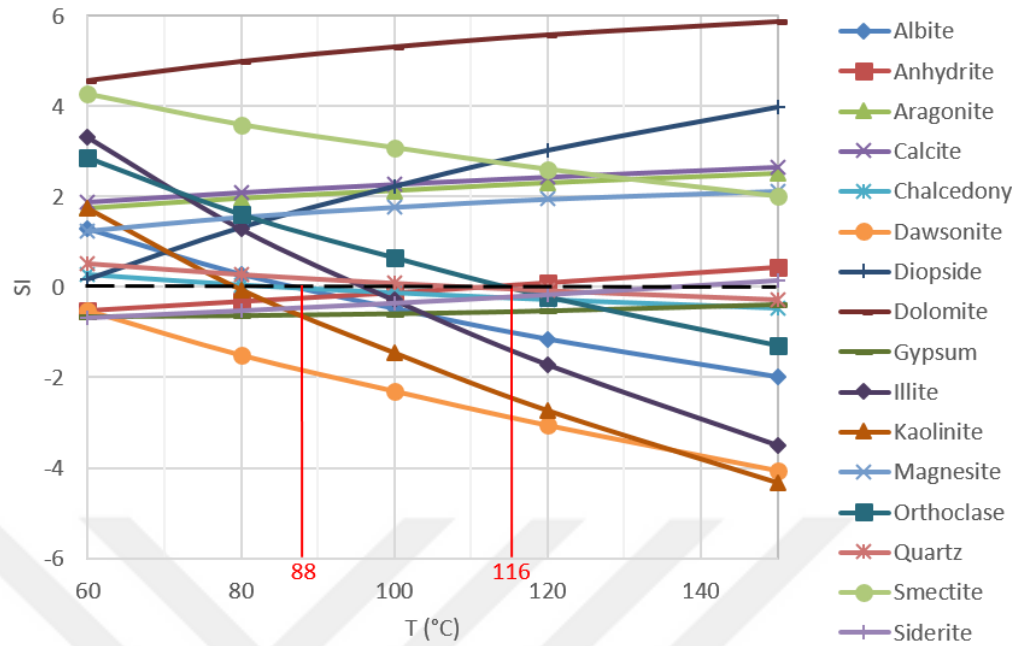


Figure 6.6. Changes in the saturation states of minerals at different temperatures of Akköy field

6.4.2 Edremit Field

Calculations for saturation indices of minerals (Avşar et al., 2013) indicate that over 110°C all waters are oversaturated with calcite, whereas below 90°C most of the samples are oversaturated with respect to quartz. Calcite oversaturation is not observed at the discharge temperatures of 42–62°C leading Avşar et al. (2013) to suggest that scaling is not a probable threat during production in the system.

Saturation index calculations conducted with predetermined alteration minerals are also utilized for the reservoir temperature estimations (Avşar et al., 2013). In this regard, the predicted temperature values are in the range of 60-150°C which show an overlap with the chemical geothermometer result of 92-211°C. Consequently, the

range estimated for the reservoir temperature of Edremit field is in between 92-150°C.

6.5 Comparison of the Hydrogeochemical Results from Akköy & Edremit Fields

Hydrogeochemical facies of the fields indicate that in both geothermal fields, the waters are in alkaline character (except for the relatively cold waters in Edremit) and SO_4 is the major anion (coupled with HCO_3 in Akköy, given the abundance of carbonate minerals).

Water-rock interactions are the effective subsurface processes controlling the geochemical characteristics of both of the systems. In addition, Edremit waters seem to be affected by mixing as well. $\delta^{18}\text{O}$ and δD isotope compositions of both fields suggest a meteoric origin. C-isotopes point to carbonate and organic sources for Akköy and Edremit fields, respectively.

Geothermometry calculations in parallel with fluid mineral equilibria, reveal the estimated reservoir temperatures are in the ranges of 88-116°C and 92-150°C for Akköy and Edremit fields, respectively, indicating a relatively higher temperature for Edremit system. Especially with increasing temperatures, likely carbonate oversaturation is observed in both fields according to the mineral saturations states.

CHAPTER 7

MODELLING OF CO₂-FLUID-ROCK INTERACTIONS

Geochemistry is an important tool in the determination of the fate of CO₂ in the subsurface during the implementation of a CCS project. The injection of CO₂ into a reservoir affects the chemistry of that system which may pose a risk for the wells, the reservoir and its surroundings. Therefore, the success of CO₂ injection and storage depends highly on understanding the subsurface behaviour of CO₂ and its interactions with the water and the rocks of the reservoir (Gaus et al., 2008). Experimental studies in laboratories may have limitations with respect to time, space and reservoir conditions, while thorough evaluation and prediction of the geochemical processes are possible with the geochemical modelling studies. In this regard, computer codes such as PHREEQC, TOUGHREACT and The Geochemist's Workbench are widely used for the geochemical simulations. Being an easily accessible and a prominent tool in geochemical studies for various applications, PHREEQC is especially endorsed by numerous literature work due to its competence of producing correct results (Hemme and van Berk, 2017 and the references therein).

The basis of geochemical models are comprised by three main processes: thermodynamics, reaction kinetics and flow and transport processes. The models in which the flow and transport processes are not taken into account, are named as “batch models”, whereas the models that couple geochemical reactions, flow and transport processes are called as “reactive transport models” (Gündoğan, 2011).

Thermodynamic Equilibrium Modelling (Speciation modelling): This is the most basic and common type of modelling. Distribution of species, their activities, saturation index values, redox state and the fugacities of the gases in the system can be calculated based on the assumption of thermodynamic equilibrium.

Kinetic Modelling: Thermodynamic equilibrium modelling approach does not take “time” into account and it is suitable for fast reactions. However, in a CO₂ storage scenario, it is important to know when the system reaches equilibrium again after the addition of CO₂ to the reservoir. This “time” variable for slow reactions (such as mineral dissolution and precipitation reactions) can be obtained through kinetic modelling.

Reactive Transport Modelling: With the injection of CO₂ into the reservoir, the balance of the system is disrupted and the equilibrium conditions are affected; flow and transport processes should be considered for the geochemical reactions. As a result, the static system (batch models) should be coupled with the flow and transport processes. In this modelling approach, the evolution of the geochemical reactions can be simulated temporally and spatially. PHREEQC software is capable of performing 1-D transport simulations coupling the equations of transport and chemical interaction with a sequential solution method (Addassi et al., 2021).

Batch models constitute a valuable tool for the establishment of the static system which includes the identification of the key reactions, aqueous species and minerals to be used as inputs for the reactive transport modelling. For the geochemical modelling of CO₂ storage, although being the most challenging technique, the reactive transport modelling is the most suitable and realistic approach due to its capabilities in the prediction of the distribution of the geochemical reactions in time and space and its ability to quantify the long-term fate of CO₂ (Gaus et al., 2008; Gündoğan, 2011).

In this study, potential fluid-rock interactions of Akköy and Edremit geothermal systems are investigated in the case of CO₂ addition with the utilization of PHREEQC software. Equilibrium, kinetic and reactive transport modelling studies are performed on the drill cutting and water samples of the relevant fields. Equilibrium modelling provides the assessment regarding the changes in fluid chemistry and mineral compositions. The dissolution/precipitation reactions that govern the systems are identified in this modelling step. Most likely trapping

mechanisms for CO₂ storage are also deduced with equilibrium modelling results. In kinetic modelling, the reactions determined via equilibrium modelling are evaluated in terms of their temporal evolutions. Comprising the final stage of the geochemical modelling studies, the spatial distribution of the reactants (i.e. minerals) is simulated with reactive transport modelling. 3 samples from each field (ADK-PS-1-1515, ADK-PS-2-840, ADK-PS-2-1380 from Akköy and EDR-912, EDR-988, EDR-1008 from Edremit) are investigated extensively in this chapter, while the modelling results of remaining samples are presented in Appendices G and H.

7.1 Input Data for the Models

Amount of minerals in moles and composition of a water sample are the principal data required for the modelling. The data used in this study as inputs are, i) “representative” rock samples that were quantified by the weight proportions of the minerals (Akköy: 10 samples and Edremit: 8 samples) (Table 7.1, 7.2, Appendix G), ii) water sample collected in 2018 from PS-1 well for Akköy, iii) EDJ-7 well data from Avşar et al. (2013) for Edremit and iv) highest estimated temperatures calculated from the geothermometry applications (116°C and 150°C for Akköy and Edremit, respectively) (Table 7.3). Since Electrical Conductivity (EC) value is used as an indicator of the hydrogeochemical evolution of the system, among the water samples studied in Avşar et al. (2013) the one with the highest EC value is used in this study (EDJ-7).

Table 7.1 Reservoir rock mineralogy of the simulated samples from Akköy field used as input values in the modelling studies

Mineral	Chemical Formula	Molecular Weight (g/mol)	PS-1-1515		PS-2-840		PS-2-1380	
			Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)
Albite	NaAlSi ₃ O ₈	263.02	13	37.27	6.7	19.21	-	-
Ankerite	CaMg _{0.3} Fe _{0.7} (CO ₃) ₂	206.39	-	-	-	-	-	-
Biotite	KFe ₃ AlSi ₃ O ₁₀ (OH) ₂	511.88	-	-	7.9	11.64	-	-
Calcite	CaCO ₃	100.09	16.3	122.81	22.8	171.78	46.8	352.61
Chlorite	Fe ₂ Al ₂ SiO ₅ (OH) ₄	341.76	12.9	28	-	-	16.3	35.97
Dolomite	CaMg(CO ₃) ₂	184.4	8.3	34	-	-	7.6	31.08
Illite	K _{0.6} Mg _{0.25} Al _{1.8} Al _{0.5} Si _{3.5} O ₁₀ (OH) ₂	383.9	-	-	12.4	24.36	-	-
Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	258.16	17.5	51	-	-	2	5.84
Muscovite	KAl ₃ Si ₃ O ₁₀ (OH) ₂	398.71	0.4	0.76	1.9	3.59	7.3	13.81
Orthoclase	KAlSi ₃ O ₈	278.33	-	-	13.7	37.12	-	-
Quartz	SiO ₂	60.08	31.5	395.38	32.5	407.94	19.9	249.78
Smectite	Ca _{0.2} Na _{1.5} K ₂ Fe _{4.5} Mg ₉ Al _{1.25} Si _{3.75} H ₂ O ₁₂	392.13	-	-	2.2	4.23	-	-

Table 7.2 Reservoir rock mineralogy of the simulated samples from Edremit field used as input values in the modelling studies

Mineral	Chemical Formula	Molecular Weight (g/mol)	EDR-912		EDR-988		EDR-1008	
			Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)
Albite	NaAlSi ₃ O ₈	263.02	-	-	25.6	50.86	-	-
Amphibole	NaCa ₂ Al ₃ Mg ₄ Si ₆ O ₂₂ (OH) ₂	835.83	-	-	-	-	-	-
Biotite	KAlMg ₃ Si ₃ O ₁₀ (OH) ₂	417.26	14.3	17.91	6.3	7.89	10.2	12.77
Bytownite	Na _{0.2} Ca _{0.8} Al _{1.8} Si _{2.2} O ₈	275.01	-	-	-	-	-	-
Calcite	CaCO ₃	100.09	1.2	6.26	5	26.1	-	-
Chlorite	Fe ₂ Al ₂ SiO ₅ (OH) ₄	341.76	-	-	12	18.35	-	-
Dolomite	CaMg(CO ₃) ₂	184.4	3.2	9.07	2	5.67	-	-
Illite	K _{0.6} Mg _{0.25} Al _{1.8} Al _{0.5} Si _{3.5} O ₁₀ (OH) ₂	383.9	-	-	-	-	11.4	15.52
Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	258.16	3	6.07	10.2	20.64	0.6	1.21
Labradorite	Na _{0.4} Ca _{0.6} Al _{1.6} Si _{2.4} O ₈	271.81	-	-	-	-	32.8	63.05
Orthoclase	KAlSi ₃ O ₈	278.33	50	93.86	-	-	23.2	43.55
Quartz	SiO ₂	60.08	28.3	246.12	38.9	338.3	21.8	189.59

Table 7.3 Hydrochemical data used in the modelling studies

PS-1	PS-1.2018	EDJ-7
T (°C)*	116	150
pH	7.6	7.61
SiO ₂ (mg/l)	69	48
Na (mg/l)	703	246
K (mg/l)	135	5.7
Mg (mg/l)	60	0.1
Ca (mg/l)	265	39
HCO ₃ (mg/l)	1789	37
Cl (mg/l)	73	63
NO ₃ (mg/l)	6.9	0.22
SO ₄ (mg/l)	894	500
Fe (µg/l)	349	79
Al (µg/l)	20.11	88

*highest estimated reservoir temperature from the geothermometry calculations

Molar amounts of minerals are calculated with the equation 4.1, using the values of rock density and porosity (for the calculation of rock volume) assigned as 2630 kg/m³ and 3.37% for Akköy (following the study of Janssen et al., 2023 in Kızıldere field), 2750 kg/m³ and 5% for Edremit (Goodman, 1989 in Avşar, 2011).

In the models, particular minerals for biotite and amphibole groups are assigned according to the results from the analyses performed for the lithogeochemical characterization of the drill cuttings. For Akköy samples, annite which is the Fe-endmember of biotite group is used following the EPMA results which revealed Fe-rich nature for mica minerals. In the Edremit samples, since phlogopite and pargasite are already identified in CRS analyses (Table 5.2), these minerals are selected as biotite and amphibole, respectively for the simulations.

Ankerite, dawsonite, magnesite and siderite are the identified secondary phases in most of the samples.

7.2 Akköy Field

7.2.1 Simulated Sample: ADK-PS-1-1515

7.2.1.1 Equilibrium Modelling

In the simulations of sample ADK-PS-1-1515, determined secondary mineral is ankerite and the calculated mol amount of CO₂ that can be completely used up is 50 moles following the preliminary Saturation Index calculations.

The equilibrium modelling results of sample ADK-PS-1-1515 are given in Tables 7.4 and 7.5. According to the results, with the addition of CO₂, pH drops down to 7.32, Al, Fe, Si contents increase and total C, Ca, K, Mg, Na, SO₄ values decrease in the water sample (Table 7.4).

Table 7.4 Equilibrium modelling results of the aqueous phase reacting with sample ADK-PS-1-1515 (Akköy field)

PS-1.2018	initial	final
pH	7.6	7.32
Al (mol/L)	7.48E-07	6.16E-06
Total C (mol/L)	0.02945	0.008101
Ca (mol/L)	0.006629	0.0001332
Cl (mol/L)	0.002052	0.002051
Fe (mol/L)	6.27E-06	0.002399
K (mol/L)	0.003457	2.91E-05
Mg (mol/L)	0.002483	1.72E-05
Na (mol/L)	0.03068	0.0292
SO ₄ (mol/L)	0.009349	0.009346
Si (mol/L)	0.0005351	0.001209

The variations in the mineral assemblage point to the dissolution of calcite, chlorite, dolomite, quartz and the precipitation of ankerite and kaolinite (Table 7.5). The carbonate mineral that “traps” CO₂ is ankerite which is likely to form through the following reaction:

Calcite + Dolomite + Chlorite + Quartz -> Ankerite + Kaolinite

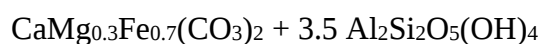
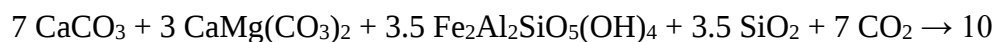


Table 7.5 Mineralogical changes with the equilibrium modelling for sample ADK-PS-1-1515 from Akköy field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	ADK-PS-1-1515		
	Initial	Final	Delta
Albite	37.27	37.27	0
Ankerite	0	71.45	71.45
Biotite	0	0	0
Calcite	122.81	72.8	-50.01
Chlorite	28.46	3.453	-25.01
Dolomite	33.94	12.51	-21.43
Illite	0	0	0
Kaolinite	51.12	76.12	25.00
Muscovite	0.76	0.7634	0.01
Orthoclase	0	0	0
Quartz	395.38	370.4	-24.98
Smectite	0	0	0
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

As a result of the reactions, 100% of the added CO₂ is trapped in minerals.

7.2.1.2 Kinetic Modelling

Reactions for sample ADK-PS-1-1515 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.1). Within the first 5 minutes of CO₂ addition, ankerite starts to precipitate (Fig.7.2a). CO₂ is totally consumed within one and a half years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.2b). The system reaches equilibrium in approximately 15 years (Fig.7.1). The initial pH value of 7.6 drops to 4.97 with the addition of CO₂, it starts to increase in time and in approximately 15 years it reaches to the final value of 7.32 (Fig.7.2c).

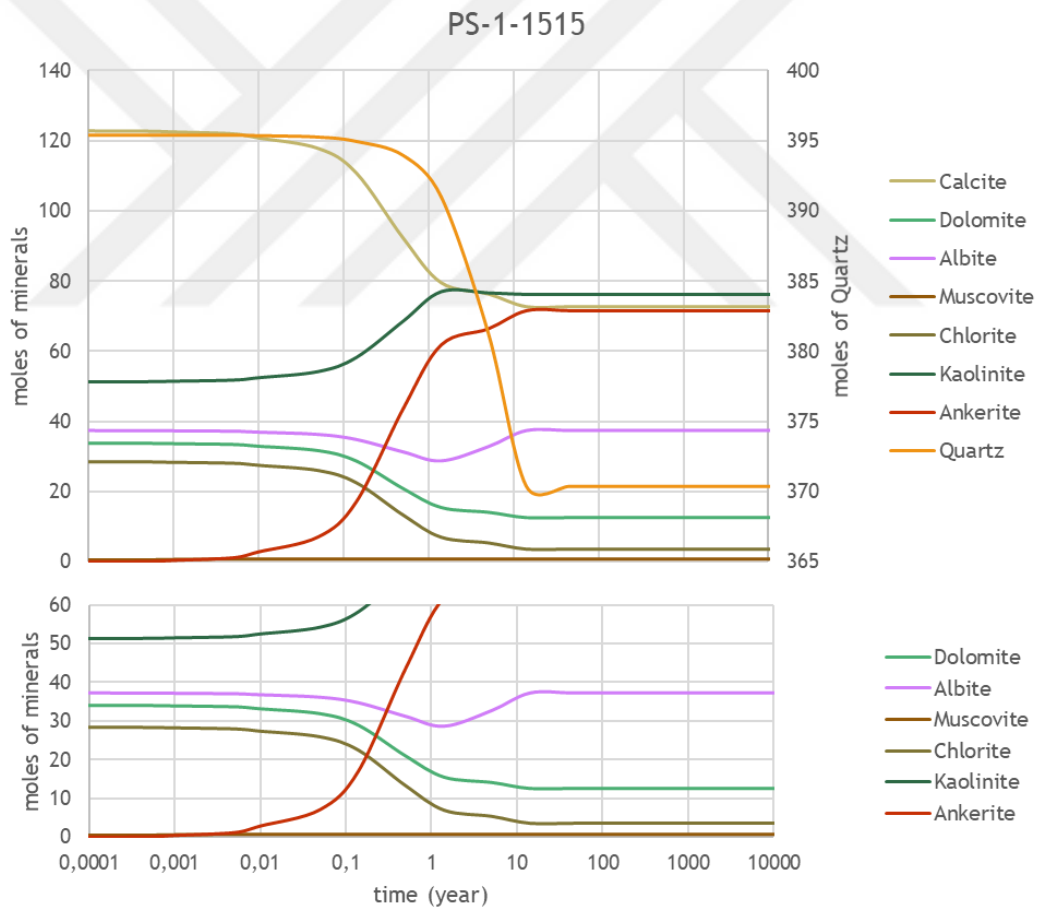


Figure 7.1. Temporal changes in the reservoir mineralogy (ADK-PS-1-1515, Akköy field) followed by CO₂ addition to the system

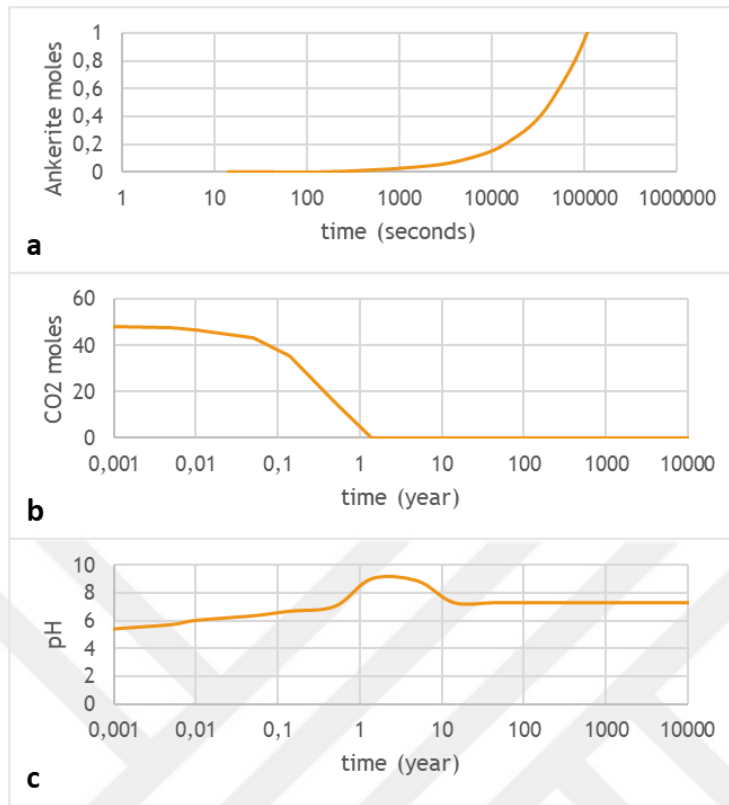


Figure 7.2. Changes that occur in time in a. the concentration of carbonate mineral reacting from the start, b. the amount of CO₂ and c. pH values of sample ADK-PS-1-1515 (Akköy field)

7.2.1.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample ADK-PS-1-1515 are illustrated in Figure 7.3 (100 m long column is zoomed in to 20 m for better inspection of results). According to the models, most of the reactions determined with equilibrium and kinetic modelling, take place in about 7-9 meters from the supposed CO₂ injection point and the effects of the reactions decrease gradually with distance. The reactions start to take place in the first year with lesser molar amounts in shorter distances (~1.5 m).

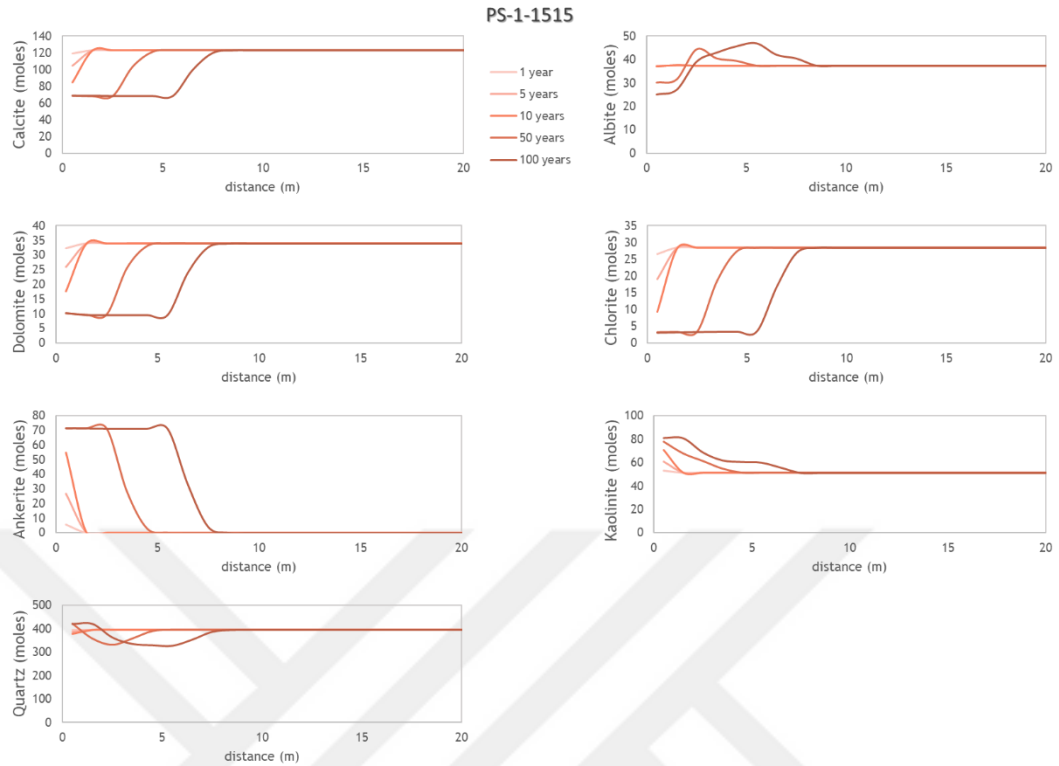


Figure 7.3. The changes in the mineral phases of sample ADK-PS-1-1515 (Akköy field) against distance in different times

7.2.2 Simulated Sample: ADK-PS-2-840

7.2.2.1 Equilibrium Modelling

In the simulations of sample ADK-PS-2-840, determined secondary minerals are ankerite, dawsonite, dolomite, siderite and the calculated mol amount of CO_2 that can be completely used up is 67 moles following the preliminary Saturation Index calculations.

The equilibrium modelling results of sample ADK-PS-2-840 are given in Tables 7.6 and 7.7. According to the results, with the addition of CO_2 , pH drops down to 6.53,

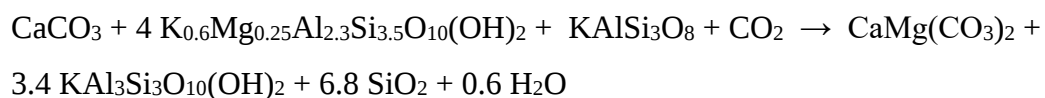
total C, Cl, Fe, Na, SO₄, Si contents increase and Al, Ca, K, Mg values decrease in the water sample (Table 7.6).

Table 7.6 Equilibrium modelling results of the aqueous phase reacting with sample ADK-PS-2-840 (Akköy field)

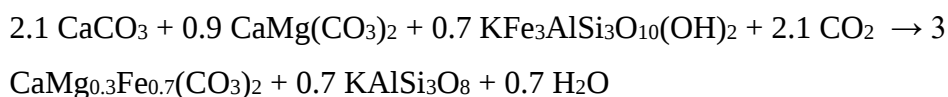
PS-1.2018	initial	final
pH	7.6	6.53
Al (mol/L)	7.48E-07	4.17E-07
Total C (mol/L)	0.02945	0.8475
Ca (mol/L)	0.006629	8.57E-05
Cl (mol/L)	0.002052	0.002138
Fe (mol/L)	6.27E-06	5.92E-03
K (mol/L)	0.003457	9.95E-03
Mg (mol/L)	0.002483	2.03E-07
Na (mol/L)	0.03068	0.4872
SO ₄ (mol/L)	0.009349	0.00974
Si (mol/L)	0.0005351	0.001194

The variations in the mineral assemblage point to the dissolution of albite, biotite, calcite, illite, smectite and the precipitation of ankerite, muscovite, orthoclase, quartz, dawsonite and siderite (Table 7.7). The carbonate minerals that “trap” CO₂ are ankerite, dawsonite and siderite. The likely series of reactions which lead up to the precipitation of these carbonate minerals are:

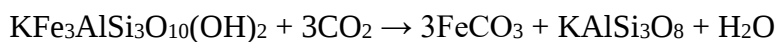
Calcite + Illite + Orthoclase -> Dolomite + Muscovite + Quartz



Calcite + Dolomite + Biotite -> Ankerite + Orthoclase



Biotite -> Siderite + Orthoclase



Albite -> Dawsonite + Quartz

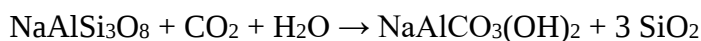


Table 7.7 Mineralogical changes with the equilibrium modelling for sample ADK-PS-2-840 from Akköy field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	ADK-PS-2-840		
	Initial	Final	Delta
Albite	19.21	0	-19.21
Ankerite	0	33	33.00
Biotite	11.64	0	-11.64
Calcite	171.78	138.9	-32.88
Chlorite	0	0	0
Dolomite	0	0	0
Illite	24.36	0	-24.36
Kaolinite	0	0	0
Muscovite	3.59	26.42	22.83
Orthoclase	37.12	41.38	4.26
Quartz	407.94	520.3	112.36
Smectite	4.23	0	-4.23
Dawsonite	0	19.41	19.41
Magnesite	0	0	0
Siderite	0	13.72	13.72

As a result of the reactions, mineral trapping is estimated as 99% and solubility trapping as 1% for CO₂ added to the system.

7.2.2.2 Kinetic Modelling

Reactions for sample ADK-PS-2-840 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.4). With CO₂ addition, dolomite starts to precipitate (Fig.7.5a) and in 3 hours ankerite also precipitates (Fig.7.5b). Dolomite dissolves in 10 hours. Precipitation of siderite starts in one and a half days. CO₂ is totally consumed within 450 years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.5c). The system reaches equilibrium in approximately 500 years (Fig.7.4). The initial pH value of 7.6 drops to 5.11 with the addition of CO₂, it starts to increase in time and in approximately 500 years it reaches to the final value of 6.53 (Fig.7.5d).

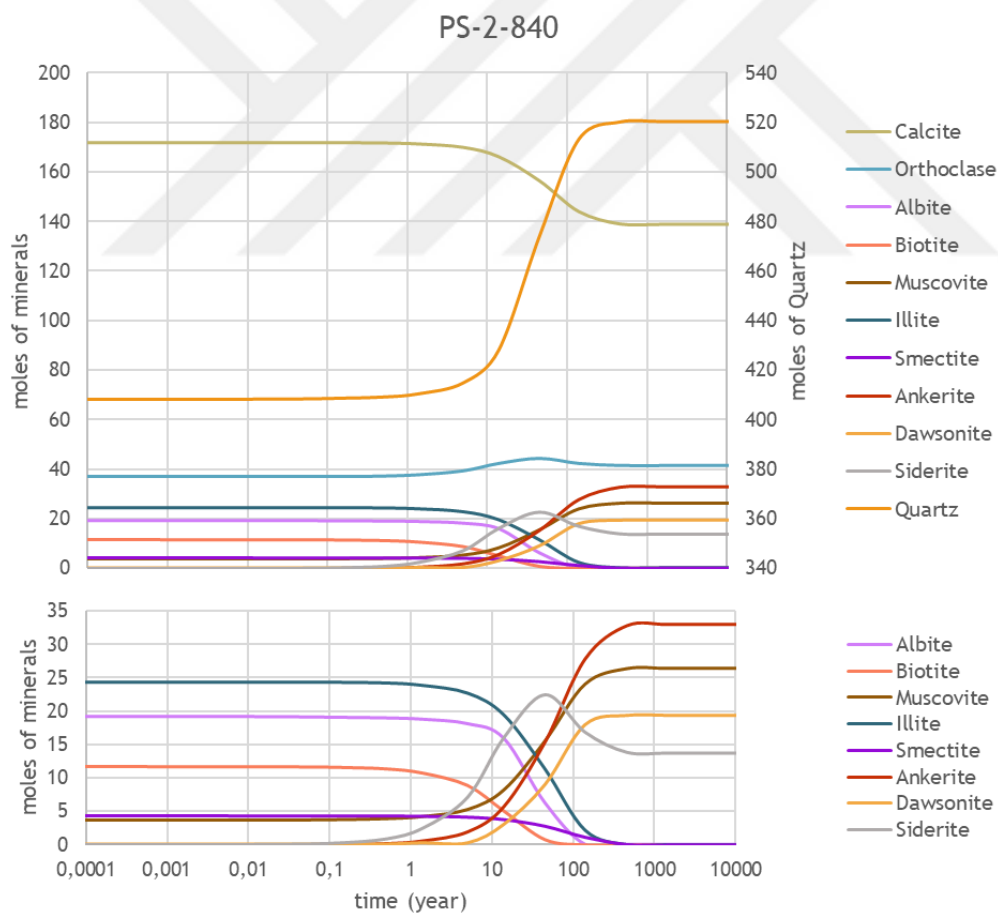


Figure 7.4. Temporal changes in the reservoir mineralogy (ADK-PS-2-840, Akköy field) followed by CO₂ addition to the system

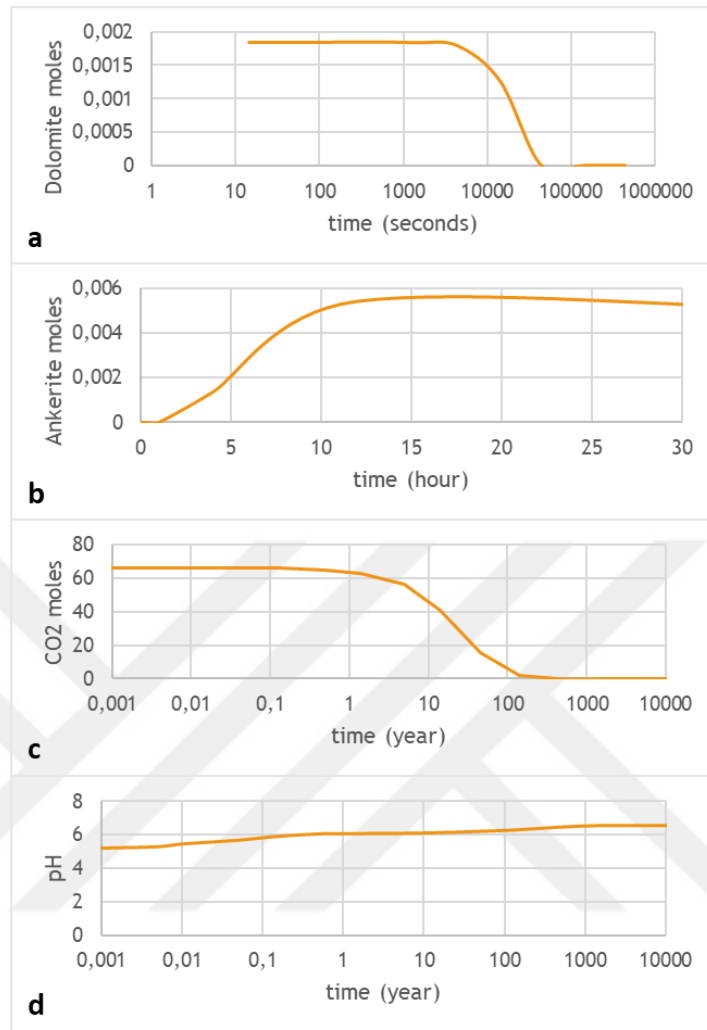


Figure 7.5. Changes that occur in time in a, b. the concentration of carbonate minerals reacting from the start, c. the amount of CO₂ and d. pH values of sample ADK-PS-2-840 (Akköy field)

7.2.2.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample ADK-PS-2-840 are illustrated in Figure 7.6 (100 m long column is zoomed in to 20 m for better inspection of results). According to the models, most of the reactions determined

with equilibrium and kinetic modelling, take place in about 18 meters from the supposed CO₂ injection point and the effects of the reactions decrease gradually with distance. Dawsonite and siderite precipitations occur close to the inlet (3.5 meters). The reactions start to take place in the first year with lesser molar amounts in shorter distances (~1.5 m).

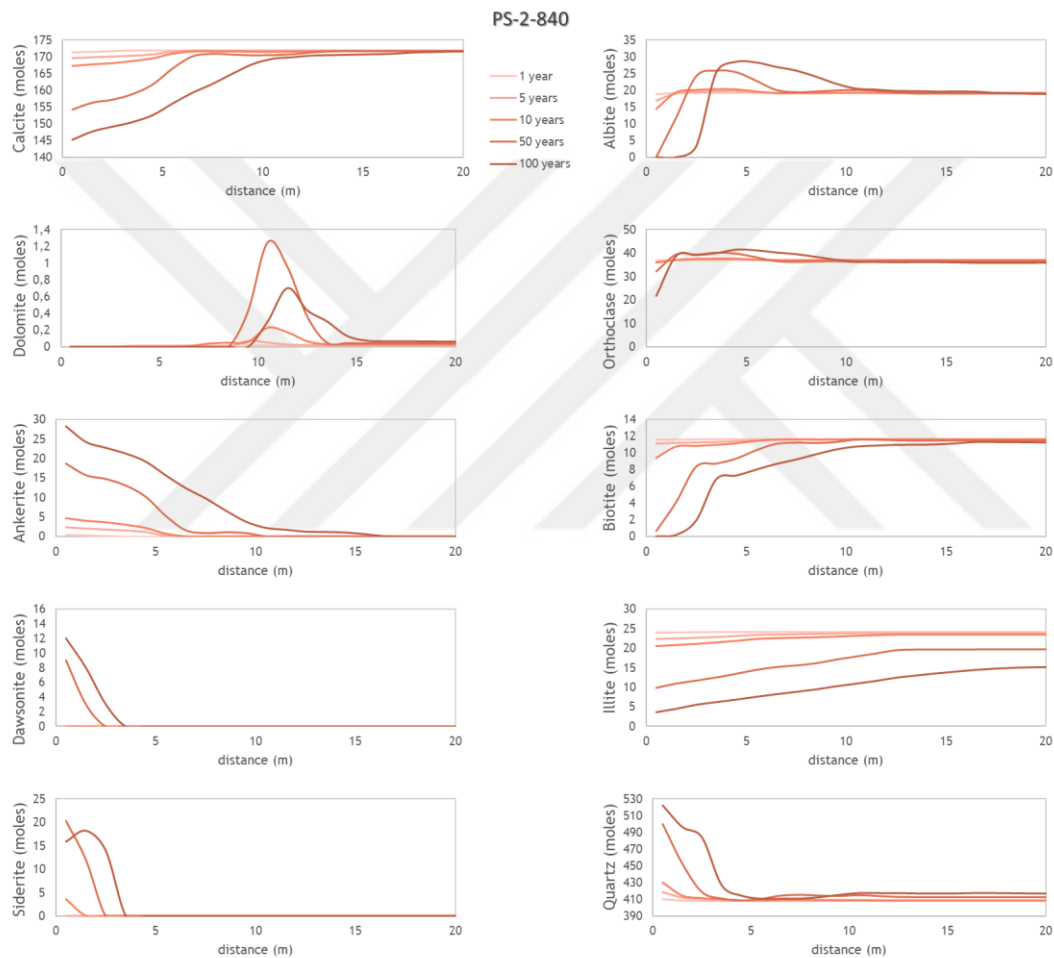


Figure 7.6. The changes in the mineral phases of sample ADK-PS-2-840 (Akköy field) against distance in different times

7.2.3 Simulated Sample: ADK-PS-2-1380

7.2.3.1 Equilibrium Modelling

In the simulations of sample ADK-PS-2-1380, determined secondary mineral is ankerite and the calculated mol amount of CO₂ that can be completely used up is 73 moles following the preliminary Saturation Index calculations.

The equilibrium modelling results of sample ADK-PS-2-1380 are given in Tables 7.8 and 7.9. According to the results, with the addition of CO₂, pH drops down to 5.03, total C, Ca, Fe, K, Si contents increase and Al, Ca, Mg values decrease in the water sample (Table 7.8).

Table 7.8 Equilibrium modelling results of the aqueous phase reacting with sample ADK-PS-2-1380 (Akköy field)

PS-1.2018	initial	final
pH	7.6	5.03
Al (mol/L)	7.48E-07	8.28E-08
Total C (mol/L)	0.02945	1.089
Ca (mol/L)	0.006629	0.007127
Cl (mol/L)	0.002052	0.002052
Fe (mol/L)	6.27E-06	5.24E-04
K (mol/L)	0.003457	0.005558
Mg (mol/L)	0.002483	6.54E-04
Na (mol/L)	0.03068	0.03068
SO ₄ (mol/L)	0.009349	0.00935
Si (mol/L)	0.0005351	0.001169

The variations in the mineral assemblage indicate the dissolution of calcite, chlorite, dolomite, quartz and the precipitation of ankerite and kaolinite (Table 7.9). The

carbonate mineral that “traps” CO₂ is ankerite. The potential reaction for ankerite formation in this sample is:

Calcite + Dolomite + Chlorite + Quartz -> Ankerite + Kaolinite

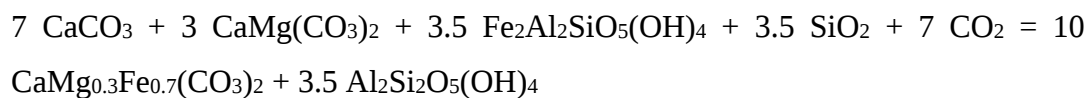


Table 7.9 Mineralogical changes with the equilibrium modelling for sample ADK-PS-2-1380 from Akköy field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	ADK-PS-2-1380		
	Initial	Final	Delta
Albite	0	0	0
Ankerite	0	102.8	102.8
Biotite	0	0	0
Calcite	352.61	280.7	-71.91
Chlorite	35.97	0	-35.97
Dolomite	31.08	0.2506	-30.83
Illite	0	0	0
Kaolinite	5.84	41.81	35.97
Muscovite	13.81	13.81	0
Orthoclase	0	0	0
Quartz	249.78	213.8	-35.98
Smectite	0	0	0
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

As a result of the reactions, 99% of the added CO₂ is trapped in minerals while 1% is held in the solution.

7.2.3.2 Kinetic Modelling

Reactions for sample ADK-PS-2-1380 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.7). With CO₂ addition, ankerite starts to precipitate (Fig.7.8a). CO₂ is totally consumed within 45 years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.8b). The system reaches equilibrium in approximately 45 years (Fig.7.7). The initial pH value of 7.6 drops to 4.99 with the addition of CO₂, it starts to increase in time and in approximately 45 years it reaches to the final value of 5.03 (Fig.7.8c).

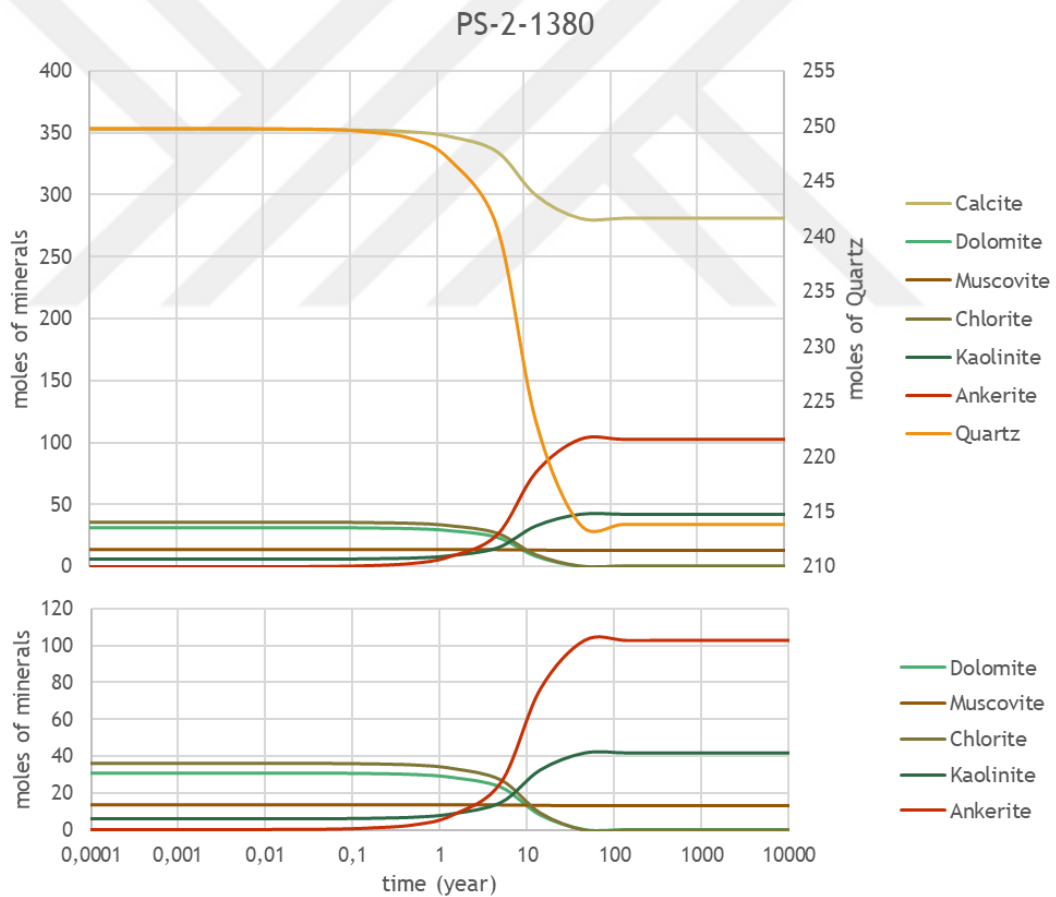


Figure 7.7. Temporal changes in the reservoir mineralogy (ADK-PS-2-1380, Akköy field) followed by CO₂ addition to the system

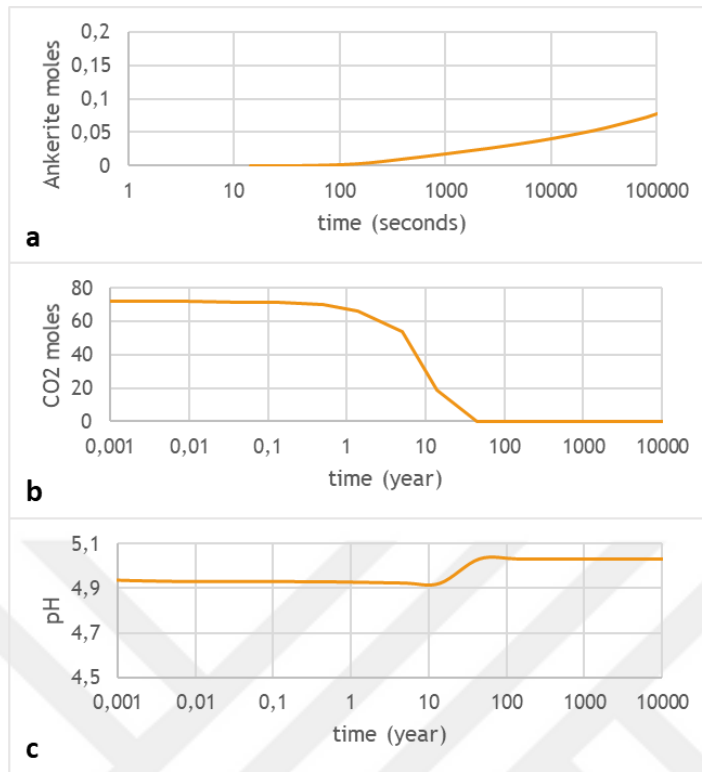


Figure 7.8. Changes that occur in time in a. the concentration of carbonate mineral reacting from the start, b. the amount of CO₂ and c. pH values of sample ADK-PS-2-1380 from Akköy field

7.2.3.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample ADK-PS-2-1380 are illustrated in Figure 7.9 (100 m-long column is zoomed in to 20 m for better inspection of results). According to the models, the reactions that are determined with equilibrium and kinetic modelling, take place in approximately 6.5 meters from the supposed CO₂ injection point and decrease gradually with distance. The results reveal that the evolution of the reactions from first year starts with lesser molar amounts in shorter distances (~1.5 m).

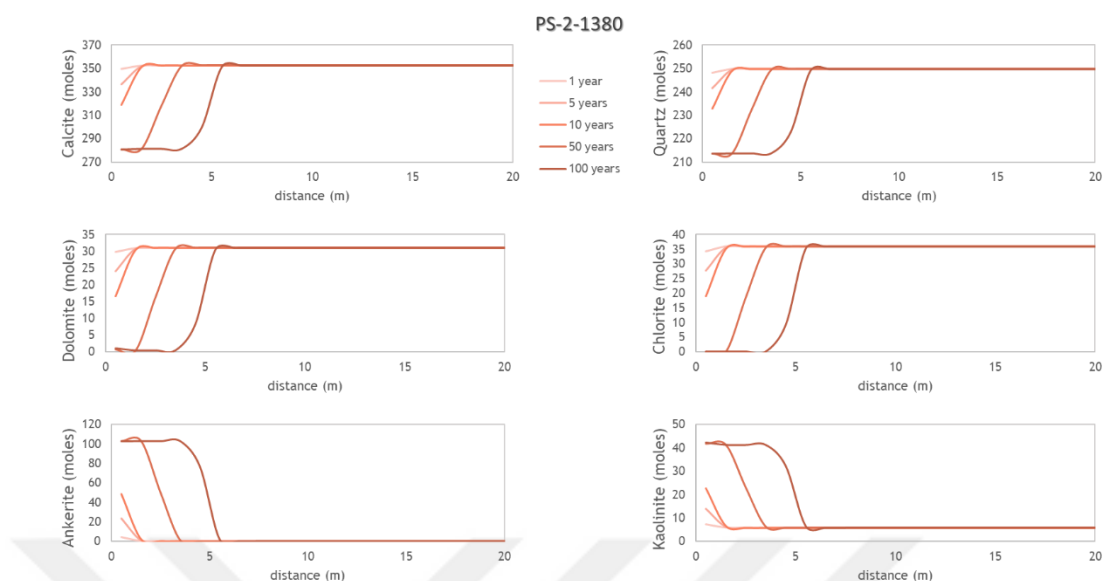


Figure 7.9. The changes in the mineral phases of sample ADK-PS-2-1380 (Akköy field) against distance in different times

7.3 Edremit Field

7.3.1 Simulated Sample: EDR-912

7.3.1.1 Equilibrium Modelling

In the simulations of sample EDR-912, determined secondary mineral is ankerite and the calculated mol amount of CO_2 that can be completely used up is 33 moles following the preliminary Saturation Index calculations.

The equilibrium modelling results of sample EDR-912 are given in Tables 7.10 and 7.11. According to the equilibrium modelling results, with the addition of CO_2 , pH drops down to 5.63, total C, K, Mg, Si contents increase and Al, Ca, Cl, Fe, Na, SO_4 values decrease in the water sample (Table 7.10).

Table 7.10 Equilibrium modelling results of the aqueous phase reacting with sample EDR-912 (Edremit field)

EDJ-7	initial	final
pH	7.61	5.63
Al (mol/L)	3.26E-06	7.43E-07
Total C (mol/L)	6.07E-04	0.2791
Ca (mol/L)	9.74E-04	8.79E-05
Cl (mol/L)	0.001779	0.001487
Fe (mol/L)	1.42E-06	1.18E-06
K (mol/L)	1.46E-04	1.12E-02
Mg (mol/L)	4.12E-06	1.69E-03
Na (mol/L)	0.01071	0.008956
SO ₄ (mol/L)	0.005211	0.004357
Si (mol/L)	0.0003739	0.001949

The variations in the mineral assemblage display the dissolution of biotite, calcite and the precipitation of dolomite, orthoclase, quartz and magnesite (Table 7.11). The amount of quartz that precipitates is very little (0.01 mol). The carbonate minerals that “trap” CO₂ are dolomite and magnesite. These minerals are likely to form through the following reaction:

Biotite + Calcite -> Dolomite + Magnesite + Orthoclase

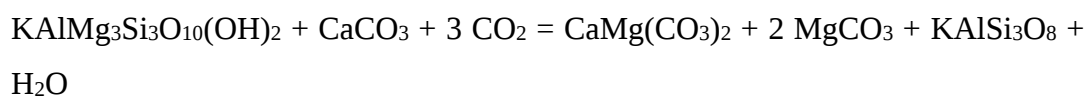


Table 7.11 Mineralogical changes with the equilibrium modelling for sample EDR-912 from Edremit field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	EDR-912		
	Initial	Final	Delta
Albite	0	0	0
Amphibole	0	0	0
Biotite	10.89	0	-10.89
Bytownite	0	0	0
Calcite	19.84	0	-19.84
Chlorite	0	0	0
Dolomite	0	19.84	19.84
Illite	9.66	9.668	0
Kaolinite	0	0	0
Labradorite	0	0	0
Orthoclase	55.38	66.25	10.87
Quartz	441.79	441.8	0.01
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	12.83	12.83
Siderite	0	0	0

As a result of the reactions, 99% of the added CO₂ is trapped in minerals and the remaining 1% is trapped in the solution.

7.3.1.2 Kinetic Modelling

Reactions for sample EDR-912 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.10). Within the first 3 hours of CO₂ addition, dolomite starts to precipitate (Fig.7.11a). Magnesite precipitates after 5 years. CO₂ is totally consumed within 40 years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.11b). The system reaches equilibrium in approximately 40 years (Fig.7.10). The initial pH value of 7.61 drops to 5.05 with the addition of CO₂, it increases in time and in approximately 40 years it reaches to the final value of 5.63 (Fig.7.11c).

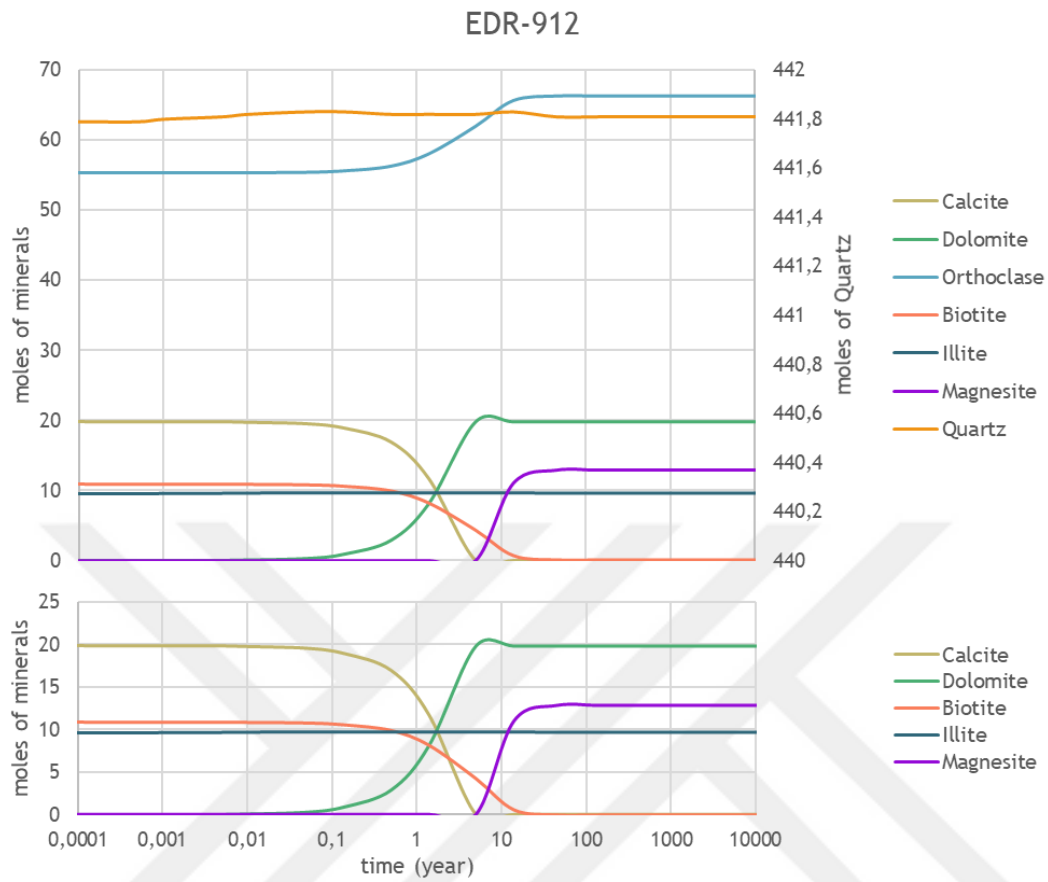


Figure 7.10. Temporal changes in the reservoir mineralogy (EDR-912, Edremit field) followed by CO₂ addition to the system

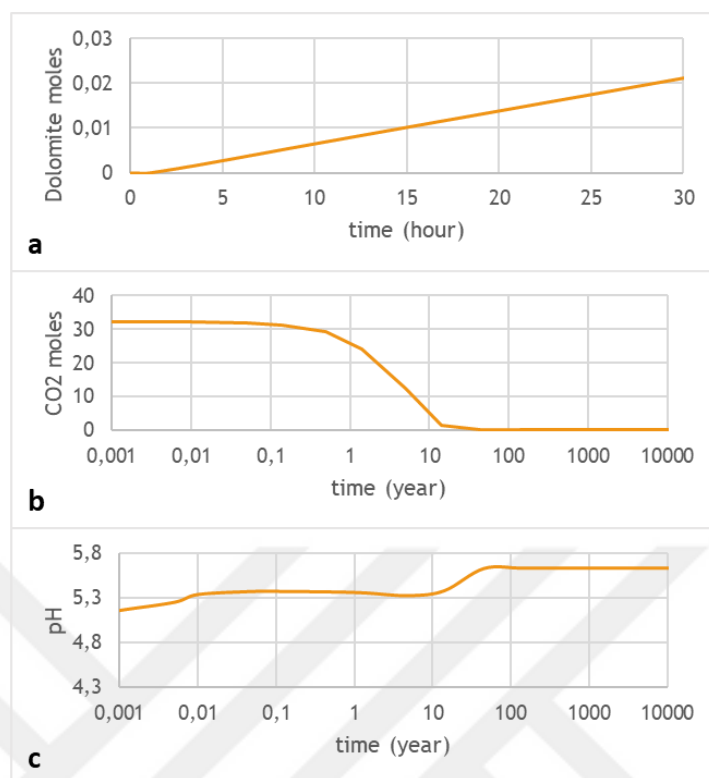


Figure 7.11. Changes that occur in time in a. the concentration of carbonate mineral reacting from the start, b. the amount of CO₂ and c. pH values of sample EDR-912 from Edremit field

7.3.1.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample EDR-912 are illustrated in Figure 7.12 (100 m long column is zoomed in to 20 m for better inspection of results). According to the models, the reactions that are determined with equilibrium and kinetic modelling, take place in approximately 8.5 meters from the supposed CO₂ injection point and decrease gradually with distance. The results reveal that the evolution of the reactions from first year starts with lesser molar amounts in shorter distances (~1.5 m) displaying increase with time.

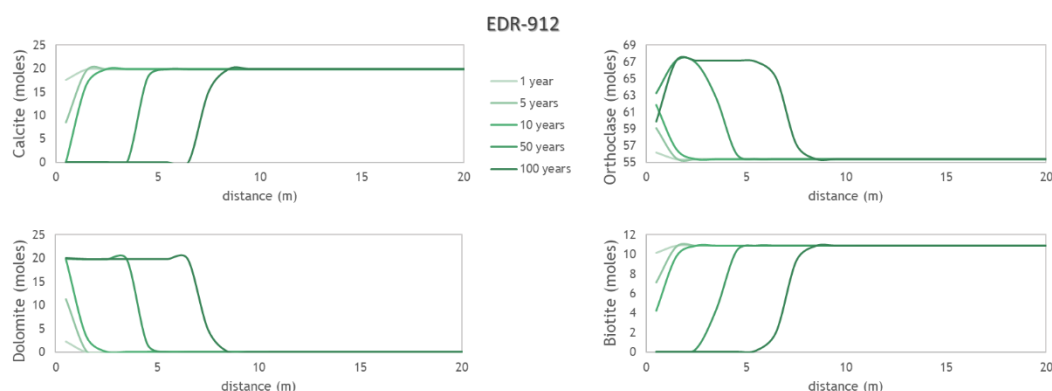


Figure 7.12. The changes in the mineral phases of sample EDR-912 (Edremit field) against distance in different times

7.3.2 Simulated Sample: EDR-988

7.3.2.1 Equilibrium Modelling

In the simulations of sample EDR-988, determined secondary mineral is ankerite and the calculated mol amount of CO_2 that can be completely used up is 27 moles following the preliminary Saturation Index calculations.

The equilibrium modelling results of sample EDR-988 are given in Tables 7.12 and 7.13. According to the equilibrium modelling results, with the addition of CO_2 , pH drops down to 6.23, total C, Fe, K, Mg, Na, Si contents increase and Al, Ca, Cl, SO_4 values decrease in the water sample (Table 7.10).

Table 7.12 Equilibrium modelling results of the aqueous phase reacting with sample EDR-988 (Edremit field)

EDJ-7	initial	final
pH	7.61	6.23
Al (mol/L)	3.26E-06	3.22E-06
Total C (mol/L)	6.07E-04	0.79
Ca (mol/L)	9.74E-04	1.70E-06
Cl (mol/L)	0.001779	0.001564
Fe (mol/L)	1.42E-06	1.37E-04
K (mol/L)	1.46E-04	0.003528
Mg (mol/L)	4.12E-06	3.59E-04
Na (mol/L)	0.01071	0.1564
SO ₄ (mol/L)	0.005211	0.004581
Si (mol/L)	0.0003739	0.001961

The variations in the mineral assemblage indicate the dissolution of albite, biotite, calcite, chlorite, quartz and the precipitation of dolomite, kaolinite, orthoclase and ankerite (Table 7.13). The carbonate minerals that “trap” CO₂ are ankerite and dolomite which are likely to form through the following reactions:

Calcite + Biotite -> Dolomite + Orthoclase



Calcite + Chlorite + Dolomite + Quartz -> Ankerite + Kaolinite

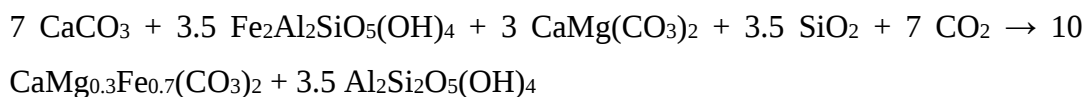


Table 7.13 Mineralogical changes with the equilibrium modelling for sample EDR-988 from Edremit field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	EDR-988		
	Initial	Final	Delta
Albite	50.86	50.69	-0.17
Amphibole	0	0	0
Biotite	7.89	0	-7.89
Bytownite	0	0	0
Calcite	26.10	0	-26.10
Chlorite	18.35	17.13	-1.22
Dolomite	5.67	28.3	22.63
Illite	0	0	0
Kaolinite	20.64	21.94	1.30
Labradorite	0	0	0
Orthoclase	0	7.89	7.89
Quartz	338.30	337.4	-0.90
Ankerite	0	3.47	3.47
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

As a result of the reactions, mineral trapping is estimated as 97% and solubility trapping as 3% for CO₂ added to the system.

7.3.2.2 Kinetic Modelling

Reactions for sample EDR-988 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.13). With CO₂ addition, ankerite starts to precipitate (Fig.7.14a). Dolomite initially dissolves for the first 15 days, but in one and a half years it precipitates. CO₂ is totally consumed within one and a half years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.14b). The system reaches equilibrium in approximately 140 years (Fig.7.13). The initial pH value of 7.61 drops

to 5.05 with the addition of CO₂, it increases in time and in approximately one and a half years it reaches to the final value of 6.23 (Fig.7.14c).

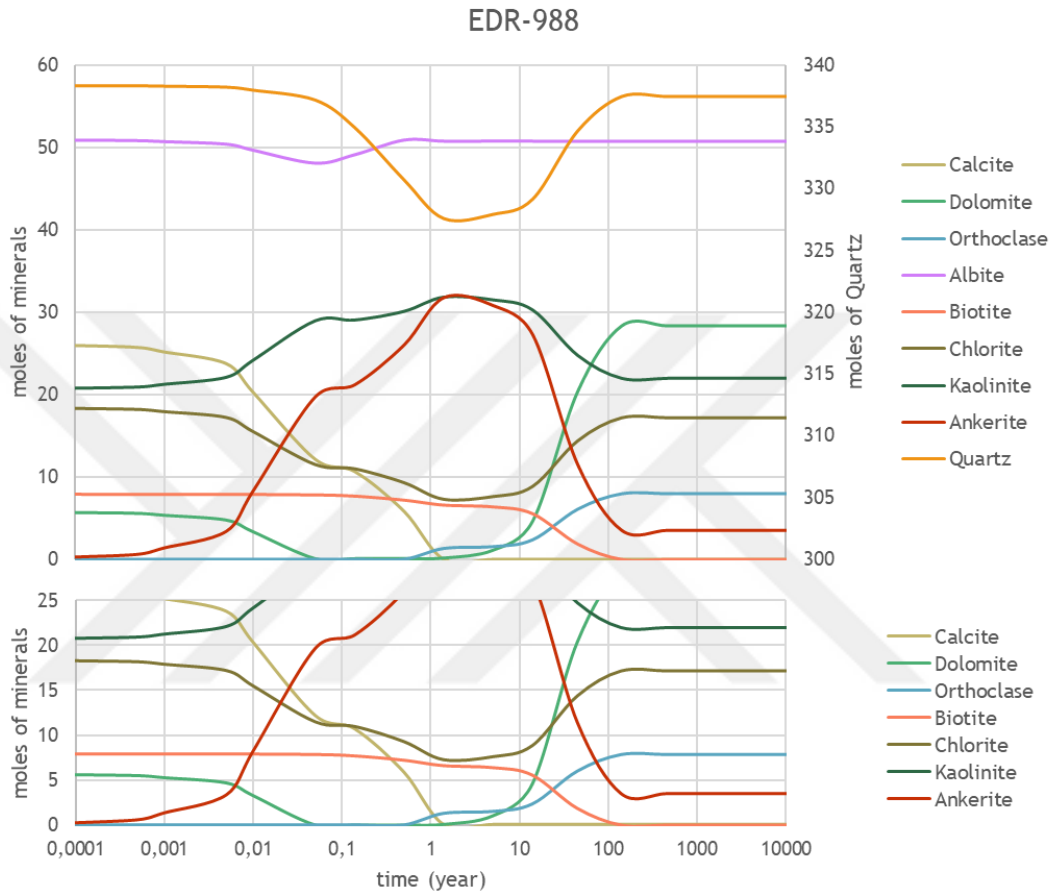


Figure 7.13. Temporal changes in the reservoir mineralogy (EDR-988, Edremit field) followed by CO₂ addition to the system

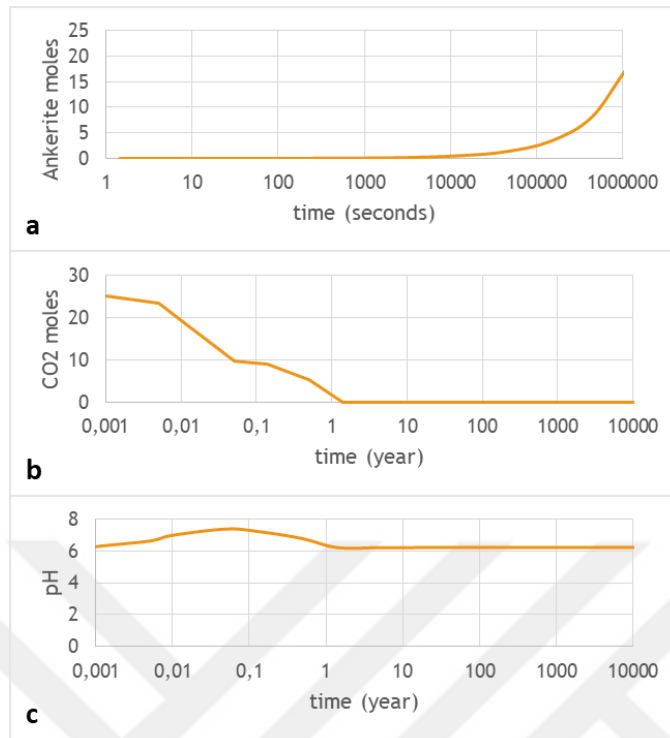


Figure 7.14. Changes that occur in time in a. the concentration of carbonate mineral reacting from the start, b. the amount of CO₂ and c. pH values for sample EDR-988 from Edremit field

7.3.2.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample EDR-988 are illustrated in Figure 7.15 (100 m long column is zoomed in to 20 m for better inspection of results). According to the models, the reactions that are determined with equilibrium and kinetic modelling, take place in approximately 10.5 meters from the supposed CO₂ injection point. The results reveal that the evolution of the reactions from first year starts with lesser molar amounts in shorter distances (~2.5 m). The fluctuations observed in dolomite, ankerite, chlorite and kaolinite values indicate the complex reaction dynamics as determined from the equilibrium and kinetic modelling results.

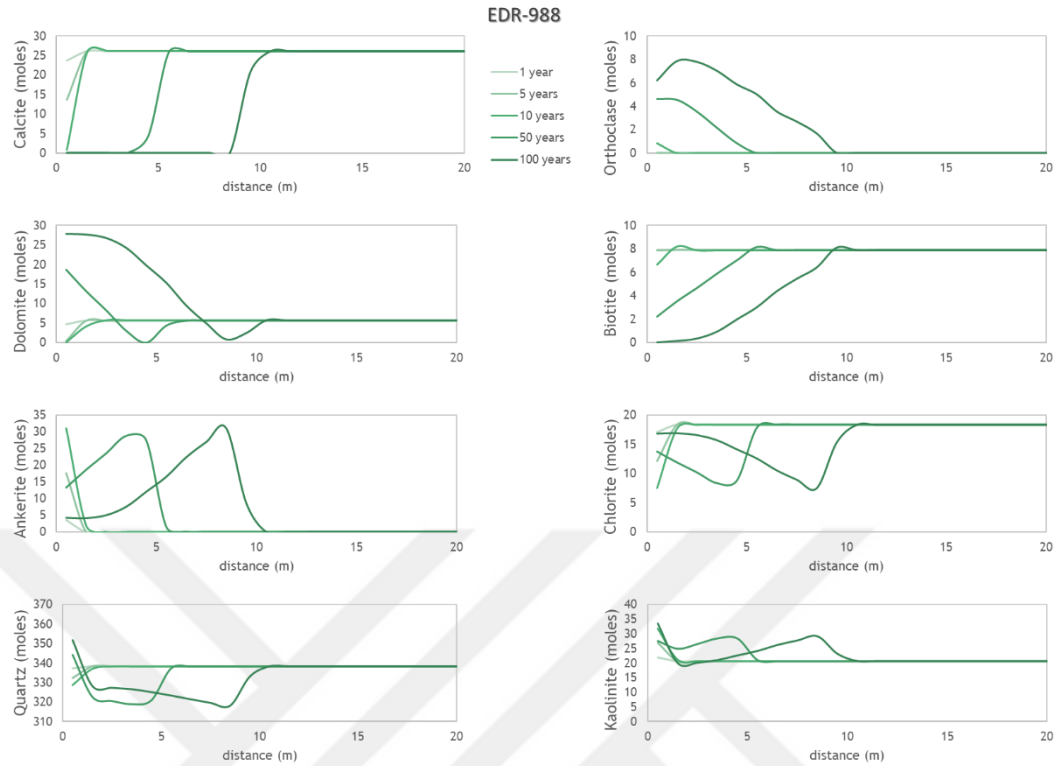


Figure 7.15. The changes in the mineral phases of sample EDR-988 (Edremit field) against distance in different times

7.3.3 Simulated Sample: EDR-1008

7.3.3.1 Equilibrium Modelling

In the simulations of sample EDR-1008, determined secondary minerals are calcite and dolomite and the calculated mol amount of CO_2 that can be completely used up is 60 moles following the preliminary Saturation Index calculations.

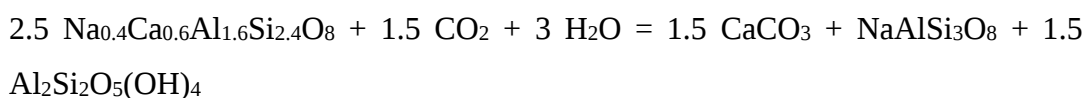
The equilibrium modelling results of sample EDR-1008 are given in Tables 7.14 and 7.15. According to the equilibrium modelling results, with the addition of CO_2 , pH drops down to 6.89, Al, total C, Cl, Fe, K, Mg, Na, SO_4 , Si contents increase and Ca values decrease in the water sample (Table 7.14).

Table 7.14 Equilibrium modelling results of the aqueous phase reacting with sample EDR-1008 (Edremit field)

EDJ-7	initial	final
pH	7.61	6.89
Al (mol/L)	3.26E-06	1.02E-05
Total C (mol/L)	6.07E-04	0.01367
Ca (mol/L)	9.74E-04	1.93E-04
Cl (mol/L)	0.001779	0.004252
Fe (mol/L)	1.42E-06	3.39E-06
K (mol/L)	1.46E-04	8.35E-04
Mg (mol/L)	4.12E-06	4.66E-05
Na (mol/L)	0.01071	0.03487
SO ₄ (mol/L)	0.005211	0.01246
Si (mol/L)	0.0003739	0.001984

The variations in the mineral assemblage point to the dissolution of biotite, kaolinite, labradorite, orthoclase and the precipitation of albite, calcite, dolomite, illite and quartz (Table 7.15). The amount of quartz that precipitates is very little (0.01 mol). The carbonate minerals that “trap” CO₂ are calcite and dolomite. These minerals are likely to form through the following reactions:

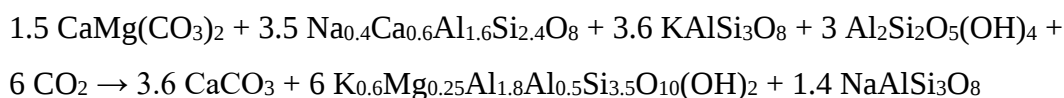
Labradorite -> Calcite + Albite + Kaolinite



Biotite + Calcite -> Dolomite + Orthoclase



Dolomite + Labradorite + Orthoclase + Kaolinite -> Calcite + Illite + Albite



In these reactions, dissolution of calcite and dolomite as well as precipitation of kaolinite and orthoclase also take place as opposed to the equilibrium results. Kinetic modelling is referred to for detailed inspection of the reactions.

Table 7.15 Mineralogical changes with the equilibrium modelling for sample EDR-1008 from Edremit field (values are as moles, blue colour indicates dissolution and red indicates precipitation, bold shows CO₂ trapping minerals)

Mineral	EDR-1008		
	Initial	Final	Delta
Albite	0	25.22	25.22
Actinolite	0	0	0
Biotite	12.77	1.554	-11.22
Bytownite	0	0	0
Calcite	0	15.67	15.67
Chlorite	0	0	0
Dolomite	0	22.16	22.16
Illite	15.52	61.45	45.93
Kaolinite	1.21	0	-1.21
Labradorite	63.05	0	-63.05
Orthoclase	43.55	27.21	-16.34
Quartz	189.59	189.6	0.01
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

As a result of the reactions, 100% of the added CO₂ is trapped in minerals.

7.3.3.2 Kinetic Modelling

Reactions for sample EDR-1008 that are determined in equilibrium modelling are investigated in terms of time (Fig.7.16). Within the first half an hour of CO₂ addition,

calcite starts to precipitate (Fig.7.17a). Dolomite formation begins in 4 hours. Kaolinite also starts to precipitate within the first half an hour, it continues to form for 6 months and afterwards, it completely dissolves in 450 years (as determined by equilibrium modelling results, Fig.7.16). In the second year of the reactions, calcite dissolution (from 27.18 moles to 15.67 moles) is observed. CO₂ is totally consumed within 14 years (i.e. the mol value of injected CO₂ becomes zero, Fig.7.17b). The system reaches equilibrium in approximately 450 years (Fig.7.16). The initial pH value of 7.61 drops to 4.21 with the addition of CO₂, it increases in time and in approximately 450 years it reaches to the final value of 6.89 (Fig.7.17c).

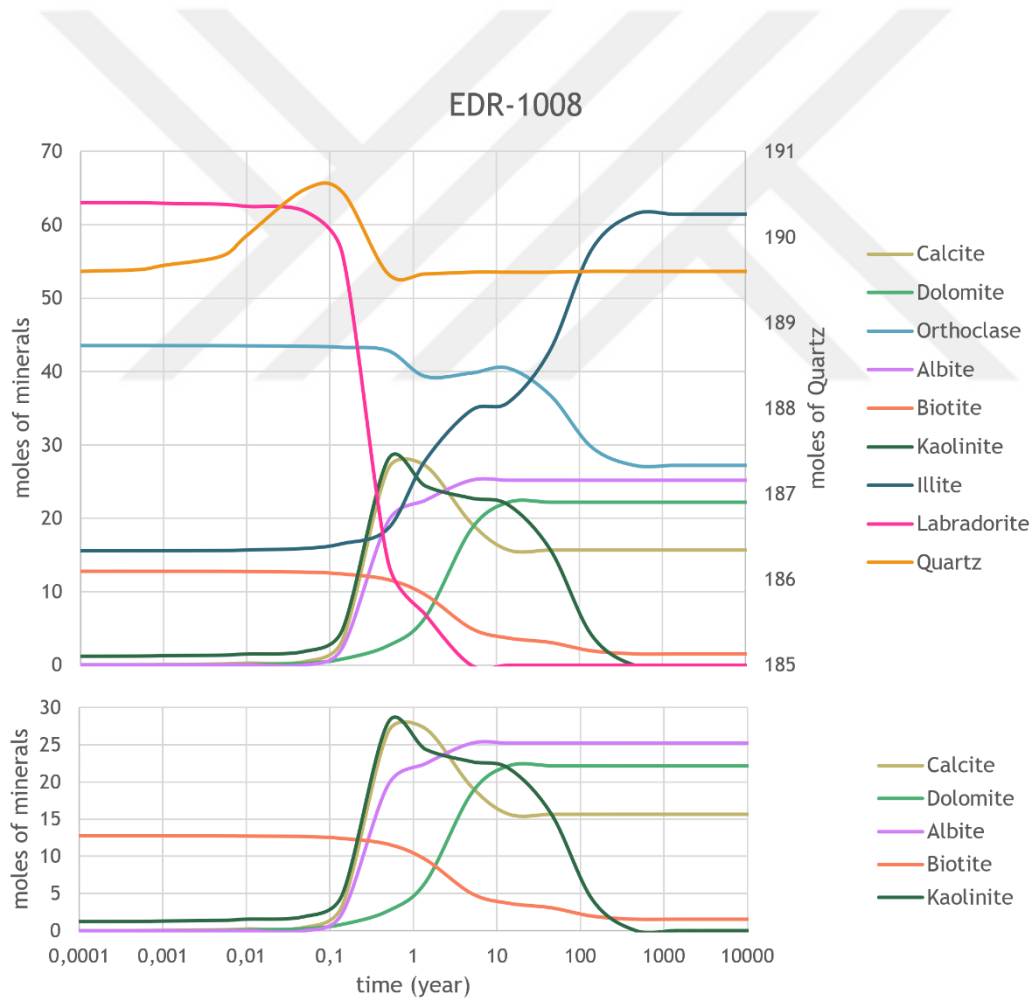


Figure 7.16. Temporal changes in the reservoir mineralogy (EDR-1008, Edremit field) followed by CO₂ addition to the system

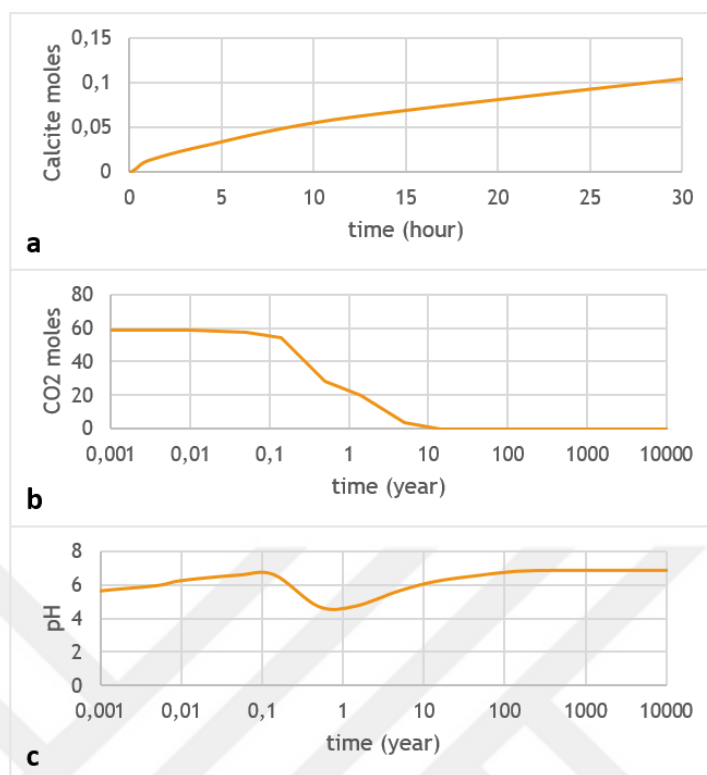


Figure 7.17. Changes that occur in time in a. the concentration of carbonate mineral reacting from the start, b. the amount of CO₂ and c. pH values of sample EDR-1008 from Edremit field

7.3.3.3 Reactive Transport Modelling

The changes in the mineral concentrations in 100 years along the reservoir which is simulated as a 100 m-long horizontal column for sample EDR-1008 are illustrated in Figure 7.18 (100 m long column is zoomed in to 20 m for better inspection of results). According to the models, the reactions that are determined with equilibrium and kinetic modelling, take place in approximately 4.5 meters from the supposed CO₂ injection point and decrease gradually with distance. The reactions start to take place in the first year with lesser molar amounts in shorter distances (~1.5 m). The likely reason for the fluctuations observed in calcite, albite and illite values is the

complex reaction dynamics that govern the system as determined from the equilibrium and kinetic modelling results.

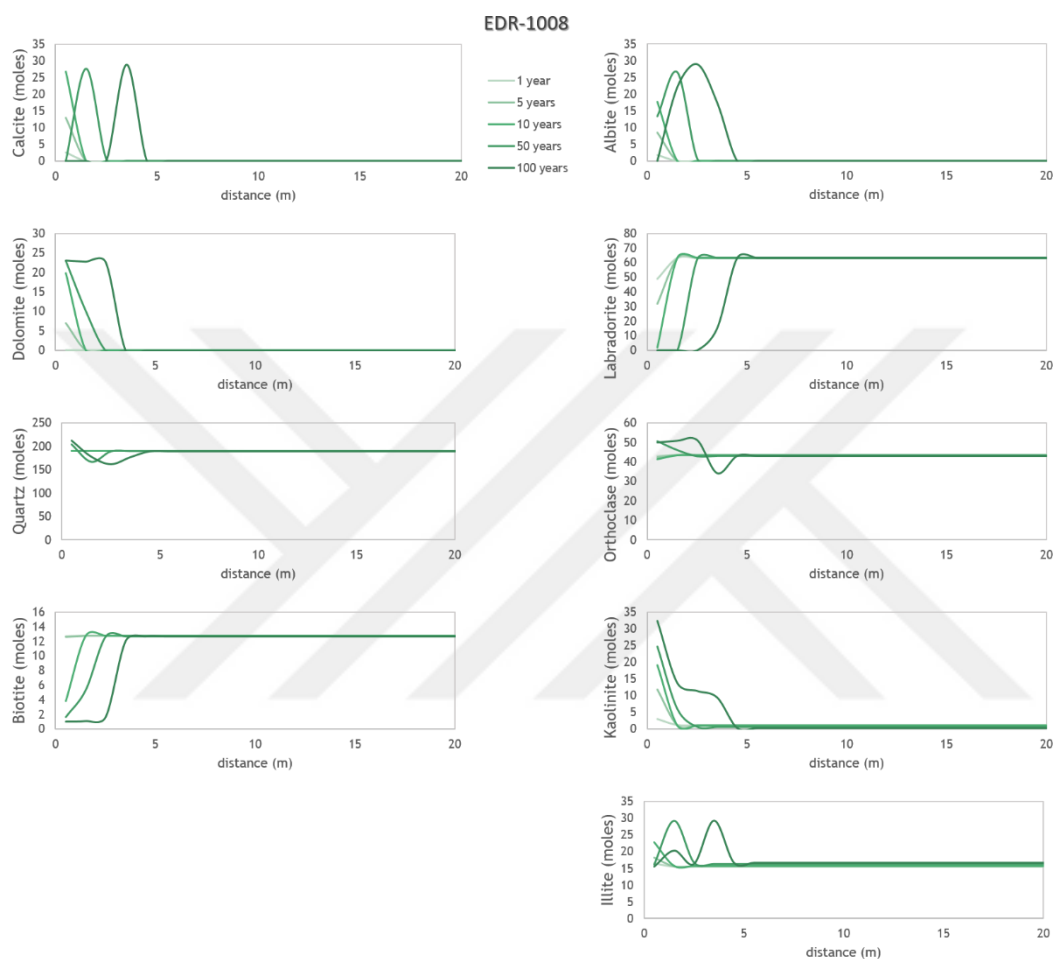


Figure 7.18. The changes in the mineral phases of sample EDR-1008 (Edremit field) against distance in different times

CHAPTER 8

DISCUSSIONS & IMPLICATIONS FOR CO₂ STORAGE

8.1 Akköy Field

In Akköy field, modelling results show that ankerite precipitates in most of the samples and it is the main carbonate phase to act as a trap for CO₂. Dawsonite, dolomite and siderite are the other carbonates which precipitate as secondary minerals and hold the added CO₂.

Alumino-silicate minerals that donate the required cations for secondary carbonate precipitation are mainly clay minerals (illite and smectite) which are followed by albite, chlorite and biotite. Calcite, being the main carbonate mineral in most of the samples, dissolves in the majority of the reactions and acts as a donor for Ca²⁺. In the presence of clay minerals, both ankerite and dolomite show precipitation in most of the samples while chlorite or biotite generally seem to promote ankerite precipitation coupled with dolomite dissolution (PS-1-1375, PS-1-1495, PS-1-1515, PS-2-1380). The dissolution of albite seems to be directly related to the formation of dawsonite (PS-1-1315, PS-1-1480, PS-2-840, PS-2-1355), however, albite is not the only source for dawsonite precipitation. Smectite dissolution also leads to dawsonite precipitation in the absence of albite (PS-1-1415, PS-2-1280).

Towards deeper levels in the samples of both PS-1 and PS-2 wells (PS-1-1495, PS-1-1515, PS-2-1380), it is observed that the effective reaction is calcite, dolomite, chlorite dissolution resulting in the precipitation of ankerite.

All reactions seem to start very quickly (either immediately or one and a half days); however, the time to reach equilibrium for these reactions changes from 10 years to 500 years (Table 8.1). It is observed that if a reaction involves the dissolution of a clay mineral (i.e. clays being a “cation donor” for the secondary carbonate

formation), that reaction's time to reach equilibrium increases significantly compared to the reactions that do not indicate clay dissolution.

Table 8.1 Timings of the kinetic reactions of Akköy field samples

Sample No.		Timing		Maximum distance in 100 years (m)	Main reactions
		Rxns start	Equilibrium reached		
PS-1	1315	one and a half days	14 yrs	42.5	Alb -> Daws + Qtz
PS-1	1375	3 hrs	500 yrs	13.5	Cal + Dol + Bio -> Ank + Orth Cal + Ill + Bio + Orth -> Ank + Musc + Qtz
PS-1	1415	one day	500 yrs	71.5	Cal + Ill -> Dol + Musc + Kaol + Qtz Cal + Ill + Sme -> Dol + Ank + Daws
PS-1	1480	instantly	500 yrs	57.5	Alb -> Daws + Qtz Cal + Sme -> Ank + Dol
PS-1	1495	5 mins	500 yrs	2	Cal + Ill + Chl + Qtz -> Dol + Bio + Kaol Cal + Dol + Chl + Qtz -> Ank + Kaol
PS-1	1515	5 mins	10 yrs	8	Cal + Dol + Chl + Qtz -> Ank + Kaol
PS-2	840	instantly	500 yrs	18	Cal + Ill + Orth -> Dol + Musc + Qtz Cal + Dol + Bio -> Ank + Orth Bio -> Sid + Orth, Alb -> Daws + Qtz
PS-2	1280	instantly	450 yrs	81.5	Cal + Sme -> Ank + Dol + Daws
PS-2	1355	one and a half days	140 yrs	23.5	Alb -> Daws + Qtz
PS-2	1380	instantly	45 yrs	6.5	Cal + Dol + Chl + Qtz -> Ank + Kaol

The spatial evolution of the samples ranges from 2 m to 81.5 m from the point that CO₂ added to the system (Table 8.1). A notable observation is that all the reactions in which smectite is one of the reactants (PS-1-1415, PS-1-1480, PS-2-1280), propagate longer distances (>50 m).

8.2 Edremit Field

Modelling studies of Edremit reveal that dolomite precipitates in most of the samples constituting the principal carbonate phase that restrains CO₂. Magnesite, calcite and ankerite are the additional secondary carbonates.

Biotite is the main cation donor of the system followed by the plagioclase minerals (albite, labradorite and bytownite), actinolite, chlorite and illite. In the samples in which calcite dissolves, calcite donates the necessary Ca²⁺ ion for the formation of dolomite and ankerite, except for the reactions where Ca-plagioclase (labradorite and bytownite) minerals are present. In fact, only cases of calcite precipitation take place coupled with the dissolution of Ca-bearing plagioclase feldspars towards relatively deeper levels (EDR-976, EDR-994, EDR-1008).

All reactions start very quickly (under 6 hours) and most of the samples reach equilibrium relatively faster (under 150 years, Table 8.2). In the samples which take longer time to attain equilibrium, it is observed that clay minerals participate in the dissolution reactions (illite and kaolinite).

Table 8.2 Timings of the kinetic reactions of Edremit field samples

Sample No.		Timing		Maximum distance in 100 years (m)	Main reactions
		Rxns start	Equilibrium reached		
EDR	912	3 hrs	40 yrs	8.5	Bio + Cal -> Dol + Mag + Orth
EDR	928	instantly	450 yrs	3.5	Cal + Ill -> Dol + Orth + Kaol
EDR	964	5 hrs	45 yrs	5.5	Bio -> Mag + Orth
EDR	976	half an hour	6 mos	8.5	Labr -> Cal + Alb + Kaol
EDR	988	instantly	140 yrs	10.5	Cal + Bio -> Dol + Orth Cal + Chl + Dol + Qtz -> Ank + Kaol
EDR	994	instantly	200 yrs	2.5	Act + Orth -> Dol + Ill + Alb + Bio Dol + Orth + Byt + Kaol -> Cal + Alb + Ill Cal + Bio -> Dol + Orth
EDR	1008	half an hour	450 yrs	4.5	Labr -> Cal + Alb + Kaol Bio + Cal -> Dol+Orth Dol + Lab + Orth + Kaol -> Cal + Ill + Alb
EDR	1032	half an hour	45 yrs	7.5	Bio + Cal -> Dol + Mag + Orth

The reactions take place in the distances from 2.5 m to 10.5 m from the inlet (Table 8.2). Shorter distances might indicate relatively faster reactions (as determined by kinetic modelling) resulting in the inhibition regarding the progress of CO₂-induced fluid further into the system.

8.3 Comparison of the Results

Main processes that are effective in Akköy and Edremit fields following a CO₂ addition to the systems determined as a result of modelling are summarized in Tables 8.3 and 8.4.

Table 8.3 Summary of modelling results of the samples from Akköy field

Sample No.		Silica	Carbonate			Feldspar		Mica		Chlorite	Clay			Secondary Carbonates		Trapping Mechanism		CO ₂ moles
		Quartz	Calcite	Dolomite	Ankerite	Orthoclase	Albite	Muscovite	Biotite		Kaolinite	Illite	Smectite	Dawsonite	Siderite	Mineral	Solubility	
PS-1	1315															89	11	8
PS-1	1375															97	3	46
PS-1	1415															91	9	13
PS-1	1480															97	3	31
PS-1	1495															100	0	20
PS-1	1515															100	0	50
PS-2	840															99	1	67
PS-2	1280															92	8	8
PS-2	1355															100	0	31
PS-2	1380															99	1	73

Dissolution
Precipitation
CO₂ Trap

Table 8.4 Summary of modelling results of the samples from Edremit field

Sample No.		Silica	Carbonate		Feldspar				Mica	Amphibole	Chlorite	Clay		Secondary Carbonates		Trapping Mechanism		CO ₂ moles
		Quartz	Calcite	Dolomite	Orthoclase	Albite	Labradorite	Bytownite	Biotite	Actinolite		Kaolinite	Illite	Ankerite	Magnesite	Mineral	Solubility	
EDR	912															99	1	33
EDR	928															90	10	4
EDR	964															98	2	46
EDR	976															100	0	27
EDR	988															97	3	27
EDR	994															100	0	69
EDR	1008															100	0	60
EDR	1032															100	0	54

Dissolution
Precipitation
CO ₂ Trap

Calcareous rocks and minerals dominate Akköy geothermal system and modelling results show that calcite (which is the main carbonate mineral) dissolves in all samples where it is present. In Edremit, on the other hand, carbonates are not as dominant as in Akköy field and calcite precipitation is observed in some samples (unlike calcite dissolution in majority of samples of Akköy).

Ankerite is the main carbonate phase that can trap the injected CO₂ in Akköy, whereas dolomite is the mineral that can sequester CO₂ in Edremit field. The formation of ankerite may point to the availability of Fe²⁺ ion due to the mineralogical composition of rocks in Akköy field. This also results in siderite precipitation in one of the samples from Akköy (PS-2-840). These findings of carbon mineralization seem to be in conformity with the results of large-scale demonstration projects that revealed ankerite and siderite as the main minerals trapping CO₂ in Wallula Basalt-USA and in Otway-Australia, respectively (Romanov et al., 2015 and the references therein; McGrail et al., 2017; White et al., 2020).

Principal “cation donors” in the reactions of Akköy and Edremit fields are clay minerals (illite, smectite) and biotite, respectively. Calcite also acts as the supplier for calcium ions in both fields. The lithological differences most likely determine the “role” of a mineral that donate its divalent cations to the system to be used in the formation of a secondary carbonate mineral.

The amount of feldspars in the samples from Edremit is almost seven times more than the samples from Akköy according to the modal mineralogy results (Table 5.3). If a feldspar (especially plagioclase) is present as a primary mineral, it dissolves in most of the samples in both fields forming a secondary carbonate mineral. One of the main reactions in Akköy field is the formation of dawsonite from the dissolution of albite. Although albite is also present in some of the Edremit samples, this reaction does not occur. The reasons might be that as the result of the reactions i) the amount of dissolved albite is very small (EDR-928 – Appendix H, EDR-988 – Table 7.13) and ii) the water sample is undersaturated with respect to dawsonite. Qu et al. (2022) and Forray et al. (2021 and the references therein) state that Al and (especially) Na

source for dawsonite formation is generally the formation water. Therefore, due to the unavailability of the required cations, dawsonite does not form in those samples.

In the samples of both fields in which clay minerals dissolve in the reactions and supply cations for secondary carbonate formation, equilibrium seems to be reached in a very long time (especially in Akköy samples in which clay minerals constitute one of the abundant phases in the mineral assemblage). Each sample in which the equilibrium is reached in longer than 150 years, a clay mineral (illite/smectite/kaolinite) dissolution is observed (PS-1-1375, PS-1-1415, PS-1-1480, PS-1-1495, PS-2-840, PS-2-1280, EDR-928, EDR-994, EDR-1008, Tables 8.1, 8.2). Time scale for the dissolution of clay minerals is described to be long-term (Rathnaweera et al., 2016 in Fatah et al., 2022), in fact, it is emphasized in Balashov et al. (2013) that equilibrations of especially clay mineral reactions take the longest time. Contrary to these slow reacting minerals, some of the relatively fast reactions of both fields contain chlorite which is reported as a very reactive mineral, rapidly engaging in reactions (Balashov et al., 2013; Higgs et al., 2015).

Most of the Edremit samples reach equilibrium faster than Akköy samples (Tables 8.1, 8.2). The clay mineral dominance as well as the relatively higher molar values of minerals in Akköy samples (e.g. determined porosity values are 3.37% and 5% in Akköy and Edremit, respectively) appear to affect the reaction times.

Although presence of clay minerals in the reactions as “cation donors” prolongs the time to reach equilibrium in those samples, there seems to be no simple relation on the distance. Relatively distal regions (>50 m) are attained especially for the reactions with smectite. Aside from the complexity of structural formula of smectite group minerals which may prolong the time and the distance of the reactions, another potential reason might be the larger surface area and hence, the higher adsorption capacity of these minerals. Due to greater adsorption capacity of smectites (Zhang et al., 2012 in Gueu et al., 2019; Kumari and Mohan, 2021), these minerals can adsorb CO₂ molecules on its interlayer domain increasing the inner spacing (Chouikhi et al., 2019 and the references therein). This may result in the adsorption of some of the

added CO₂ in smectite structure (to be used later) while the remaining CO₂ in the fluid travels further in the system (as opposed to being quickly consumed in the reactions close to inlet) increasing the time and the distance for these reactions.

The average maximum distances in 100 years that reactions take place from the presumed point of CO₂ injection are approximately 30 m for Akköy field and 6 m for Edremit field. The longest distance in Akköy field reaches up to 81.5 m in sample PS-2-1280 (Appendix H). Most notable difference of these two systems is the lithology. Known as the complex silicates, clay minerals have distinctive properties due to their layered structures, chemical compositions and adsorption capacities (Kumari and Mohan, 2021). The complex nature of these minerals is the likely cause for the slow-moving reactions which lead to transportation of aqueous species for longer distances resulting in the precipitation of secondary minerals around more distal parts of the reservoir. On the contrary, the “straightforward” chemical reactions due to the relatively simple structured minerals in Edremit field limit the spatial scale of the reactions. Higher mass fractions of minerals such as calcite, dolomite, biotite, chlorite dissolved close to the inlet and gradually decreased with distance. Fast kinetic reaction rates of carbonate minerals also speed up these processes. Precipitation of carbonates restricts the fluids to become oversaturated with bicarbonate species and reduces the transportation distances for these constituents which as a result, paves the way for a small-scaled or in-situ precipitations of secondary carbonate minerals such as dolomite and ankerite (Ma et al., 2020). It is also important to note that Kampman et al. (2014) stated that the existence of multiple mineral phases in a system complicates the approach to equilibrium due to the reaction rate differences of each mineral having a diverse effect on the solution chemistry.

Regarding the amount of CO₂ that can be added to the system, the range is between 8-73 moles for Akköy (Table 8.3) and 4-69 moles for Edremit field (Table 8.4). To give a general idea to the reader, these mol amounts can roughly be converted to volume by using the $PV = nRT$ relationship. In the calculations, the temperature and pressure values are taken as those utilized in the models (i.e. T = highest estimated

reservoir temperature, P = hydrostatic pressure at the relevant depth). The results of calculations yield a range of 2-26 liters for Akköy, and 1.5-24 liters for Edremit field. It should be noted here that a more realistic approach would require 3-D modelling of the reservoir.

A striking comparison is that, the reactions take place in the mainly metamorphic/sedimentary rocks of Akköy in longer times and distances while in the dominantly igneous reservoir of Edremit, the time and the distance of the reactions are relatively quicker and shorter. Recent studies regarding suitability and feasibility of rock formations for effective CO₂ storage highlight that igneous rocks constitute more favourable settings in terms of carbon mineralization, especially as opposed to sedimentary formations in which the reactivity of CO₂ may be low due to higher quartz content and as a result, mobile CO₂ may remain in the reservoir for centuries (Luhmann et al., 2017; Kelemen et al., 2019; Snaebjörnsdóttir et al., 2020; Ratouis, 2022; Raza et al., 2022; Kim et al., 2023). Although the simulations performed in this study have shown that both fields reach the desired outcome of CO₂ confinement through mineral trapping, an injection into the igneous rocks of Edremit field may yield better results. The quicker times and shorter distances of resulted reactions may also limit the potentially negative changes induced by CO₂ addition to the overall properties of the reservoir (such as porosity, permeability, integrity and rock strength).

8.4 Effect of CO₂ Amount

The simulations are performed with the assumption of abundant CO₂ is supplied into the system. The mol amount is calculated specific to each sample which differs due to the mineralogical differences. In order to investigate the effect of CO₂ amount on the reaction kinetics, among the simulated samples one from each field are chosen (PS-2-840 and EDR-988) and modelled with 10 moles of CO₂.

PS-2-840 was initially modelled with 67 moles of CO₂, the reactions resulted in the precipitation of 33 moles of ankerite, 19.41 moles of dawsonite and 13.72 moles of siderite (Table 7.7). An insignificant amount of dolomite was also precipitated, but it dissolved in a short time at the beginning of reactions. The reactions initiated with CO₂ addition and equilibrated in approximately 500 years. CO₂ was completely consumed within 450 years. At the end of the reactions, the initial pH value 7.6 dropped down to 6.53. The reactions of the model in which 10 moles of CO₂ is added, started with CO₂ addition and lasted for 500 years (similar results with previous modelling). CO₂ consumption is realised in 45 years and pH value is reduced to 7.51. The decreased amount of CO₂ resulted in the reduced degree of mineral interactions (i.e. minerals are dissolved/precipitated in lesser molar amounts). As a result of the reactions with 10 moles of CO₂, 5.55 moles of ankerite and 4.41 moles of dolomite precipitated.

The modelling of the sample EDR-988 was initially performed with 27 moles of CO₂. As a result, 22.63 moles of dolomite and 3.47 moles of ankerite were precipitated (Table 7.13). The reactions started immediately and continued for approximately 140 years. CO₂ was consumed within one and a half years. The initial value of pH (7.61) dropped to 6.23. In the model with 10 moles of CO₂, the reactions similarly start with CO₂ addition; however, the equilibration of the system takes place within 6 months and pH value becomes 7.00. CO₂ is also used up relatively quickly, in half a month. While dolomite dissolved in this scenario, ankerite precipitated for 14.25 moles.

The increase in the CO₂ amount has caused i) lower pH values, ii) the prolonged time of CO₂ consumption and iii) the raise in the molar values of minerals resulted from the reactions for both samples. The reactions of Edremit sample have also reached equilibrium in longer time with higher amount of CO₂. Moreover in both samples, increased CO₂ has resulted in the precipitation of additional secondary minerals. It can be deduced that mineralogical differences are also reflected in the changes induced by various CO₂ quantities.

8.5 Limitations & Uncertainties

In this thesis study, the major limitations and uncertainties are those related to i) the type of samples (drill cuttings) and ii) the assumptions, as well as the parameters used in modelling.

Drill cutting samples may result in geochemical bias due to i) loss of less resistant minerals during sample collection, ii) mixing of collapsed material from shallower levels, iii) contamination related to the drilling processes (drilling mud, equipment, fractures etc.) (Fowler and Zierenberg, 2016 and the references therein; Sanei et al., 2020). Textural, lithologic, paragenetic relationships of mineral phases as well as the potential alteration products may not be well-preserved and easily assessed in fine-grained particles of drill cuttings. In this regard, drill core samples yield better conserved properties and geochemical studies performed on such samples offer more credible results. Despite these limitations, however, drill cuttings are widely used in various geothermal studies (Nasution et al., 2003; Hebert et al., 2011; Libbey and Williams-Jones, 2016a; Libbey and Williams-Jones, 2016b; Mauriohoo et al., 2016; Kölbel et al., 2020; Elidemir et al., 2022; Galeczka et al., 2022). One potential advantage of cuttings is even mentioned in the study of Libbey and Williams-Jones (2016a): in litho-geochemical investigations, the fine-grained, randomized nature of cutting samples provides unbiased insight compared to the core samples in which the small scale heterogeneities (e.g. veins) may contradict the larger scale geochemical signature of a system. Moreover, drill cuttings are not as costly as core samples and they are easily accessible in a drilling operation. In this study, the variety of the geochemical analyses performed on the cutting samples may minimize the potential errors. It should also be noted that all the minerals which are regarded as less-resistant and prone to be lost during sample collection (e.g. chlorite, actinolite, clay minerals - Fowler and Zierenberg, 2016) are observed in the studied samples which may indicate the relatively better quality of these samples.

Uncertainties regarding geochemical modelling are mainly the assumptions made in the setup and the associated kinetic parameters. In the setup stage, the scaling of rock

volume to 1 liter of water filling the pore space (leading to the simulations of smaller scaled rock samples) and the limited availability of well log data from the studied fields, may cause a biased representation of the whole reservoir lithology. Furthermore, the major sources of uncertainties regarding kinetic parameters which may affect the accuracy of modelling, include those relevant to reactive surface areas, reaction rate constants and heterogeneities/impurities in the minerals and/or reservoir (Gaus et al., 2005; Gündoğan, 2011; Pham et al., 2012; Balashov et al., 2013; Hellevang et al., 2013; Fatah et al., 2022; Galeczka et al., 2022; Luo et al., 2022). For example, reactive surface area of minerals is calculated for ideal mineral phases, in other words, it may not reflect the reservoir conditions in which the area of minerals may be affected from various geochemical interactions that take place in the system (Fatah et al., 2022). Compared to batch modelling, even higher levels of uncertainty is present in reactive transport models. Large set of parameters is required to be used in reactive transport modelling studies and lengthy computation time is needed to solve the complete geochemical reactions (e.g. increasing the cell number with smaller cell lengths for detailed simulation) that can accurately represent the system for large-scale reservoir simulations (Gündoğan, 2011; Hellevang et al., 2013). Nevertheless, geochemical models are useful tools to make predictions and have an insight regarding the geochemical mechanisms in a system since natural systems are complex and continuously change over time.

CHAPTER 9

CONCLUSIONS & RECOMMENDATIONS

The lithogeochemical and hydrogeochemical properties of Akköy and Edremit geothermal fields are investigated, as potential sites for CO₂ storage, for the modelling of CO₂-fluid-rock interactions.

Petrographic examinations of the cuttings from Akköy field have revealed that the majority of rock fragments are comprised of calcareous rocks (marble/limestone) and quartz, calcite and clay minerals are determined as the primary mineral phases. For Edremit field, the dominant grains are identified as granitic rocks while quartz, feldspars, micas, carbonates and amphiboles are the main minerals. XRD, CRS and EPMA studies have provided additional insight regarding detailed characterization of mineral phases. The effects of hydrothermal fluid in the system (e.g. notable sulphur presence, sulphide mineralization) are also reflected in the results of these analyses as well as in the whole rock geochemistry results for both fields. Modal mineralogy evaluations indicate that carbonate and clay minerals are more abundant in Akköy samples than in Edremit whereas percentages of feldspars are distinctly higher in Edremit.

The waters are characterized as Na + K – HCO₃ – SO₄ type and Na + K – SO₄ type for Akköy and Edremit fields, respectively. Geothermometry and fluid mineral equilibria calculations of Akköy samples reveal 88-116°C as the estimated range for the reservoir temperature, slightly lower than the range of 92-150°C for Edremit field.

Utilizing the geochemical data of the studied rock and water samples, CO₂-fluid-rock interactions of Akköy and Edremit fields are simulated with equilibrium, kinetic and reactive transport modelling. The results have shown that:

- 1) The principal carbonate phases which precipitate as secondary minerals acting as traps for CO₂ are ankerite, followed by dawsonite and dolomite for Akköy field. Clay minerals (illite/smectite) and calcite constitute the main “cation donors” for ankerite and dolomite, while albite seems to be the main source for dawsonite. In deeper levels of Akköy field, chlorite dissolution (accompanied by calcite and dolomite) appears to be the effective reaction supplying the cations for ankerite.
- 2) In Edremit field, the main minerals that trap CO₂ are dolomite, followed by magnesite and calcite. Biotite seems to be the major Mg²⁺ supplier for dolomite and/or magnesite, while the source of Ca²⁺ ion is most likely calcite or Ca-plagioclase, depending on the mineralogical assemblage.
- 3) Dissolution of clay minerals has been observed to increase the time for reactions to reach equilibrium (longer than 150 years). Moreover for the reactions that include smectite, the reactions seem to propagate longer distances (>50 m) which may be due to i) complex mineralogical structure and ii) greater adsorption capacity of smectite than other clays.
- 4) When both fields are compared, the time and the distance of the reactions are observed to be longer in Akköy field where clay minerals are present in higher abundances and the reservoir rocks are dominantly metamorphic/sedimentary. Given that the reservoir of Edremit field is composed mainly of igneous rocks, coupled with the shorter time and distance for the reactions, makes Edremit field a more favourable site for CO₂ storage.
- 5) Increased CO₂ amount have also resulted in lower pH values, the increase of the time that CO₂ is consumed in the system and the increase in the amounts of the produced minerals, even causing the precipitation of an additional secondary trapping mineral.

The modelling results point to the importance of the lithological/mineralogical characteristics of a reservoir in CO₂-fluid-rock interactions. The “role” of the mineral (i.e. donor, trap) seems to be closely interrelated with the mineral composition and

assemblage of the rock sample which as a result, directly affects the fate of CO₂ in a possible injection scenario. Thorough geochemical investigation also has a significant importance on the characterization of a reservoir to be as accurate as possible. Lithogeochemical studies, in this regard, complement the hydrogeochemical data providing useful insight from an additional viewpoint for a deep geothermal system that may otherwise have plenty of unknowns.

For a better assessment of the reservoir rock in a possible CO₂ storage scenario, the utilization of core samples instead of cuttings is recommended, especially for detailed and depth-related investigations. Potential reactions and geochemical mechanisms that may affect the system should then be evaluated since the lithologic and/or mineralogic differences have critical importance in CO₂-fluid-rock interactions. 3-D reactive transport simulations should also be incorporated into such studies, as 1-D models are limited and the evolution of a natural system where CO₂ is injected, can be more realistically evaluated as a multidimensional process. It must also be noted here that, although relatively simple, 1-D geochemical models provide key points of understanding for the fundamental predictions regarding the fate of CO₂ in the underground storage studies.

Geochemical approaches are an essential part of any CCS study. From geochemical analyses to modelling, each step provides distinctive knowledge on various aspects of the studied system. This thesis study underlines the importance of lithogeochemical characterization especially accompanied by hydrogeochemical investigations in a multiphase system such as geothermal fields. Furthermore, the modelling studies constitute remarkably helpful tools in evaluation of the evolution of these systems, notably in the case of CO₂ storage. Following the geochemical analyses and simulations performed within the scope of this thesis work, the studied fields, Akköy and Edremit, are revealed to be suitable candidates for a possible CCS project.

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APPENDICES

A. Views from Microscopic Examinations of Samples from Akköy and Edremit Fields

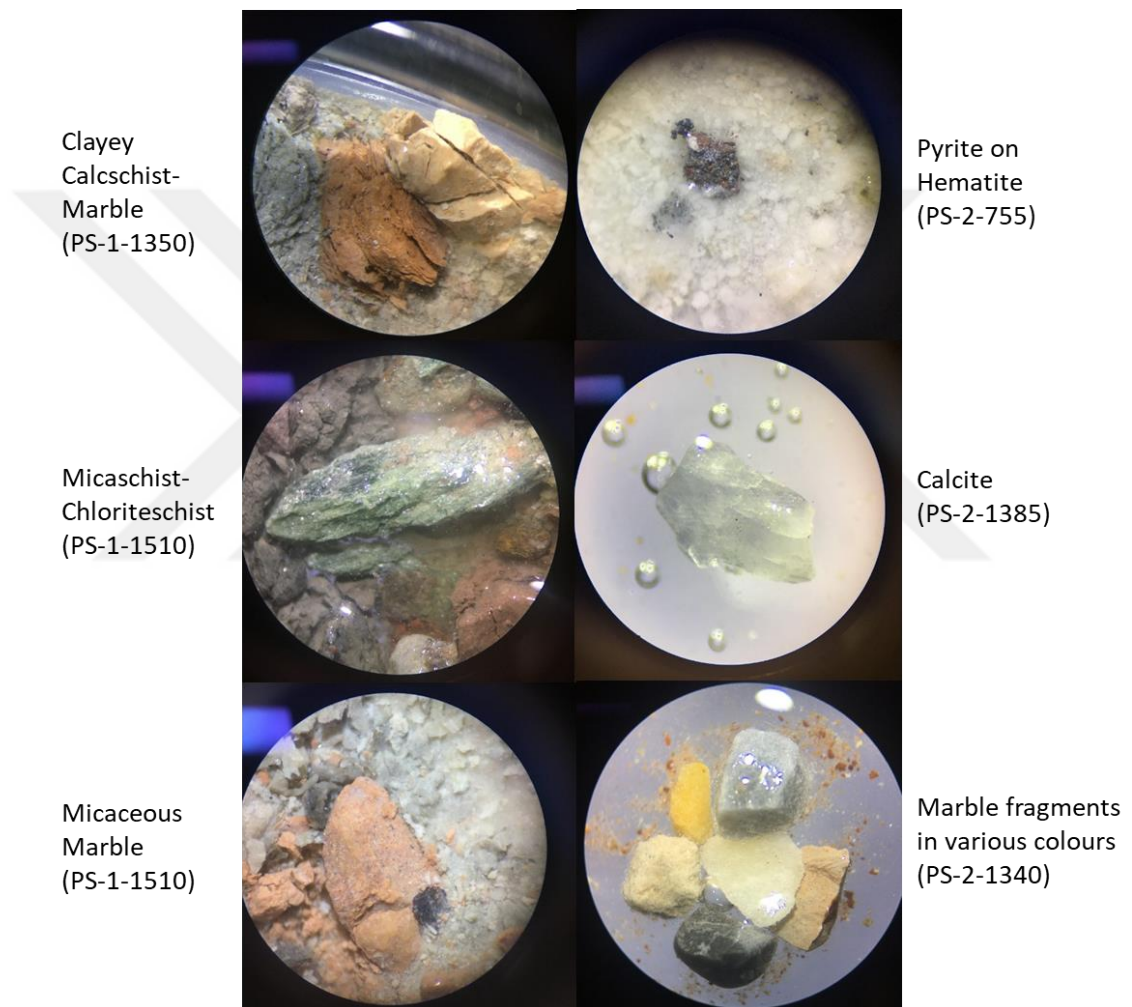


Figure A.1. Macroscopic views of Akköy samples

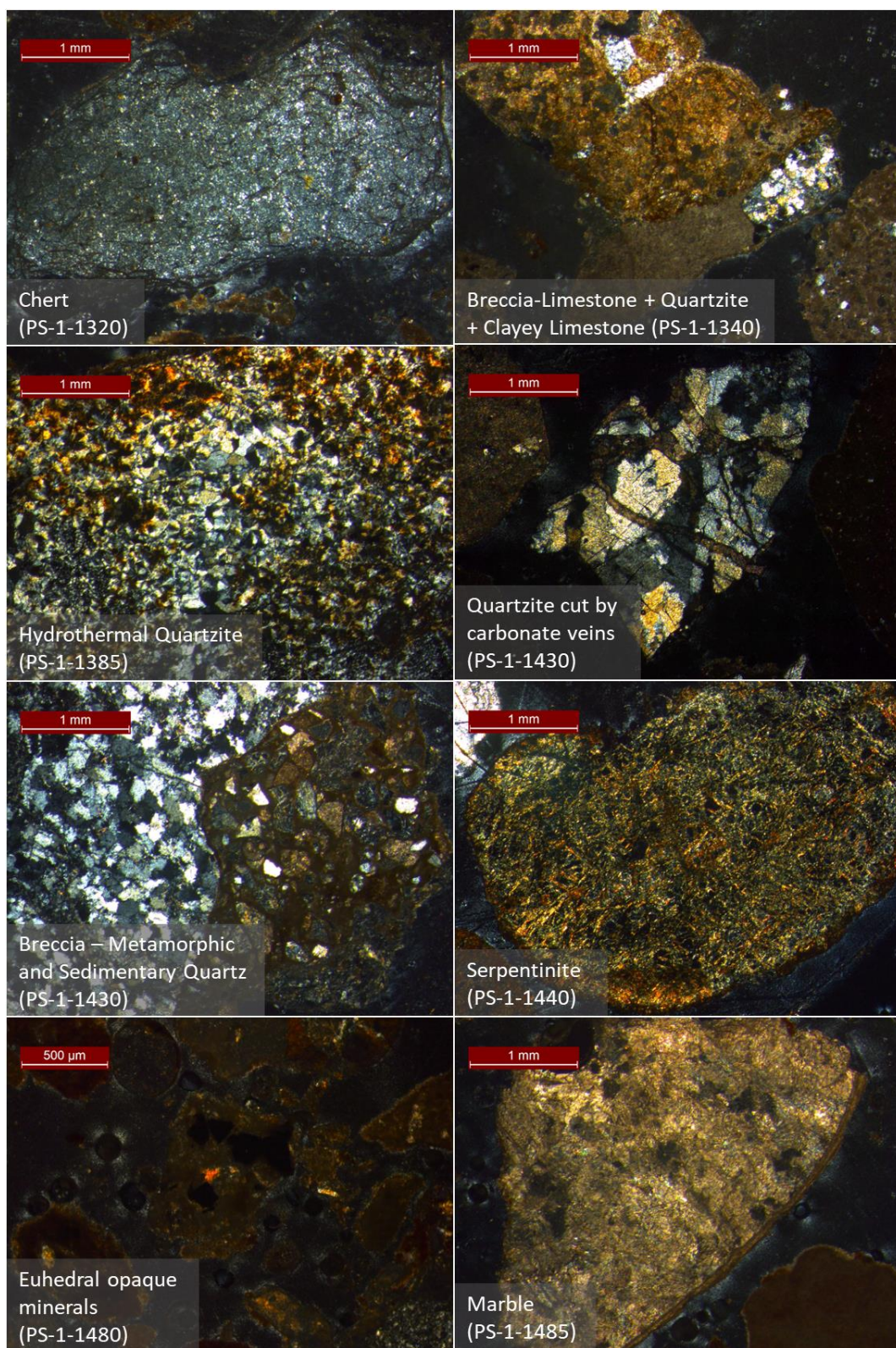


Figure A.2. Microscopic views of Akköy samples

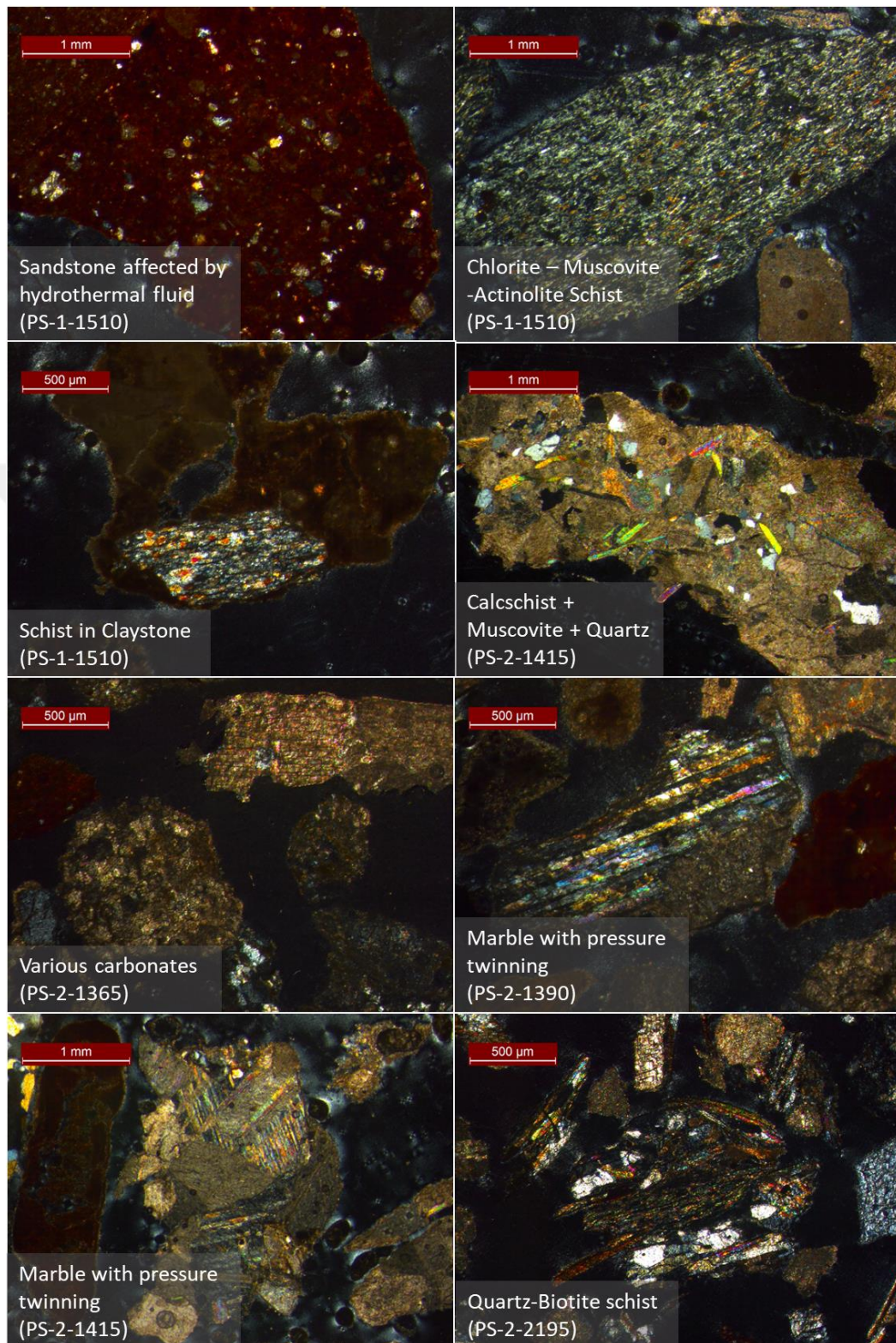
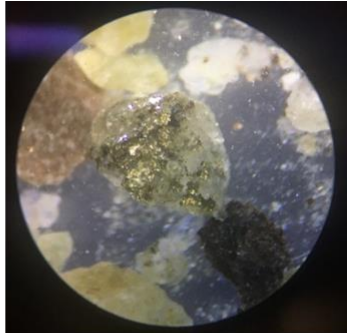
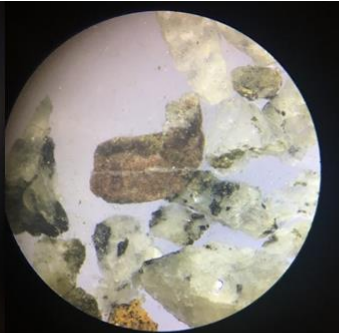


Figure A.3. Microscopic views of Akköy samples

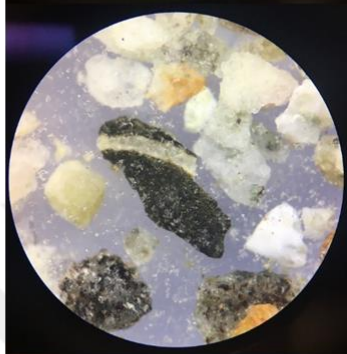
Quartz grain
with pyrite
and biotite
(EDR-900)



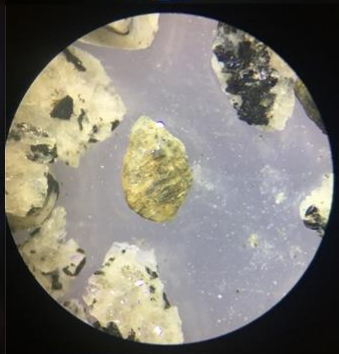
Pyrite + granite
fragment cut
by quartz vein
(EDR-1010)



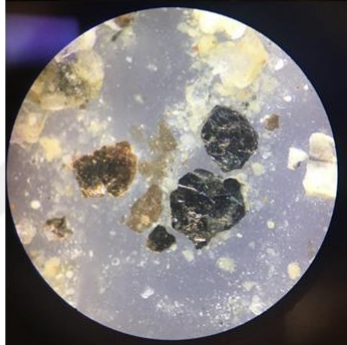
Gabbroic
fragment cut
by quartz vein
(EDR-924)



Schist + quartz
with biotite
(EDR-1024)



Muscovite +
biotite
(EDR-932)



Quartz with
biotite
(EDR-1024)

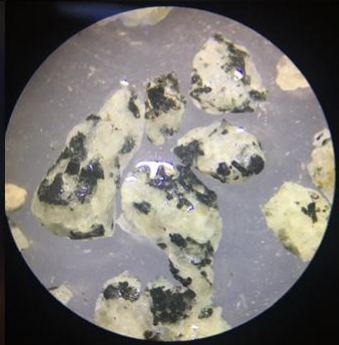


Figure A.4. Macroscopic views of Edremit samples

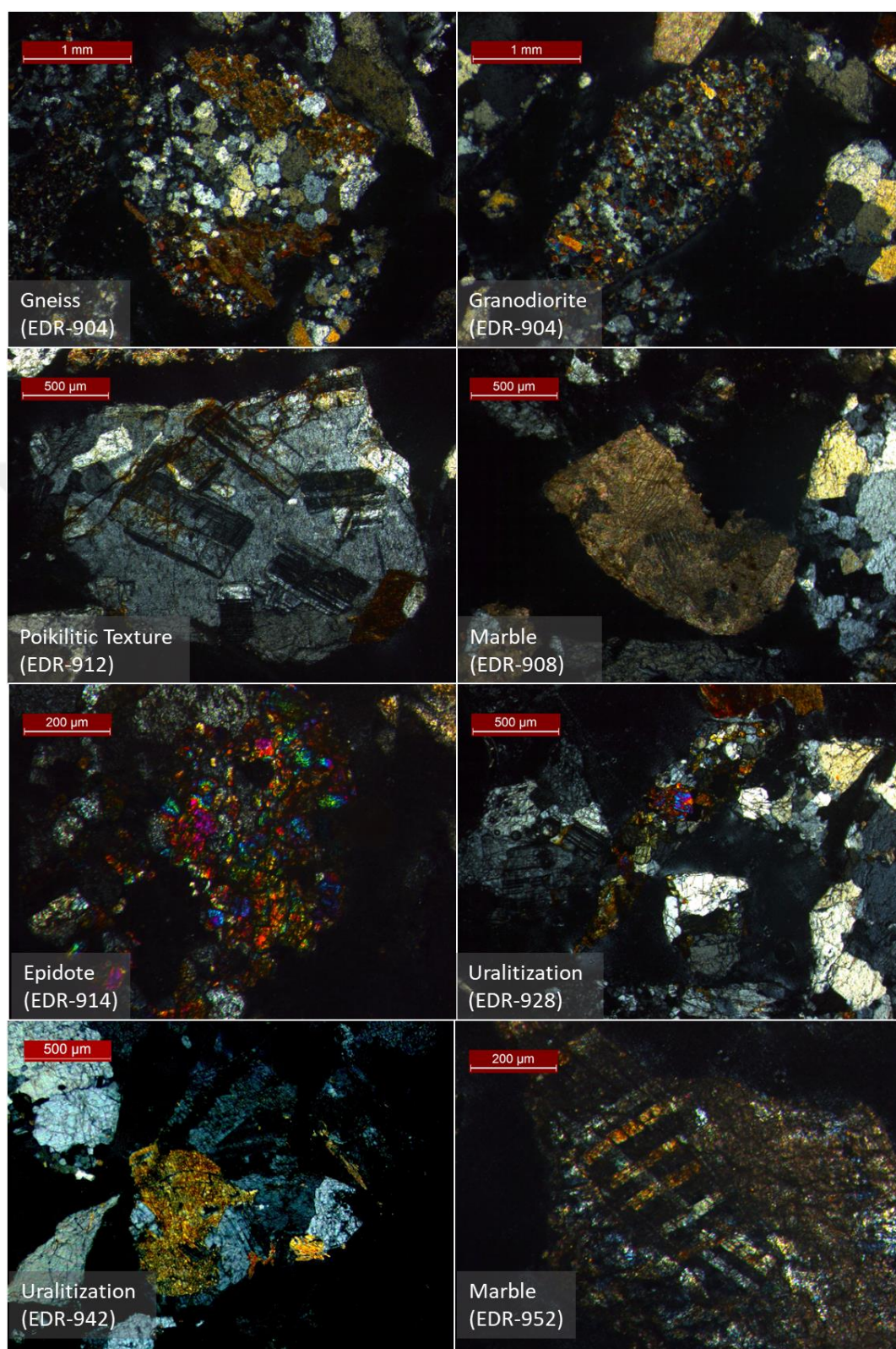


Figure A.5. Microscopic views of Edremit samples

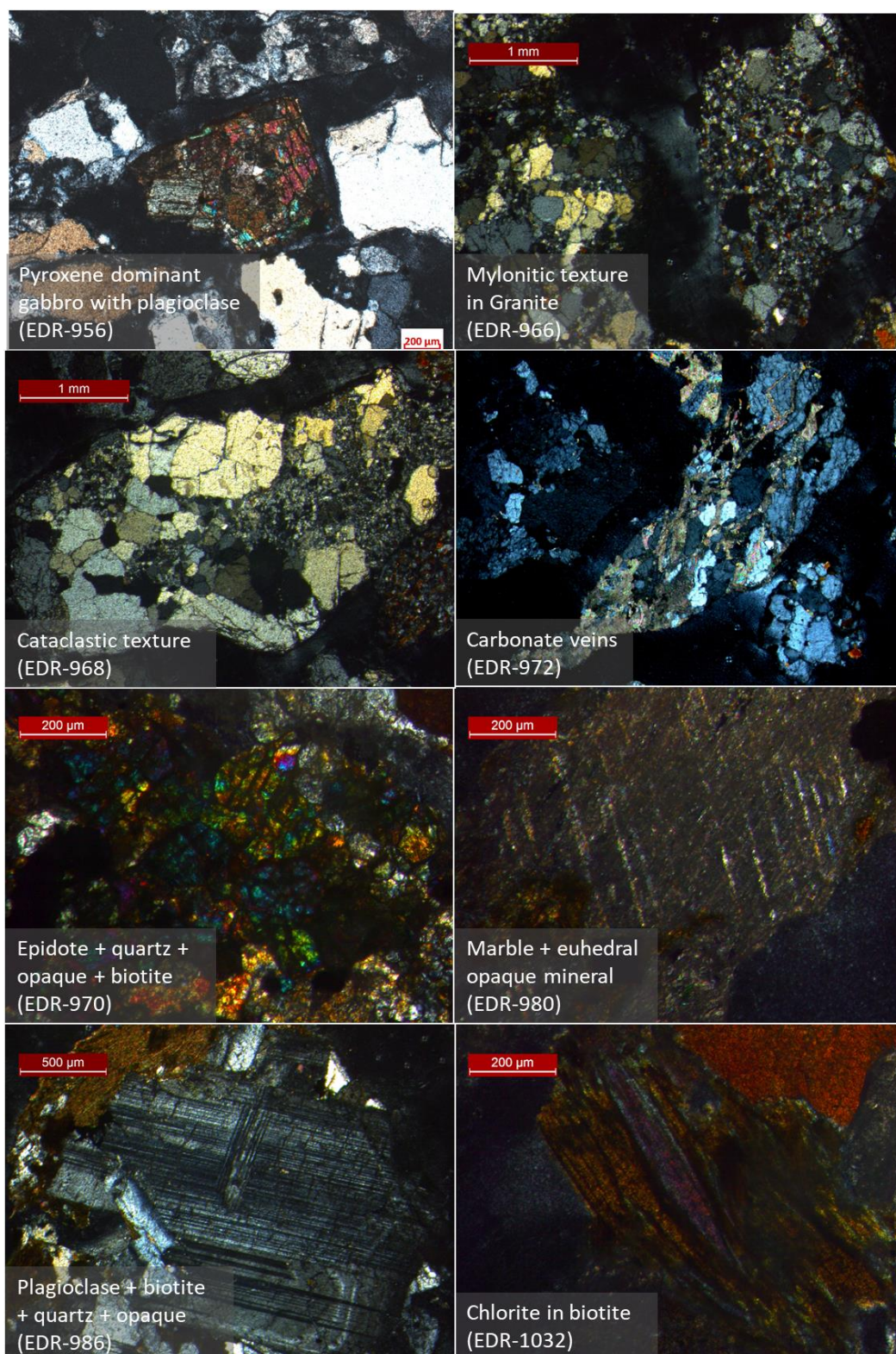


Figure A.6. Microscopic views of Edremit samples

B. XRD Patterns of Samples from Akköy and Edremit Fields

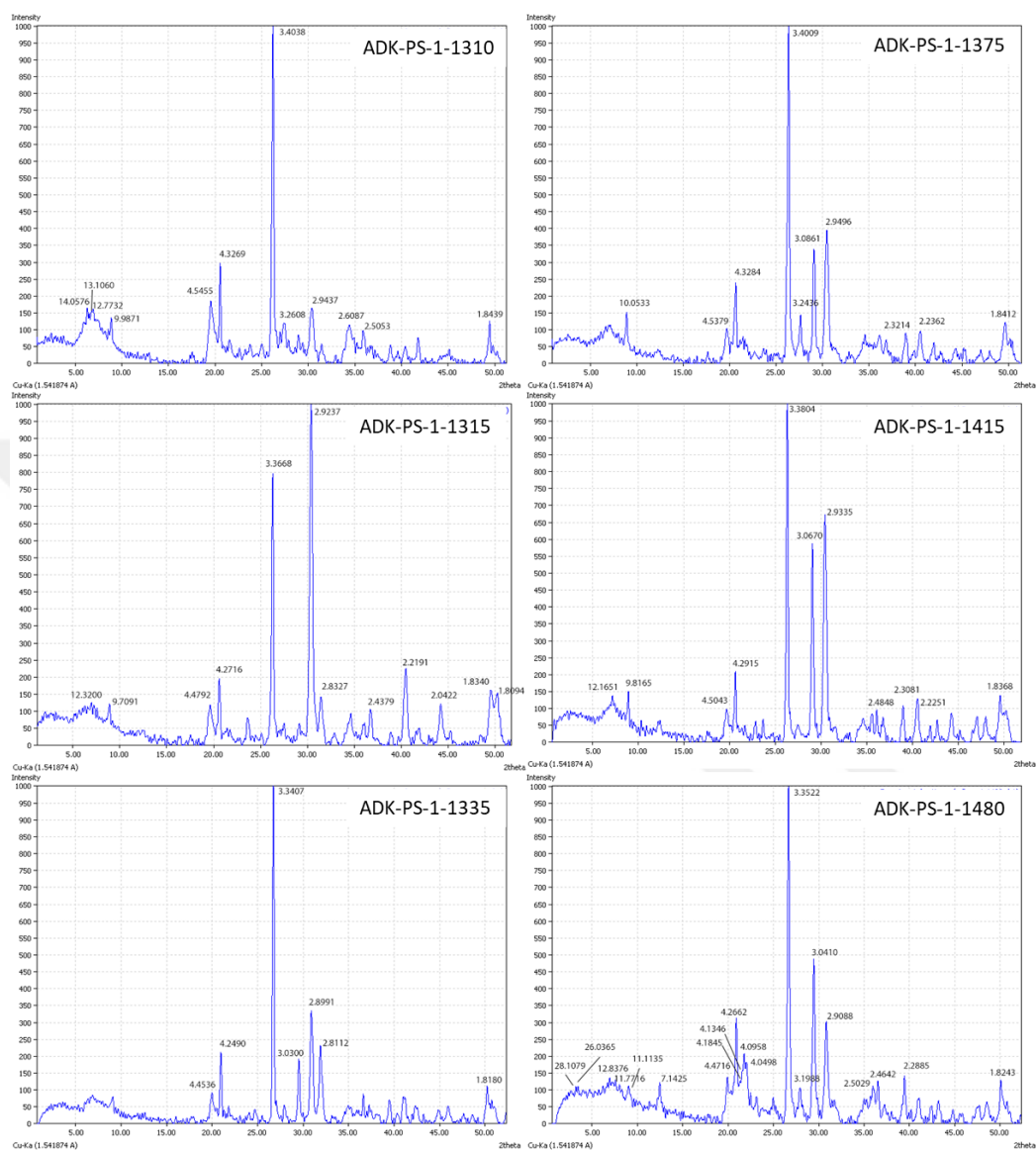


Figure B.1. XRD patterns of Akköy samples

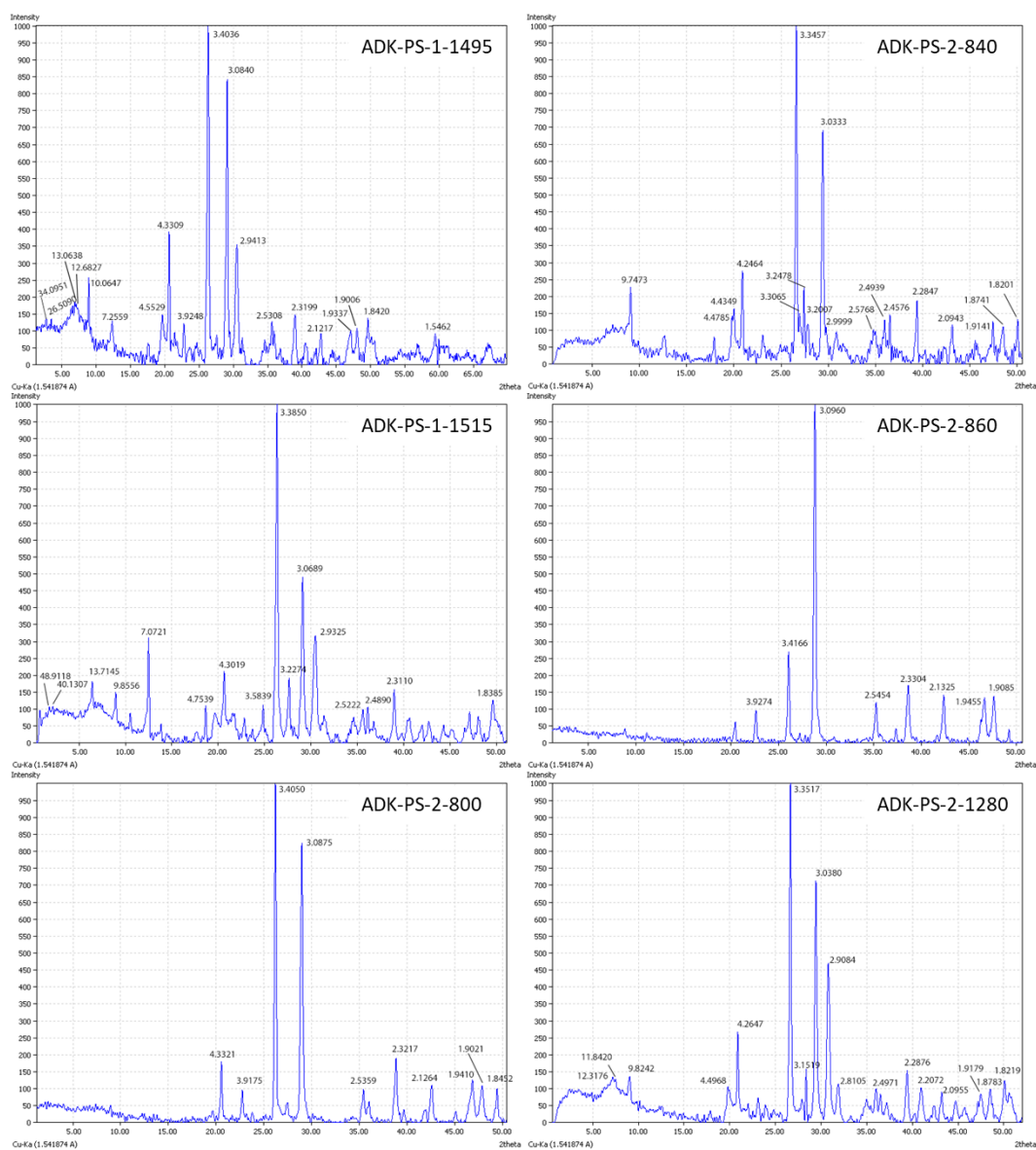


Figure B.2. XRD patterns of Akköy samples

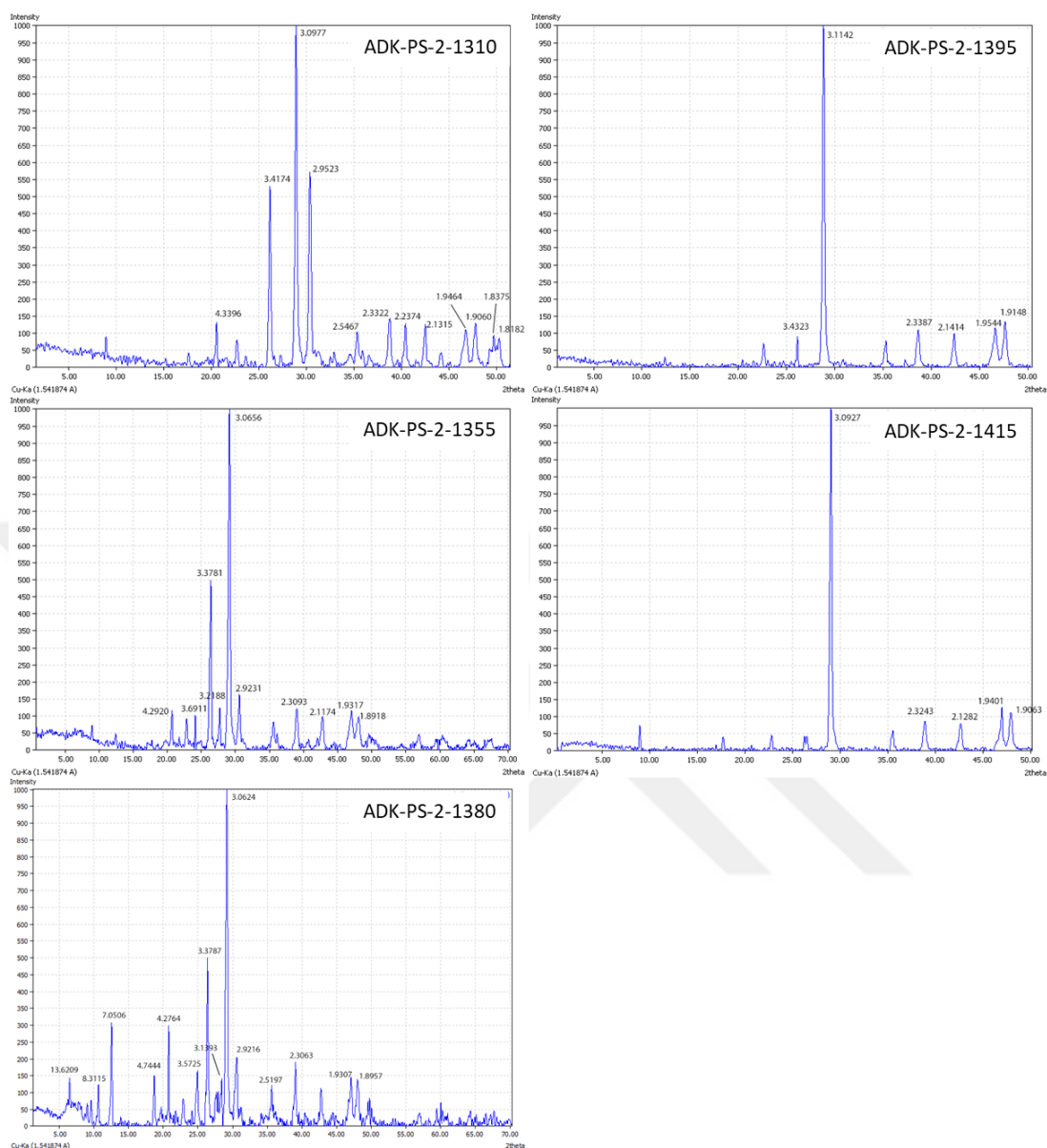


Figure B.3. XRD patterns of Akköy samples

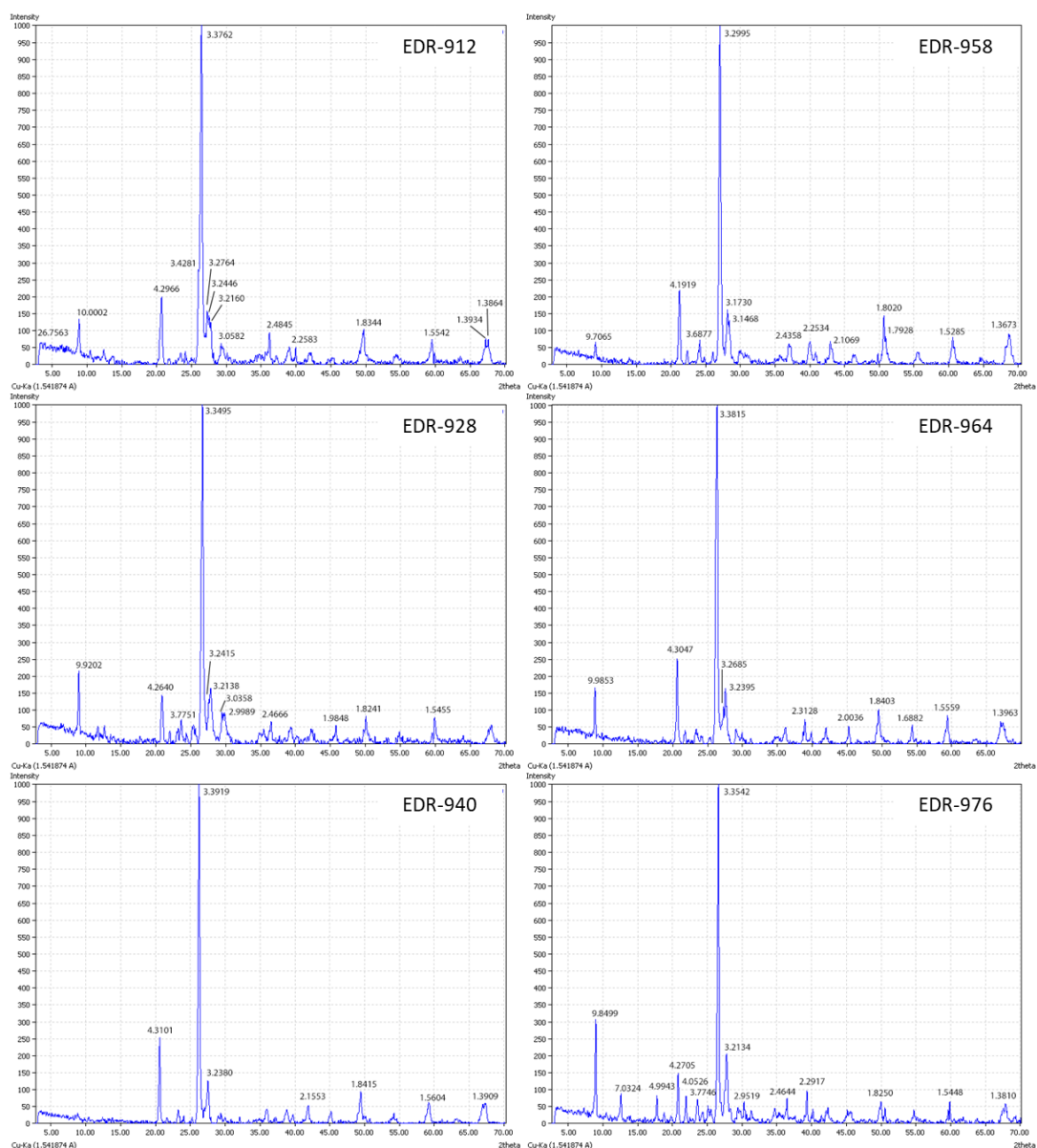


Figure B.4. XRD patterns of Edremet samples

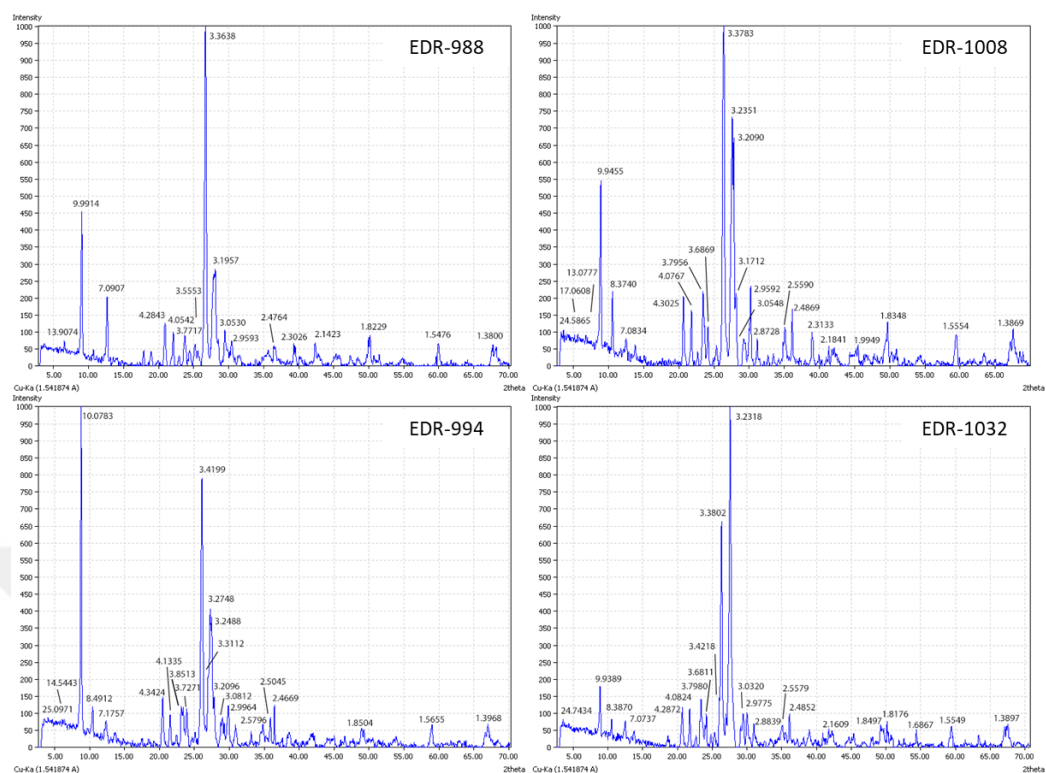


Figure B.5. XRD patterns of Edremit samples

C. Raman Spectrums of Various Minerals from Akköy and Edremit Fields

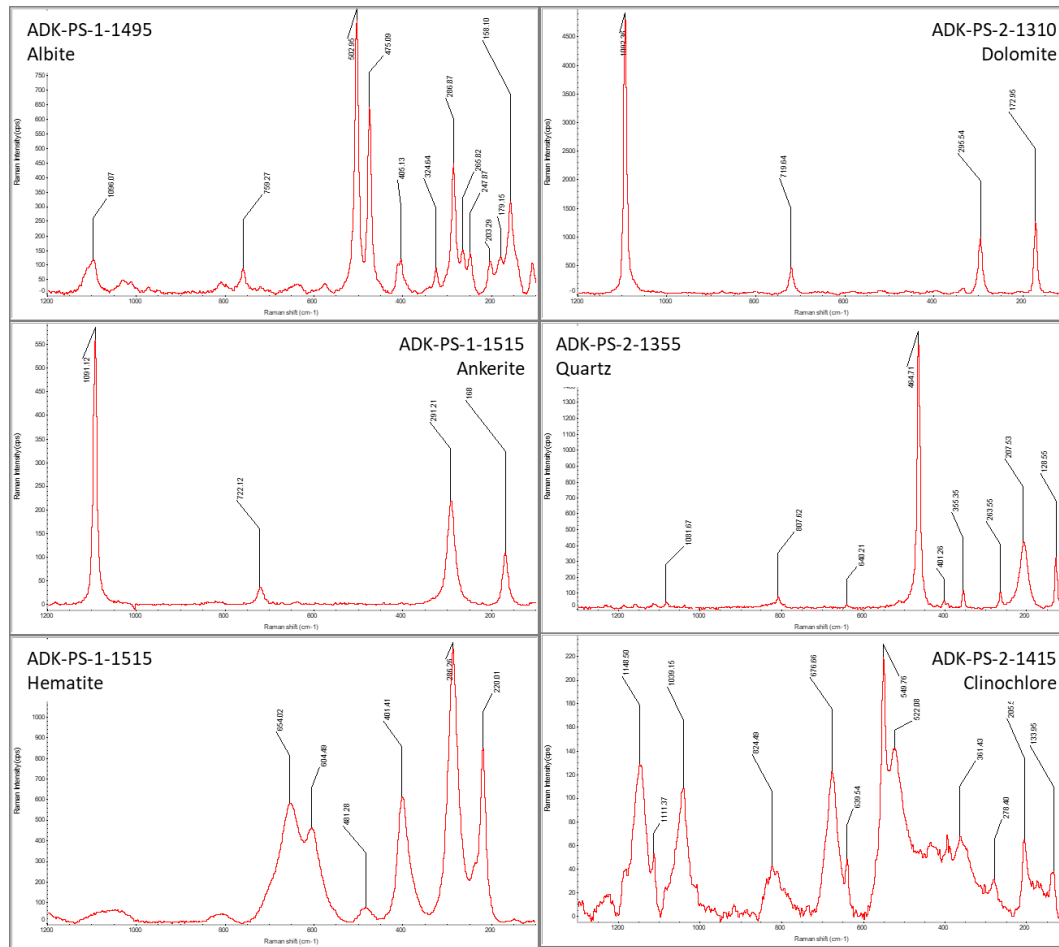


Figure C.1. Raman spectrums of various minerals from Akköy field

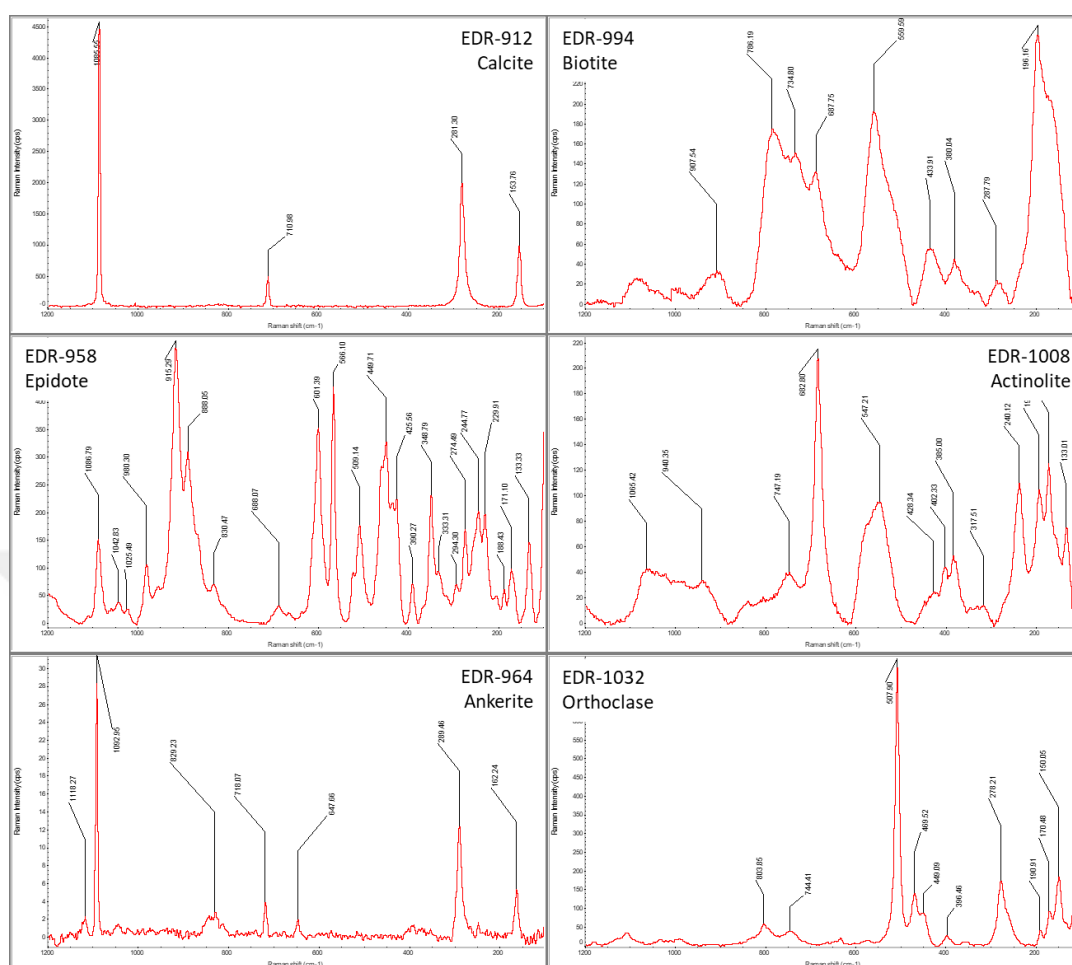


Figure C.2. Raman spectrums of various minerals from Edremit field

D. EPMA Results of Samples from Akköy and Edremit Fields

Table D.1 EPMA results of feldspar minerals from Akköy field

Feldspar	Sample No.	PS-1-1510						PS-1-1515						PS-2-1270						PS-2-1270	
	Region/Mineral	1/1						1/1		1/2	1/3			1/1						1/2	
	Spot No.	1	2	3	5	6	7	1	3	5	2	1	2	3	4	2	3	4	5	6	1
	SiO ₂	61,96	61,56	62,11	62,71	62,42	62,74	68,10	67,78	67,40	66,54	66,51	65,91	66,16	67,46	61,41	61,69	62,02	63,51	62,69	60,16
	TiO ₂	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,01	0,00	0,00	0,00	0,02	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Al ₂ O ₃	19,54	19,33	19,66	19,99	19,56	19,87	20,85	20,91	20,88	20,45	20,53	20,29	22,02	20,86	19,47	19,62	19,57	19,95	19,89	24,02	
FeO	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,01	0,02	0,01	0,10	0,04	0,00	0,02	0,03	0,03	0,02	0,03	0,05	0,14	
MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
MgO	0,01	0,00	0,02	0,01	0,00	0,01	0,00	0,01	0,02	0,01	0,02	0,00	0,04	0,02	0,00	0,00	0,01	0,01	0,00	0,00	
CaO	0,01	0,04	0,10	0,05	0,04	0,07	0,16	0,15	0,11	0,03	0,12	0,13	0,10	0,12	0,21	0,26	0,14	0,14	0,29	4,33	
Na ₂ O	1,01	0,98	1,05	0,98	0,71	0,77	12,41	12,88	12,41	12,77	12,48	12,02	11,74	12,84	1,32	1,81	0,87	0,78	0,54	9,19	
K ₂ O	16,46	16,49	16,46	16,51	16,74	16,58	0,02	0,03	0,03	0,01	0,03	0,02	0,02	0,02	15,69	15,27	16,35	16,39	16,54	0,46	
SO ₃	0,01	0,01	0,02	0,01	0,00	0,01	0,03	0,05	0,03	0,02	0,00	0,01	0,03	0,02	0,02	0,01	0,01	0,04	0,04	0,02	
Total	99,04	98,43	99,44	100,28	99,50	100,05	101,63	101,81	100,90	99,85	99,80	98,42	100,11	101,35	98,15	98,70	98,99	100,84	100,02	98,32	
Formula																					
Si	11,66	11,67	11,65	11,65	11,69	11,67	11,76	11,71	11,73	11,72	11,71	11,75	11,58	11,70	11,64	11,62	11,67	11,70	11,67	10,89	
Al	4,34	4,32	4,35	4,37	4,32	4,36	4,24	4,26	4,28	4,25	4,26	4,26	4,54	4,27	4,35	4,36	4,34	4,33	4,36	5,13	
Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,005	0,002	0,00	0,00	0,002	0,001	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Fe	0,004	0,003	0,003	0,002	0,003	0,003	0,004	0,001	0,003	0,002	0,015	0,005	0,00	0,002	0,004	0,004	0,003	0,005	0,007	0,021	
Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Mg	0,003	0,001	0,004	0,001	0,001	0,002	0,000	0,003	0,006	0,003	0,004	0,00	0,010	0,004	0,001	0,001	0,003	0,002	0,00	0,00	
Ca	0,00	0,01	0,02	0,01	0,01	0,01	0,03	0,03	0,02	0,01	0,02	0,02	0,02	0,02	0,04	0,05	0,03	0,03	0,06	0,84	
Na	0,37	0,36	0,38	0,35	0,26	0,28	4,15	4,31	4,18	4,36	4,26	4,15	3,98	4,32	0,49	0,66	0,32	0,28	0,19	3,23	
K	3,95	3,99	3,94	3,91	4,00	3,93	0,00	0,01	0,01	0,00	0,01	0,00	0,00	0,00	3,79	3,67	3,92	3,85	3,93	0,11	
Total	20,33	20,35	20,34	20,30	20,28	20,26	20,20	20,32	20,23	20,34	20,29	20,20	20,14	20,32	20,32	20,37	20,28	20,20	20,21	20,21	
End Members																					
Or	91,39	91,54	90,75	91,48	93,76	93,08	0,12	0,13	0,14	0,05	0,15	0,11	0,09	0,10	87,77	83,71	91,89	92,68	94,00	2,55	
Ab	8,54	8,29	8,78	8,27	6,04	6,59	99,19	99,24	99,37	99,81	99,32	99,29	99,45	99,38	11,25	15,08	7,46	6,66	4,63	77,33	
An	0,07	0,17	0,47	0,25	0,21	0,33	0,69	0,63	0,49	0,14	0,54	0,59	0,45	0,52	0,98	1,21	0,65	0,66	1,37	20,12	
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	

Table D.1 EPMA results of feldspar minerals from Akköy field (cont'd)

Feldspar	Sample No.	PS-2-1270																				
	Region/Mineral	1/2										1/3	2/1						2/2			
	Spot No.	2	3	4	5	6	7	8	9	10	11	1	1	2	3	4	5	6	2	3	4	5
	SiO ₂	62,43	61,65	61,82	60,87	61,25	60,79	60,88	60,38	61,29	59,99	61,95	63,36	62,39	62,90	63,35	63,07	63,49	62,91	63,60	63,99	62,77
	TiO ₂	0,00	0,00	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,04
Al ₂ O ₃	24,54	24,39	24,60	24,48	24,42	24,39	24,41	24,37	24,57	24,39	24,07	19,45	19,11	19,54	19,60	19,34	19,36	19,68	19,71	20,02	19,67	
FeO	0,15	0,16	0,16	0,11	0,14	0,13	0,17	0,16	0,14	0,15	0,15	0,06	0,03	0,02	0,03	0,04	0,07	0,70	0,20	0,20	1,40	
MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
MgO	0,00	0,00	0,00	0,02	0,00	0,01	0,00	0,00	0,00	0,02	0,00	0,00	0,01	0,00	0,01	0,01	0,02	0,39	0,07	0,06	0,53	
CaO	4,30	4,27	4,36	4,28	4,25	4,32	4,20	4,23	4,22	4,38	4,30	0,28	0,07	0,06	0,10	0,23	0,24	0,06	0,10	0,06	0,33	
Na ₂ O	9,82	9,64	9,85	9,50	9,61	9,42	9,23	9,47	9,59	9,44	9,49	0,33	0,37	0,28	0,28	0,37	0,32	0,29	0,30	0,40	0,42	
K ₂ O	0,40	0,48	0,42	0,47	0,43	0,41	0,44	0,44	0,43	0,38	0,45	17,08	17,03	17,22	17,38	17,29	17,25	16,60	17,02	17,03	16,46	
SO ₃	0,02	0,00	0,02	0,02	0,02	0,00	0,02	0,04	0,05	0,04	0,04	0,02	0,00	0,02	0,02	0,01	0,01	0,00	0,00	0,00	0,00	
Total	101,67	100,58	101,24	99,73	100,14	99,46	99,37	99,09	100,29	98,78	100,44	100,58	99,00	100,04	100,77	100,36	100,75	100,64	101,01	101,77	101,62	
Formula																						
Si	10,93	10,91	10,88	10,87	10,89	10,88	10,89	10,86	10,88	10,83	10,97	11,74	11,75	11,72	11,73	11,73	11,75	11,66	11,72	11,70	11,57	
Al	5,06	5,09	5,10	5,15	5,12	5,14	5,15	5,17	5,14	5,19	5,03	4,25	4,24	4,29	4,28	4,24	4,22	4,30	4,28	4,32	4,27	
Ti	0,00	0,00	0,001	0,000	0,000	0,001	0,002	0,000	0,001	0,001	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,001	0,001	0,006	
Fe	0,022	0,023	0,024	0,016	0,021	0,019	0,025	0,025	0,020	0,022	0,022	0,009	0,004	0,003	0,005	0,006	0,011	0,108	0,031	0,031	0,216	
Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Mg	0,001	0,000	0,000	0,005	0,00	0,002	0,000	0,000	0,001	0,005	0,00	0,001	0,002	0,00	0,001	0,002	0,006	0,11	0,02	0,02	0,15	
Ca	0,81	0,81	0,82	0,82	0,81	0,83	0,80	0,81	0,80	0,85	0,82	0,05	0,01	0,01	0,02	0,05	0,05	0,01	0,02	0,01	0,06	
Na	3,33	3,31	3,36	3,29	3,31	3,27	3,20	3,30	3,30	3,30	3,26	0,12	0,14	0,10	0,10	0,13	0,11	0,10	0,11	0,14	0,15	
K	0,09	0,11	0,09	0,11	0,10	0,09	0,10	0,10	0,10	0,09	0,10	4,04	4,09	4,09	4,10	4,10	4,07	3,92	4,00	3,97	3,87	
Total	20,25	20,25	20,29	20,25	20,25	20,23	20,18	20,26	20,25	20,27	20,19	20,21	20,24	20,23	20,23	20,27	20,23	20,21	20,19	20,20	20,30	
End Members																						
Or	2,13	2,56	2,22	2,51	2,33	2,21	2,47	2,37	2,31	2,04	2,43	95,85	96,48	97,30	97,16	95,79	96,18	97,10	96,94	96,27	94,74	
Ab	78,80	78,28	78,59	78,05	78,50	78,02	77,95	78,31	78,57	77,97	78,03	2,85	3,19	2,40	2,36	3,13	2,70	2,59	2,56	3,45	3,67	
An	19,07	19,15	19,19	19,44	19,18	19,77	19,58	19,32	19,11	19,99	19,55	1,30	0,33	0,30	0,47	1,08	1,13	0,31	0,49	0,28	1,59	
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	

Table D.1 EPMA results of feldspar minerals from Akköy field (cont'd)

Feldspar	Sample No.	PS-2-1345				PS-2-1355										PS-2-1380						
	Region/Mineral	1/1				2/1										2/1						
	Spot No.	5	7	9	10	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
	SiO ₂	67,23	67,70	67,94	66,92	66,74	67,17	66,84	67,41	66,63	67,23	66,61	66,89	67,39	67,52	67,33	65,84	67,57	68,70	66,25	66,11	66,54
	TiO ₂	0,01	0,01	0,01	0,09	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,01	0,03	0,00
	Al ₂ O ₃	21,00	19,63	20,66	20,33	20,38	20,55	20,53	20,73	20,26	20,62	20,42	20,35	20,78	20,82	20,53	20,32	20,56	20,61	20,48	20,66	20,53
	FeO	0,09	0,26	0,07	0,08	0,02	0,04	0,01	0,04	0,00	0,03	0,04	0,02	0,02	0,04	0,03	0,03	0,03	0,03	0,02	0,03	0,04
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	0,01	0,06	0,00	0,00	0,02	0,00	0,01	0,01	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,01	0,00	0,02	0,01	0,02	0,01
	CaO	0,66	0,36	0,14	0,29	0,04	0,18	0,12	0,08	0,04	0,11	0,21	0,04	0,30	0,28	0,04	0,06	0,05	0,08	0,05	0,09	0,07
	Na ₂ O	12,70	12,42	13,01	12,49	12,60	12,84	12,75	13,02	12,56	12,79	12,87	12,55	12,91	12,85	12,60	12,65	12,80	11,84	12,69	12,67	12,79
	K ₂ O	0,06	0,06	0,06	0,06	0,06	0,06	0,05	0,06	0,06	0,05	0,05	0,06	0,06	0,06	0,06	0,05	0,04	0,05	0,05	0,04	0,04
	SO ₃	0,01	0,01	0,00	0,01	0,01	0,01	0,00	0,01	0,01	0,02	0,02	0,00	0,02	0,03	0,01	0,02	0,02	0,00	0,01	0,02	0,01
	Total	101,77	100,50	101,89	100,26	99,87	100,84	100,31	101,37	99,57	100,85	100,23	99,91	101,47	101,61	100,60	98,97	101,07	101,35	99,58	99,66	100,03
	Formula																					
	Si	11,64	11,85	11,73	11,74	11,74	11,72	11,72	11,71	11,76	11,72	11,71	11,76	11,69	11,70	11,76	11,71	11,75	11,85	11,70	11,67	11,70
	Al	4,29	4,05	4,21	4,20	4,23	4,23	4,24	4,24	4,21	4,24	4,23	4,22	4,25	4,25	4,22	4,26	4,21	4,19	4,26	4,30	4,26
	Ti	0,001	0,002	0,001	0,011	0,000	0,000	0,000	0,002	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,002	0,001	0,004	0,00
	Fe	0,012	0,038	0,010	0,012	0,003	0,006	0,001	0,006	0,000	0,005	0,006	0,002	0,003	0,005	0,004	0,004	0,004	0,005	0,003	0,005	0,006
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,003	0,02	0,000	0,000	0,004	0,00	0,002	0,002	0,00	0,00	0,00	0,00	0,002	0,006	0,002	0,002	0,001	0,006	0,002	0,004	0,004
	Ca	0,12	0,07	0,03	0,05	0,01	0,03	0,02	0,01	0,01	0,02	0,04	0,01	0,05	0,05	0,01	0,01	0,01	0,01	0,01	0,02	0,01
	Na	4,27	4,21	4,36	4,25	4,30	4,34	4,34	4,38	4,30	4,33	4,39	4,28	4,34	4,32	4,27	4,36	4,32	3,96	4,35	4,34	4,36
	K	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Total	20,35	20,24	20,35	20,28	20,30	20,34	20,33	20,37	20,29	20,33	20,38	20,28	20,36	20,34	20,27	20,35	20,30	20,04	20,34	20,35	20,35
	End Members																					
	Or	0,32	0,31	0,29	0,30	0,30	0,29	0,27	0,29	0,30	0,28	0,24	0,29	0,28	0,28	0,29	0,27	0,21	0,25	0,25	0,22	0,20
	Ab	96,90	98,13	99,13	98,45	99,52	98,92	99,20	99,39	99,53	99,25	98,85	99,52	98,48	98,53	99,54	99,48	99,60	99,39	99,52	99,41	99,48
	An	2,79	1,55	0,58	1,26	0,18	0,78	0,53	0,32	0,17	0,48	0,91	0,19	1,24	1,19	0,17	0,25	0,19	0,35	0,23	0,37	0,31
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table D.1 EPMA results of feldspar minerals from Akköy field (cont'd)

	Sample No.	PS-2-1405																	
	Region/Mineral	1/1					1/2										1/3		
	Spot No.	2	3	4	5	6	1	2	3	4	6	7	8	9	10	11	1	2	3
	SiO ₂	66,78	68,17	67,39	66,46	66,82	66,36	67,25	67,40	67,42	67,39	67,16	66,92	68,13	67,17	67,66	66,29	66,87	67,58
	TiO ₂	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,02	0,00	0,00	0,02	0,00	0,01	0,00
	Al ₂ O ₃	20,30	20,54	20,66	20,23	20,49	20,25	20,48	20,56	20,50	20,55	20,52	20,51	20,44	20,22	20,51	20,43	20,80	20,76
	FeO	0,01	0,02	0,01	0,01	0,02	0,06	0,04	0,01	0,05	0,03	0,02	0,04	0,04	0,02	0,03	0,03	0,03	0,05
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	0,00	0,01	0,00	0,05	0,00	0,00	0,00	0,01	0,02	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,01
	CaO	0,04	0,05	0,12	0,07	0,08	0,34	0,08	0,06	0,17	0,20	0,12	0,12	0,08	0,15	0,09	0,05	0,28	0,06
Feldspar	Na ₂ O	12,40	12,94	12,95	12,36	12,62	12,68	12,70	13,09	12,73	12,99	12,71	12,84	12,69	12,52	12,82	12,57	12,32	12,89
	K ₂ O	0,06	0,06	0,06	0,06	0,06	0,05	0,06	0,05	0,05	0,06	0,05	0,06	0,05	0,06	0,05	0,05	0,05	0,06
	SO ₃	0,00	0,00	0,12	0,03	0,02	0,01	0,00	0,02	0,00	0,01	0,00	0,02	0,02	0,00	0,01	0,01	0,01	0,00
	Total	99,59	101,79	101,30	99,27	100,11	99,75	100,61	101,20	100,95	101,21	100,59	100,52	101,45	100,14	101,19	99,44	100,37	101,39
	Formula																		
	Si	11,77	11,77	11,72	11,76	11,73	11,71	11,75	11,72	11,74	11,72	11,74	11,72	11,79	11,78	11,76	11,72	11,70	11,72
	Al	4,22	4,18	4,23	4,22	4,24	4,21	4,22	4,22	4,21	4,21	4,23	4,23	4,17	4,18	4,20	4,26	4,29	4,24
	Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,002	0,00	0,00	0,002	0,00	0,00	0,002	0,001	0,002	0,000
	Fe	0,002	0,002	0,001	0,001	0,003	0,009	0,005	0,002	0,007	0,005	0,003	0,006	0,005	0,003	0,005	0,005	0,004	0,007
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mg	0,000	0,002	0,000	0,014	0,00	0,00	0,00	0,002	0,004	0,001	0,00	0,003	0,00	0,00	0,00	0,000	0,000	0,002	
Ca	0,01	0,01	0,02	0,01	0,02	0,06	0,02	0,01	0,03	0,04	0,02	0,02	0,01	0,03	0,02	0,01	0,05	0,01	
Na	4,24	4,33	4,37	4,24	4,30	4,34	4,30	4,41	4,30	4,38	4,31	4,36	4,26	4,26	4,32	4,31	4,18	4,33	
K	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	
	Total	20,25	20,31	20,36	20,26	20,30	20,35	20,30	20,38	20,31	20,37	20,31	20,35	20,26	20,26	20,31	20,31	20,24	20,33
Feldspar	End Members																		
	Or	0,33	0,32	0,32	0,31	0,31	0,25	0,30	0,27	0,26	0,25	0,30	0,25	0,28	0,25	0,28	0,28	0,28	0,28
	Ab	99,48	99,48	99,19	99,40	99,33	98,28	99,35	99,47	99,02	98,91	99,18	99,25	99,38	99,08	99,35	99,52	98,47	99,47
	An	0,19	0,20	0,49	0,30	0,36	1,47	0,35	0,26	0,73	0,84	0,52	0,49	0,33	0,67	0,37	0,20	1,25	0,25
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table D.2 EPMA results of amphibole minerals from Akköy field

Amphibole	Sample No.	PS-2-1270									
	Region/Mineral	1/1				2/1			2/2	2/3	
	Spot No.	2	4	5	6	1	3	4	1	1	3
	SiO ₂	45,73	44,00	45,41	43,91	40,27	40,00	39,96	53,36	51,38	50,01
	TiO ₂	0,37	0,45	0,41	0,45	1,58	1,56	1,61	0,03	0,03	0,05
	Al ₂ O ₃	8,13	8,40	8,92	8,81	11,07	11,09	11,13	2,17	2,35	4,08
	Cr ₂ O ₃	0,14	0,16	0,18	0,19	0,03	0,01	0,03	0,02	0,02	0,00
	FeO	17,47	17,64	17,64	17,91	22,88	23,01	23,09	14,38	15,01	16,84
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	12,21	11,68	12,38	11,73	8,16	8,01	8,02	15,17	14,72	13,82
	CaO	11,60	11,53	11,49	11,50	11,56	11,41	11,37	12,04	12,47	12,06
	Na ₂ O	1,36	1,40	1,49	1,44	1,55	1,75	1,64	0,36	0,35	0,56
	K ₂ O	0,71	0,76	0,77	0,82	1,51	1,58	1,59	0,19	0,12	0,28
	<i>Total</i>	<i>97,72</i>	<i>96,00</i>	<i>98,70</i>	<i>96,76</i>	<i>98,61</i>	<i>98,42</i>	<i>98,44</i>	<i>97,71</i>	<i>96,45</i>	<i>97,72</i>
	O	23	23	23	23	23	23	23	23	23	23
	Cation	15	15	15	15	15	15	15	15	15	15
	Formula										
	Si	6,76	6,64	6,64	6,58	6,12	6,12	6,10	7,70	7,57	7,31
	Ti	0,04	0,05	0,05	0,05	0,18	0,18	0,18	0,00	0,00	0,01
	Al-iv	1,24	1,36	1,36	1,42	1,88	1,88	1,90	0,30	0,43	0,69
	Al-vi	0,17	0,14	0,17	0,13	0,11	0,11	0,10	0,07	0,00	0,01
	Cr	0,02	0,02	0,02	0,02	0,00	0,00	0,00	0,00	0,00	0,00
	Fe ³⁺	0,63	0,69	0,73	0,75	0,77	0,73	0,78	0,22	0,24	0,50
	Fe ²⁺	1,53	1,54	1,43	1,49	2,14	2,22	2,17	1,51	1,61	1,56
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	2,69	2,63	2,70	2,62	1,85	1,83	1,83	3,26	3,23	3,01
	Ca	1,84	1,86	1,80	1,85	1,88	1,87	1,86	1,86	1,97	1,89
	Na	0,39	0,41	0,42	0,42	0,46	0,52	0,48	0,10	0,10	0,16
	K	0,13	0,15	0,14	0,16	0,29	0,31	0,31	0,04	0,02	0,05
	<i>Total</i>	<i>15,44</i>	<i>15,48</i>	<i>15,46</i>	<i>15,49</i>	<i>15,69</i>	<i>15,76</i>	<i>15,72</i>	<i>15,07</i>	<i>15,16</i>	<i>15,19</i>
	CaB	1,84	1,86	1,80	1,85	1,88	1,87	1,86	1,86	1,97	1,89
	NaB	0,09	0,07	0,11	0,08	0,06	0,07	0,07	0,07	0,00	0,02
	NaA	0,30	0,34	0,31	0,33	0,39	0,45	0,41	0,03	0,14	0,14
	KA	0,13	0,15	0,14	0,16	0,29	0,31	0,31	0,04	0,02	0,05

Table D.3 EPMA results of mica minerals from Akköy field

Mica	Sample No.	PS-2-1315							PS-2-1355		
	Region/Mineral	1/1	2/1				2/2			1/1	
	Spot No.	5	2	3	5	1	2	3	3	4	5
	SiO ₂	49,27	45,02	42,77	45,78	44,96	44,74	42,01	51,68	49,77	50,44
	TiO ₂	0,74	0,29	0,33	0,32	0,31	0,23	0,29	0,14	0,20	0,19
	Al ₂ O ₃	26,45	32,99	29,71	32,07	32,91	34,78	30,19	24,33	26,79	25,21
	FeO	8,24	2,62	2,31	2,72	2,56	2,22	2,46	3,40	3,15	5,63
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	2,24	0,92	0,81	1,05	1,00	0,59	0,86	4,26	3,47	3,92
	CaO	0,07	0,05	0,03	0,06	0,03	0,05	0,07	0,06	0,09	0,09
	Na ₂ O	0,26	0,61	0,52	0,63	0,58	0,63	0,54	0,23	0,53	0,45
	K ₂ O	11,33	10,58	10,56	10,59	10,94	10,90	9,77	10,97	10,73	10,28
	Cr ₂ O ₃	0,01	0,02	0,01	0,00	0,02	0,03	0,02	0,73	0,68	0,60
	SO ₃	0,03	0,04	0,02	0,04	0,03	0,01	0,03	0,00	0,01	0,01
	<i>Total</i>	<i>98,62</i>	<i>93,14</i>	<i>87,08</i>	<i>93,26</i>	<i>93,34</i>	<i>94,15</i>	<i>86,23</i>	<i>95,79</i>	<i>95,42</i>	<i>96,82</i>
	<i>Formula</i>										
	Si	6,60	6,20	6,32	6,29	6,19	6,09	6,24	6,94	6,71	6,76
	Al-iv	1,40	1,80	1,68	1,71	1,81	1,91	1,76	1,06	1,29	1,24
	Al-vi	2,78	3,55	3,49	3,49	3,53	3,67	3,53	2,78	2,96	2,75
	Ti	0,07	0,03	0,04	0,03	0,03	0,02	0,03	0,01	0,02	0,02
	Cr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,07	0,06
	Fe ⁺²	0,92	0,30	0,29	0,31	0,29	0,25	0,31	0,38	0,35	0,63
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,45	0,19	0,18	0,22	0,20	0,12	0,19	0,85	0,70	0,78
	Ca	0,01	0,01	0,00	0,01	0,00	0,01	0,01	0,01	0,01	0,01
	Na	0,07	0,16	0,15	0,17	0,16	0,17	0,16	0,06	0,14	0,12
	K	1,94	1,86	1,99	1,86	1,92	1,89	1,85	1,88	1,84	1,76
	<i>Total</i>	<i>14,24</i>	<i>14,10</i>	<i>14,13</i>	<i>14,09</i>	<i>14,14</i>	<i>14,13</i>	<i>14,08</i>	<i>14,06</i>	<i>14,10</i>	<i>14,13</i>
	Fe/Fe+Mg	0,67	0,62	0,62	0,59	0,59	0,68	0,62	0,31	0,34	0,45
	Fe+Mn+Ti	1,00	0,33	0,32	0,35	0,33	0,28	0,34	0,40	0,38	0,65
	Mg-Li	0,45	0,19	0,18	0,22	0,20	0,12	0,19	0,85	0,70	0,78

Table D.4 EPMA results of pyroxene minerals from Akköy field

Pyroxene	Sample No.	PS-2-1270							
	Region/Mineral	1/1		2/1					2/2
	Spot No.	1	3	2	5	6	7	8	2
	SiO ₂	46,52	47,13	40,67	40,49	40,18	39,91	41,59	47,52
	TiO ₂	0,39	0,41	1,53	1,61	1,60	1,65	1,55	0,17
	Al ₂ O ₃	8,10	8,55	11,21	11,60	11,50	11,50	11,19	6,89
	Cr ₂ O ₃	0,16	0,15	0,02	0,04	0,03	0,03	0,04	0,00
	FeO	17,57	17,41	22,87	23,12	23,16	23,22	22,85	18,42
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	12,63	12,98	8,30	8,20	8,17	8,00	8,48	12,28
Pyroxene	CaO	11,59	11,63	11,38	11,34	11,37	11,37	11,43	12,32
	Na ₂ O	1,36	1,32	1,73	1,78	1,79	1,75	1,62	0,99
	K ₂ O	0,69	0,68	1,56	1,62	1,64	1,63	1,56	0,29
	Total	99,00	100,26	99,25	99,80	99,43	99,06	100,30	98,88
	O	6	6	6	6	6	6	6	6
	Cation	4	4	4	4	4	4	4	4
	Formula								
	Si	1,79	1,79	1,63	1,62	1,61	1,61	1,64	1,83
	Ti	0,01	0,01	0,05	0,05	0,05	0,05	0,05	0,00
	Al	0,37	0,38	0,53	0,55	0,54	0,55	0,52	0,31
Pyroxene	Cr	0,005	0,005	0,001	0,001	0,001	0,001	0,001	0,00
	Fe	0,57	0,55	0,77	0,77	0,78	0,78	0,75	0,59
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,73	0,73	0,50	0,49	0,49	0,48	0,50	0,71
	Ca	0,48	0,47	0,49	0,48	0,49	0,49	0,48	0,51
	Na	0,10	0,10	0,13	0,14	0,14	0,14	0,12	0,07
	K	0,03	0,03	0,08	0,08	0,08	0,08	0,08	0,01
	End Members								
	Es	41,00	41,74	28,32	27,97	27,86	27,41	28,75	39,02
	Wo	27,02	26,87	27,91	27,79	27,86	27,99	27,84	28,14
Pyroxene	Fs	31,98	31,39	43,77	44,24	44,28	44,60	43,41	32,84
	Total	100	100	100	100	100	100	100	100

Table D.5 EPMA results of feldspar minerals from Edremit field

Feldspar	Sample No.	EDR-912																			
	Region/Mineral	2/1				2/2			2/3			4/1					4/2				
	Spot No.	1	2	4	5	2	3	4	1	2	5	1	2	3	4	5	2	3	5	6	8
	SiO ₂	61,83	62,97	63,41	62,56	58,40	56,14	57,86	57,15	55,01	55,84	62,26	62,20	63,39	56,30	55,20	60,43	54,07	54,38	57,71	55,20
	TiO ₂	0,00	0,00	0,00	0,01	0,00	0,03	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,02	0,00	0,00	0,00	0,00
	Al ₂ O ₃	19,33	20,21	19,36	19,18	26,03	27,96	26,30	26,76	28,37	28,33	19,48	19,48	19,66	27,20	27,77	24,08	28,70	28,62	26,12	27,90
	FeO	0,11	0,11	0,08	0,10	0,23	0,20	0,19	0,24	0,27	0,23	0,10	0,12	0,12	0,23	0,23	0,13	0,23	0,23	0,23	0,26
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	0,01	0,03	0,00	0,01	0,01	0,02	0,02	0,02	0,00	0,01	0,00	0,01	0,01	0,01	0,00	0,00	0,00	0,01	0,00	0,01
	CaO	0,03	0,06	0,03	0,05	5,60	7,32	5,76	6,20	7,80	7,41	0,06	0,06	0,04	6,92	7,31	4,36	8,59	8,10	5,79	7,41
Feldspar	Na ₂ O	1,42	1,81	0,99	1,72	8,43	7,64	8,45	8,26	6,99	6,94	1,42	1,50	2,18	7,77	7,32	9,58	6,81	6,77	8,57	7,19
	K ₂ O	15,39	14,97	16,29	15,32	0,18	0,15	0,18	0,13	0,22	0,25	15,74	15,61	14,98	0,22	0,23	0,33	0,18	0,20	0,26	0,21
	SO ₃	0,01	0,003	0,00	0,004	0,01	0,00	0,01	0,01	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,003	0,01	0,01	0,02	0,002
	Total	98,12	100,16	100,17	98,95	98,89	99,45	98,77	98,77	98,67	99,02	99,06	98,98	100,39	98,65	98,07	98,93	98,57	98,32	98,69	98,17
	Formula																				
	Si	11,70	11,64	11,76	11,73	10,54	10,13	10,47	10,36	10,02	10,11	11,68	11,68	11,70	10,24	10,11	10,88	9,89	9,95	10,46	10,09
	Al	4,31	4,40	4,23	4,24	5,54	5,95	5,61	5,72	6,09	6,04	4,31	4,31	4,28	5,83	5,99	5,11	6,19	6,17	5,58	6,01
	Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Fe	0,02	0,02	0,01	0,02	0,03	0,03	0,03	0,04	0,04	0,03	0,02	0,02	0,02	0,04	0,04	0,02	0,03	0,04	0,03	0,04
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mg	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Ca	0,01	0,01	0,01	0,01	1,08	1,42	1,12	1,20	1,52	1,44	0,01	0,01	0,01	1,35	1,43	0,84	1,68	1,59	1,12	1,45	
Na	0,52	0,65	0,36	0,63	2,95	2,67	2,96	2,90	2,47	2,44	0,51	0,55	0,78	2,74	2,60	3,34	2,42	2,40	3,01	2,55	
K	3,71	3,53	3,85	3,66	0,04	0,03	0,04	0,03	0,05	0,06	3,77	3,74	3,53	0,05	0,05	0,08	0,04	0,05	0,06	0,05	
Total	20,26	20,25	20,23	20,29	20,19	20,24	20,23	20,25	20,20	20,12	20,30	20,31	20,31	20,24	20,22	20,27	20,25	20,19	20,28	20,20	
Feldspar	End Members																				
	Or	87,60	84,26	91,43	85,24	1,00	0,82	1,02	0,72	1,26	1,48	87,75	86,98	81,74	1,24	1,33	1,79	1,00	1,17	1,43	1,20
	Ab	12,25	15,45	8,44	14,55	72,42	64,86	71,89	70,18	61,07	61,97	11,99	12,73	18,06	66,20	63,59	78,45	58,35	59,47	71,77	62,93
	An	0,15	0,29	0,14	0,21	26,58	34,33	27,09	29,10	37,67	36,55	0,26	0,29	0,20	32,56	35,09	19,75	40,65	39,36	26,79	35,87
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table D.5 EPMA results of feldspar minerals from Edremit field (cont'd)

Feldspar	Sample No.	EDR-912				EDR-958	EDR-964													
	Region/Mineral	4/2		4/3		1/1	1/1					1/2			1/3	2/1			2/3	2/4
	Spot No.	9	10	5	6	3	1	2	3	4	5	1	2	3	3	1	2	3	1	4
	SiO ₂	56,73	62,34	55,74	62,00	64,44	58,42	55,27	54,56	54,90	55,21	56,79	53,39	55,06	60,64	55,92	55,86	57,69	56,67	55,79
	TiO ₂	0,00	0,00	0,02	0,00	0,00	0,01	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Al ₂ O ₃	26,74	19,40	27,55	19,26	19,38	25,83	27,39	27,97	28,24	28,25	26,60	28,17	28,27	23,58	27,57	27,45	26,53	27,24	27,43
	FeO	0,22	0,04	0,19	0,10	0,02	0,14	0,16	0,21	0,22	0,20	0,18	0,23	0,23	0,19	0,20	0,20	0,16	0,20	0,21
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	0,00	0,01	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,00	0,01	0,01	0,02	0,00	0,00	0,01	0,00
	CaO	6,45	0,19	6,84	0,02	0,01	5,90	7,79	8,15	8,05	7,91	6,60	8,52	7,80	3,75	6,80	7,16	5,94	6,77	6,98
	Na ₂ O	8,07	4,46	7,66	0,93	0,90	8,67	7,23	7,04	6,91	7,26	7,84	6,46	7,06	10,07	7,68	7,62	8,38	7,95	7,47
	K ₂ O	0,17	11,93	0,13	16,73	16,35	0,25	0,21	0,18	0,19	0,17	0,22	0,21	0,21	0,34	0,31	0,17	0,26	0,20	0,20
	SO ₃	0,01	0,001	0,002	0,01	0,02	0,01	0,00	0,00	0,004	0,01	0,01	0,01	0,00	0,02	0,01	0,01	0,01	0,01	0,02
	<i>Total</i>	<i>98,41</i>	<i>98,37</i>	<i>98,13</i>	<i>99,06</i>	<i>101,11</i>	<i>99,25</i>	<i>98,06</i>	<i>98,10</i>	<i>98,51</i>	<i>99,01</i>	<i>98,25</i>	<i>96,98</i>	<i>98,64</i>	<i>98,59</i>	<i>98,50</i>	<i>98,47</i>	<i>98,96</i>	<i>99,04</i>	<i>98,10</i>
	Formula																			
	Si	10,33	11,66	10,18	11,69	11,82	10,53	10,13	10,01	10,02	10,03	10,35	9,92	10,03	10,95	10,18	10,18	10,43	10,26	10,20
	Al	5,74	4,28	5,93	4,28	4,19	5,49	5,92	6,05	6,07	6,05	5,71	6,17	6,07	5,02	5,92	5,90	5,65	5,81	5,91
	Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Fe	0,03	0,01	0,03	0,02	0,00	0,02	0,02	0,03	0,03	0,03	0,03	0,04	0,03	0,03	0,03	0,03	0,02	0,03	0,03
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Ca	1,26	0,04	1,34	0,00	0,00	1,14	1,53	1,60	1,57	1,54	1,29	1,70	1,52	0,73	1,33	1,40	1,15	1,31	1,37
	Na	2,85	1,62	2,71	0,34	0,32	3,03	2,57	2,50	2,45	2,56	2,77	2,33	2,49	3,53	2,71	2,69	2,94	2,79	2,65
	K	0,04	2,85	0,03	4,02	3,83	0,06	0,05	0,04	0,05	0,04	0,05	0,05	0,05	0,08	0,07	0,04	0,06	0,05	0,05
	<i>Total</i>	<i>20,25</i>	<i>20,44</i>	<i>20,22</i>	<i>20,35</i>	<i>20,16</i>	<i>20,27</i>	<i>20,22</i>	<i>20,24</i>	<i>20,19</i>	<i>20,25</i>	<i>20,20</i>	<i>20,19</i>	<i>20,20</i>	<i>20,34</i>	<i>20,25</i>	<i>20,24</i>	<i>20,25</i>	<i>20,25</i>	<i>20,20</i>
	End Members																			
	Or	0,94	63,24	0,74	92,10	92,25	1,34	1,20	1,02	1,11	0,96	1,25	1,20	1,19	1,78	1,74	0,96	1,47	1,12	1,16
	Ab	68,70	35,93	66,45	7,81	7,69	71,68	61,93	60,36	60,18	61,85	67,42	57,12	61,34	81,45	65,99	65,19	70,80	67,26	65,18
	An	30,36	0,83	32,82	0,10	0,06	26,98	36,87	38,62	38,71	37,19	31,33	41,68	37,47	16,77	32,27	33,85	27,74	31,62	33,66
	<i>Total</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>

Table D.5 EPMA results of feldspar minerals from Edremit field (cont'd)

Feldspar	Sample No.	EDR-964			EDR-994													EDR-1008			
	Region/Mineral	2/5			1/1				2/1					2/2				3/1		3/2	
	Spot No.	1	2	3	1	2	3	4	1	2	3	4	5	6	7	2	3	4	2	3	5
	SiO ₂	62,71	62,60	62,38	57,15	56,62	56,97	56,99	55,86	55,86	55,10	56,16	55,44	55,86	55,76	58,79	55,69	56,24	54,98	58,07	54,74
	TiO ₂	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,02	0,00	0,02	0,00	0,02	0,00	0,00	0,00	0,00
	Al ₂ O ₃	19,34	19,19	19,27	27,15	26,97	27,71	27,69	27,47	27,60	28,03	27,85	27,60	27,88	27,83	25,47	28,06	27,02	28,23	26,66	28,31
	FeO	0,11	0,11	0,06	0,21	0,21	0,14	0,16	0,17	0,22	0,24	0,25	0,26	0,25	0,25	0,08	0,20	0,19	0,25	0,16	0,25
MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
MgO	0,00	0,00	0,01	0,01	0,00	0,00	0,01	0,00	0,01	0,00	0,01	0,01	0,01	0,02	0,03	0,00	0,03	0,00	0,01	0,00	0,00
CaO	0,06	0,05	0,03	7,53	7,67	7,72	7,55	7,87	7,85	8,19	7,69	7,78	7,58	7,78	5,55	7,80	7,15	7,91	6,50	7,88	
Na ₂ O	1,11	1,51	1,39	7,57	7,48	7,41	7,40	7,35	7,22	6,80	7,11	7,04	7,09	7,15	8,52	7,01	7,39	6,87	8,22	6,88	
K ₂ O	15,97	15,48	15,62	0,22	0,22	0,18	0,16	0,20	0,25	0,22	0,30	0,29	0,28	0,24	0,19	0,17	0,22	0,18	0,21	0,21	
SO ₃	0,001	0,00	0,02	0,01	0,00	0,003	0,01	0,02	0,02	0,01	0,00	0,001	0,01	0,001	0,002	0,01	0,00	0,02	0,01	0,01	
Total	99,30	98,94	98,76	99,85	99,16	100,13	99,97	98,93	99,03	98,60	99,37	98,43	98,95	99,07	98,59	98,99	98,21	98,45	99,83	98,28	
Feldspar	Formula																				
	Si	11,73	11,74	11,73	10,27	10,25	10,21	10,22	10,15	10,14	10,05	10,15	10,12	10,13	10,11	10,63	10,10	10,26	10,03	10,41	10,01
	Al	4,27	4,24	4,27	5,75	5,76	5,85	5,85	5,88	5,90	6,02	5,93	5,94	5,96	5,95	5,43	6,00	5,81	6,07	5,63	6,10
	Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Fe	0,02	0,02	0,01	0,03	0,03	0,02	0,02	0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,01	0,03	0,03	0,04	0,02	0,04
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,01	0,00	0,00	0,00	0,00
	Ca	0,01	0,01	0,01	1,45	1,49	1,48	1,45	1,53	1,53	1,60	1,49	1,52	1,47	1,51	1,07	1,52	1,40	1,55	1,25	1,54
	Na	0,40	0,55	0,50	2,64	2,62	2,57	2,57	2,59	2,54	2,40	2,49	2,49	2,49	2,52	2,99	2,46	2,61	2,43	2,86	2,44
	K	3,81	3,70	3,75	0,05	0,05	0,04	0,04	0,05	0,06	0,05	0,07	0,07	0,06	0,06	0,04	0,04	0,05	0,04	0,05	0,05
	Total	20,24	20,26	20,26	20,20	20,21	20,18	20,16	20,23	20,21	20,17	20,17	20,19	20,17	20,19	20,17	20,15	20,17	20,17	20,22	20,18
	End Members																				
	Or	90,18	86,84	88,01	1,23	1,22	0,99	0,92	1,09	1,39	1,28	1,73	1,66	1,58	1,37	1,04	0,99	1,25	1,02	1,13	1,21
Ab	9,53	12,91	11,86	63,74	63,04	62,84	63,33	62,14	61,59	59,27	61,53	61,04	61,88	61,59	72,78	61,29	64,35	60,50	68,80	60,52	
An	0,29	0,25	0,12	35,03	35,74	36,17	35,75	36,77	37,02	39,45	36,74	37,30	36,54	37,03	26,18	37,72	34,40	38,48	30,07	38,27	
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	

Table D.5 EPMA results of feldspar minerals from Edremit field (cont'd)

Feldspar	Sample No.	EDR-1032														
	Region/Mineral	1/1				2/1				2/2					2/3	
	Spot No.	1	2	3	4	1	2	3	4	1	2	3	4	5	1	4
	SiO ₂	57,08	57,80	56,48	57,18	62,53	55,95	55,28	63,09	55,66	55,53	57,60	54,75	56,17	54,78	58,61
	TiO ₂	0,01	0,00	0,00	0,01	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,00
	Al ₂ O ₃	26,70	26,18	26,46	28,50	19,26	27,40	27,63	19,32	27,12	27,89	26,66	28,63	28,15	28,03	26,15
	FeO	0,25	0,25	0,23	0,23	0,07	0,20	0,21	0,10	0,19	0,14	0,19	0,24	0,17	0,25	0,10
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	0,01	0,02	0,01	0,05	0,00	0,00	0,00	0,00	0,00	0,02	0,01	0,01	0,01	0,01	0,00
	CaO	6,91	6,45	6,83	7,43	0,05	7,33	7,46	0,07	7,52	7,92	6,48	8,25	7,46	7,83	5,70
Na ₂ O	7,90	8,02	7,75	7,45	1,34	7,50	7,22	1,61	7,36	7,17	8,09	6,61	7,47	6,92	8,53	
K ₂ O	0,27	0,22	0,26	0,21	15,82	0,19	0,21	15,37	0,26	0,22	0,26	0,24	0,21	0,21	0,15	
SO ₃	0,01	0,00	0,00	0,02	0,00	0,00	0,01	0,02	0,00	0,03	0,01	0,01	0,02	0,01	0,02	
Total	99,15	98,93	98,01	101,09	99,06	98,58	98,01	99,57	98,12	98,90	99,29	98,73	99,66	98,04	99,25	
Formula	Si	10,33	10,45	10,33	10,14	11,73	10,19	10,12	11,75	10,19	10,09	10,39	9,97	10,12	10,04	10,54
	Al	5,69	5,58	5,70	5,96	4,26	5,88	5,97	4,24	5,85	5,97	5,67	6,14	5,98	6,05	5,54
	Ti	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Fe	0,04	0,04	0,04	0,03	0,01	0,03	0,03	0,01	0,03	0,02	0,03	0,04	0,03	0,04	0,01
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	0,00	0,01	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Ca	1,34	1,25	1,34	1,41	0,01	1,43	1,46	0,01	1,48	1,54	1,25	1,61	1,44	1,54	1,10
	Na	2,77	2,81	2,75	2,56	0,49	2,65	2,56	0,58	2,61	2,53	2,83	2,34	2,61	2,46	2,97
	K	0,06	0,05	0,06	0,05	3,78	0,04	0,05	3,65	0,06	0,05	0,06	0,06	0,05	0,05	0,03
	Total	20,24	20,19	20,22	20,18	20,28	20,22	20,20	20,25	20,22	20,21	20,22	20,15	20,22	20,18	20,20
End Members	Or	1,51	1,23	1,46	1,20	88,38	1,06	1,18	85,99	1,47	1,23	1,44	1,40	1,17	1,20	0,84
	Ab	66,40	68,38	66,27	63,69	11,38	64,24	62,88	13,69	62,97	61,32	68,33	58,36	63,69	60,76	72,40
	An	32,08	30,39	32,27	35,11	0,23	34,69	35,94	0,32	35,56	37,44	30,24	40,23	35,15	38,04	26,76
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table D.6 EPMA results of amphibole minerals from Edremit field

Amphibole	Sample No.	EDR-912				EDR-958			EDR-964											
	Region/Mineral	2/1				1/1			1/1						1/3					
	Spot No.	1	2	3	5	1	3	4	1	2	3	4	5	6	1	2	3	4	5	6
	SiO ₂	46,25	46,65	46,38	55,13	58,13	54,53	55,52	45,21	46,37	45,14	45,57	45,31	47,92	46,96	45,96	44,75	42,43	42,50	44,50
	TiO ₂	1,60	1,54	1,64	0,03	0,00	0,00	0,004	1,41	1,07	1,37	1,31	1,29	1,07	1,05	1,20	1,72	2,50	2,39	1,94
	Al ₂ O ₃	6,89	6,74	6,90	25,81	24,87	27,13	27,12	6,31	5,89	6,31	6,15	6,21	5,52	5,20	6,01	7,01	9,16	8,75	7,79
Cr ₂ O ₃	0,01	0,01	0,00	0,01	0,02	0,00	0,00	0,00	0,007	0,00	0,00	0,006	0,00	0,00	0,006	0,00	0,003	0,002	0,00	
FeO	14,83	14,68	14,49	1,86	0,11	0,20	0,21	17,06	16,00	16,99	17,01	16,92	15,86	16,25	15,98	15,45	16,77	16,67	16,33	
MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
MgO	14,04	14,54	14,38	0,24	0,01	0,00	0,00	12,76	13,24	12,64	12,65	12,85	13,81	13,49	13,47	13,30	11,89	11,86	12,75	
CaO	11,04	10,91	11,18	6,73	6,12	8,83	8,56	11,39	11,75	11,37	11,38	11,39	11,37	11,59	11,32	11,18	11,27	11,47	11,34	
Na ₂ O	1,47	1,49	1,47	7,58	8,74	7,17	7,30	1,22	0,84	1,22	1,14	1,23	1,07	1,01	1,28	1,58	1,80	1,63	1,60	
K ₂ O	0,69	0,73	0,72	0,39	0,48	0,23	0,26	0,66	0,57	0,68	0,60	0,68	0,48	0,55	0,65	0,68	0,95	0,94	0,80	
Total	96,81	97,29	97,15	97,77	98,47	98,09	98,96	96,03	95,73	95,71	95,81	95,88	97,09	96,10	95,88	95,66	96,76	96,21	97,05	
O	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	
Cation	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	
Formula																				
Si	6,85	6,87	6,84	7,77	8,12	7,70	7,75	6,85	6,96	6,86	6,90	6,87	7,07	7,06	6,93	6,77	6,41	6,45	6,66	
Ti	0,18	0,17	0,18	0,003	0,00	0,00	0,00	0,16	0,12	0,16	0,15	0,15	0,12	0,12	0,14	0,20	0,28	0,27	0,22	
Al-iv	1,15	1,13	1,16	0,23	0,00	0,30	0,25	1,15	1,04	1,14	1,10	1,13	0,93	0,94	1,07	1,23	1,59	1,55	1,34	
Al-vi	0,05	0,04	0,04	4,05	4,09	4,21	4,22	-0,02	0,00	-0,01	0,00	-0,02	0,03	-0,02	0,00	0,02	0,04	0,02	0,03	
Cr	0,001	0,001	0,00	0,001	0,002	0,00	0,00	0,00	0,001	0,00	0,00	0,00	0,001	0,00	0,00	0,001	0,00	0,00	0,00	
Fe ³⁺	0,37	0,33	0,35	-2,66	-3,09	-3,06	-3,04	0,28	0,45	0,31	0,35	0,29	0,38	0,25	0,29	0,29	0,41	0,40	0,37	
Fe ²⁺	1,46	1,48	1,44	2,87	3,10	3,08	3,06	1,88	1,56	1,85	1,81	1,86	1,58	1,79	1,72	1,66	1,70	1,72	1,67	
Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Mg	3,10	3,19	3,16	0,05	0,00	0,00	0,00	2,88	2,96	2,86	2,86	2,91	3,04	3,02	3,03	3,00	2,68	2,68	2,84	
Ca	1,75	1,72	1,77	1,02	0,92	1,34	1,28	1,85	1,89	1,85	1,85	1,85	1,80	1,87	1,83	1,81	1,82	1,87	1,82	
Na	0,42	0,43	0,42	2,07	2,37	1,96	1,98	0,36	0,24	0,36	0,33	0,36	0,31	0,29	0,37	0,46	0,53	0,48	0,46	
K	0,13	0,14	0,14	0,07	0,09	0,04	0,05	0,13	0,11	0,13	0,12	0,13	0,09	0,10	0,12	0,13	0,18	0,18	0,15	
Total	15,46	15,49	15,49	15,48	15,60	15,58	15,54	15,52	15,34	15,51	15,45	15,53	15,34	15,43	15,50	15,57	15,64	15,62	15,56	
CaB	1,75	1,72	1,77	1,02	0,92	1,34	1,28	1,85	1,89	1,85	1,85	1,85	1,80	1,87	1,83	1,81	1,82	1,87	1,82	
NaB	0,09	0,07	0,07	0,98	1,08	0,66	0,72	-0,04	0,01	-0,02	0,00	-0,03	0,06	-0,03	0,00	0,03	0,07	0,04	0,05	
NaA	0,33	0,35	0,35	1,09	1,28	1,30	1,26	0,40	0,24	0,38	0,34	0,40	0,25	0,33	0,38	0,43	0,46	0,44	0,41	
KA	0,13	0,14	0,14	0,07	0,09	0,04	0,05	0,13	0,11	0,13	0,12	0,13	0,09	0,10	0,12	0,13	0,18	0,18	0,15	

Table D.6 EPMA results of amphibole minerals from Edremit field (cont'd)

Amphibole	Sample No.	EDR-964					EDR-994		EDR-1008								
	Region/Mineral	2/1					2/1		1/1								
	Spot No.	1	2	3	4	5	2	3	1	2	3	4	5	6	7	8	9
	SiO ₂	45,04	45,63	48,99	47,83	49,76	46,19	46,92	44,23	45,31	46,23	44,68	48,90	49,50	47,04	46,11	45,80
	TiO ₂	1,52	1,49	0,57	0,42	0,46	1,54	1,60	1,45	1,54	1,63	1,52	0,60	0,59	1,04	1,21	1,50
	Al ₂ O ₃	6,75	6,71	4,62	4,53	4,93	6,71	7,05	6,63	6,82	7,19	6,85	4,54	4,16	5,26	6,28	6,64
	Cr ₂ O ₃	0,006	0,002	0,007	0,00	0,00	0,003	0,00	0,005	0,00	0,009	0,007	0,00	0,00	0,00	0,003	0,00
	FeO	16,83	16,61	15,10	15,60	15,10	16,49	16,54	16,18	15,29	15,07	16,12	14,24	14,04	15,35	15,76	14,97
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	12,53	12,94	14,10	13,92	14,74	13,16	13,32	12,82	13,78	14,12	12,63	14,87	14,97	13,96	13,61	14,02
	CaO	11,57	11,41	11,82	11,99	11,88	11,17	11,22	11,01	11,03	11,05	11,06	11,68	11,69	11,25	11,40	10,99
	Na ₂ O	1,13	1,21	0,78	0,74	0,88	1,39	1,58	1,25	1,44	1,58	1,40	0,70	0,73	1,14	1,20	1,47
	K ₂ O	0,69	0,65	0,31	0,32	0,33	0,63	0,64	0,66	0,64	0,70	0,67	0,31	0,33	0,47	0,63	0,67
	Total	96,06	96,65	96,30	95,34	98,07	97,29	98,86	94,22	95,85	97,57	94,93	95,84	96,00	95,50	96,21	96,05
	O	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00
	Cation	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
	Formula																
	Si	6,80	6,83	7,23	7,18	7,20	6,86	6,84	6,80	6,81	6,80	6,81	7,23	7,30	7,07	6,90	6,85
	Ti	0,17	0,17	0,06	0,05	0,05	0,17	0,18	0,17	0,17	0,18	0,17	0,07	0,07	0,12	0,14	0,17
	Al-iv	1,20	1,17	0,77	0,82	0,80	1,14	1,16	1,20	1,19	1,20	1,19	0,77	0,70	0,93	1,10	1,15
	Al-vi	0,00	0,01	0,03	-0,02	0,04	0,03	0,06	0,00	0,01	0,04	0,03	0,02	0,02	0,00	0,01	0,02
	Cr	0,001	0,00	0,001	0,00	0,00	0,00	0,00	0,001	0,00	0,001	0,001	0,00	0,00	0,00	0,00	0,00
	Fe ³⁺	0,40	0,39	0,45	0,40	0,50	0,37	0,39	0,36	0,34	0,38	0,40	0,43	0,36	0,29	0,38	0,32
	Fe ²⁺	1,73	1,69	1,41	1,56	1,33	1,68	1,63	1,72	1,58	1,48	1,66	1,33	1,37	1,64	1,59	1,55
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	2,82	2,89	3,10	3,12	3,18	2,91	2,90	2,94	3,09	3,10	2,87	3,28	3,29	3,13	3,04	3,13
	Ca	1,87	1,83	1,87	1,93	1,84	1,78	1,75	1,81	1,78	1,74	1,80	1,85	1,85	1,81	1,83	1,76
	Na	0,33	0,35	0,22	0,21	0,25	0,40	0,45	0,37	0,42	0,45	0,41	0,20	0,21	0,33	0,35	0,43
	K	0,13	0,12	0,06	0,06	0,06	0,12	0,12	0,13	0,12	0,13	0,13	0,06	0,06	0,09	0,12	0,13
	Total	15,46	15,45	15,22	15,31	15,24	15,46	15,46	15,50	15,51	15,50	15,48	15,23	15,23	15,41	15,45	15,51
	CaB	1,87	1,83	1,87	1,93	1,84	1,78	1,75	1,81	1,78	1,74	1,80	1,85	1,85	1,81	1,83	1,76
	NaB	0,01	0,02	0,07	-0,03	0,07	0,06	0,10	0,00	0,03	0,08	0,06	0,03	0,04	0,01	0,02	0,05
	NaA	0,33	0,33	0,16	0,25	0,18	0,34	0,34	0,37	0,39	0,37	0,35	0,17	0,17	0,32	0,33	0,38
	KA	0,13	0,12	0,06	0,06	0,06	0,12	0,12	0,13	0,12	0,13	0,13	0,06	0,06	0,09	0,12	0,13

Table D.6 EPMA results of amphibole minerals from Edremit field (cont'd)

	Sample No.	EDR-1008																			
	Region/Mineral	2/1										3/1									
	Spot No.	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	
	SiO ₂	45,59	44,62	45,06	45,58	45,12	45,01	45,25	45,73	44,72	45,12	45,99	45,63	46,04	45,65	47,71	46,00	46,10	45,33	45,54	
	TiO ₂	1,63	1,66	1,65	1,60	1,60	1,62	1,48	1,29	1,55	1,63	1,36	1,49	1,55	1,42	0,86	1,50	1,57	1,66	1,65	
Amphibole	Al ₂ O ₃	6,65	6,71	6,90	6,68	6,75	6,92	6,93	6,37	6,81	6,81	6,59	6,49	6,78	6,70	5,35	6,73	6,77	7,14	7,12	
	Cr ₂ O ₃	0,002	0,006	0,01	0,00	0,003	0,001	0,01	0,00	0,01	0,01	0,00	0,00	0,001	0,00	0,005	0,00	0,004	0,002	0,005	
	FeO	15,09	15,24	15,37	15,05	15,18	15,27	15,99	15,87	15,66	14,93	15,99	14,78	15,09	15,34	15,03	16,23	14,67	15,20	14,94	
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	MgO	13,61	13,11	13,31	13,90	13,51	13,47	13,16	13,40	13,35	13,80	13,44	13,88	13,80	13,46	14,09	13,15	14,22	13,57	13,55	
	CaO	11,11	11,17	11,12	11,01	11,04	10,94	10,97	11,14	10,88	11,14	11,35	11,17	11,19	11,46	11,63	11,40	11,26	11,23	11,12	
	Na ₂ O	1,56	1,58	1,49	1,50	1,54	1,58	1,57	1,39	1,48	1,54	1,39	1,42	1,40	1,22	0,99	1,12	1,46	1,50	1,44	
	K ₂ O	0,67	0,69	0,64	0,64	0,66	0,66	0,65	0,62	0,68	0,64	0,61	0,62	0,64	0,61	0,49	0,61	0,59	0,68	0,62	
	Total	95,90	94,79	95,56	95,95	95,39	95,48	96,03	95,81	95,13	95,63	96,72	95,47	96,49	95,86	96,15	96,73	96,64	96,31	95,98	
	O	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	
	Cation	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	
	Formula																				
	Si	6,85	6,81	6,80	6,84	6,82	6,80	6,81	6,89	6,79	6,80	6,86	6,87	6,85	6,84	7,09	6,85	6,84	6,77	6,80	
	Ti	0,18	0,19	0,19	0,18	0,18	0,18	0,17	0,15	0,18	0,19	0,15	0,17	0,17	0,16	0,10	0,17	0,18	0,19	0,19	
	Al-iv	1,15	1,19	1,20	1,16	1,18	1,20	1,19	1,11	1,21	1,20	1,14	1,13	1,15	1,16	0,91	1,15	1,16	1,23	1,20	
	Al-vi	0,03	0,02	0,03	0,02	0,02	0,03	0,03	0,02	0,01	0,01	0,02	0,02	0,04	0,02	0,02	0,03	0,02	0,03	0,05	
	Cr	0,00	0,001	0,001	0,00	0,00	0,00	0,002	0,00	0,001	0,002	0,00	0,00	0,00	0,00	0,001	0,00	0,00	0,00	0,001	
	Fe ³⁺	0,27	0,26	0,34	0,29	0,30	0,32	0,37	0,34	0,32	0,28	0,37	0,31	0,38	0,43	0,40	0,45	0,34	0,37	0,43	
	Fe ²⁺	1,62	1,69	1,60	1,59	1,62	1,60	1,64	1,66	1,67	1,60	1,63	1,55	1,50	1,49	1,46	1,57	1,48	1,53	1,43	
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Mg	3,05	2,98	2,99	3,11	3,04	3,03	2,95	3,01	3,02	3,10	2,99	3,11	3,06	3,01	3,12	2,92	3,15	3,02	3,02	
	Ca	1,79	1,83	1,80	1,77	1,79	1,77	1,77	1,80	1,77	1,80	1,81	1,80	1,78	1,84	1,85	1,82	1,79	1,80	1,78	
	Na	0,45	0,47	0,44	0,44	0,45	0,46	0,46	0,40	0,44	0,45	0,40	0,41	0,40	0,35	0,29	0,32	0,42	0,44	0,42	
	K	0,13	0,14	0,12	0,12	0,13	0,13	0,13	0,12	0,13	0,12	0,12	0,12	0,12	0,12	0,09	0,12	0,11	0,13	0,12	
	Total	15,53	15,57	15,51	15,52	15,53	15,54	15,52	15,49	15,54	15,55	15,48	15,50	15,46	15,42	15,34	15,39	15,49	15,51	15,44	
		CaB	1,79	1,83	1,80	1,77	1,79	1,77	1,77	1,80	1,77	1,80	1,81	1,80	1,78	1,84	1,85	1,82	1,79	1,80	1,78
		NaB	0,05	0,03	0,05	0,03	0,04	0,05	0,06	0,03	0,02	0,02	0,03	0,04	0,07	0,05	0,04	0,05	0,04	0,06	0,10
		NaA	0,40	0,43	0,39	0,40	0,41	0,41	0,39	0,37	0,41	0,43	0,37	0,38	0,33	0,31	0,24	0,27	0,37	0,38	0,32
		KA	0,13	0,14	0,12	0,12	0,13	0,13	0,13	0,12	0,13	0,12	0,12	0,12	0,12	0,12	0,09	0,12	0,11	0,13	0,12

Table D.6 EPMA results of amphibole minerals from Edremit field (cont'd)

	Sample No.	EDR-1008					EDR-1032									
		Region/Mineral	3/2					1/1		2/1				2/2		
	Spot No.	1	2	3	4	5	2	4	1	2	3	4	1	2	3	4
	SiO ₂	45,65	47,62	45,11	45,33	46,18	46,83	47,19	46,73	47,48	46,09	46,89	47,82	47,28	48,20	45,66
	TiO ₂	1,43	0,99	1,54	1,54	1,38	1,57	1,57	1,55	1,50	1,57	1,57	1,18	1,35	1,13	1,58
	Al ₂ O ₃	6,80	5,34	6,85	6,88	6,50	6,67	6,79	6,58	6,59	6,52	6,57	5,29	6,14	4,95	6,78
	Cr ₂ O ₃	0,00	0,01	0,005	0,004	0,004	0,00	0,007	0,003	0,00	0,02	0,00	0,005	0,00	0,00	0,003
	FeO	16,83	15,85	16,41	16,26	15,82	15,98	15,31	15,98	15,38	15,16	15,17	14,39	14,97	14,70	15,60
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	12,82	13,60	12,71	12,66	13,29	13,30	13,80	13,63	14,13	13,89	14,14	14,53	14,25	14,50	13,14
CaO	11,29	11,63	11,28	11,23	11,03	11,52	11,33	11,22	11,12	11,24	11,13	11,42	11,28	11,31	11,18	
Na ₂ O	1,30	0,91	1,31	1,24	1,42	1,32	1,39	1,49	1,64	1,49	1,59	1,06	1,31	1,15	1,50	
K ₂ O	0,65	0,49	0,66	0,66	0,57	0,63	0,59	0,62	0,59	0,59	0,62	0,47	0,57	0,43	0,62	
Total	96,77	96,45	95,87	95,79	96,19	97,82	97,97	97,80	98,43	96,56	97,68	96,16	97,15	96,36	96,07	
Amphibole	O	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00	23,00
	Cation	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
	Formula															
	Si	6,83	7,08	6,81	6,82	6,90	6,89	6,89	6,89	6,92	6,87	6,90	7,09	6,97	7,15	6,85
	Ti	0,16	0,11	0,17	0,17	0,16	0,17	0,17	0,17	0,16	0,18	0,17	0,13	0,15	0,13	0,18
	Al-iv	1,17	0,92	1,19	1,18	1,10	1,11	1,11	1,11	1,08	1,13	1,10	0,91	1,03	0,85	1,15
	Al-vi	0,02	0,02	0,02	0,04	0,05	0,04	0,06	0,03	0,05	0,02	0,04	0,02	0,03	0,02	0,05
	Cr	0,00	0,001	0,001	0,00	0,00	0,00	0,001	0,00	0,00	0,002	0,00	0,001	0,00	0,00	0,00
	Fe ³⁺	0,42	0,39	0,40	0,46	0,40	0,39	0,43	0,31	0,32	0,28	0,29	0,30	0,34	0,23	0,36
	Fe ²⁺	1,69	1,58	1,67	1,59	1,58	1,57	1,44	1,66	1,55	1,61	1,58	1,48	1,50	1,59	1,59
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	2,86	3,02	2,86	2,84	2,96	2,92	3,01	3,00	3,07	3,09	3,10	3,21	3,13	3,21	2,94
	Ca	1,81	1,85	1,82	1,81	1,77	1,82	1,77	1,77	1,74	1,80	1,75	1,81	1,78	1,80	1,80
	Na	0,38	0,26	0,38	0,36	0,41	0,38	0,39	0,42	0,46	0,43	0,45	0,31	0,37	0,33	0,44
	K	0,12	0,09	0,13	0,13	0,11	0,12	0,11	0,12	0,11	0,11	0,12	0,09	0,11	0,08	0,12
	Total	15,46	15,32	15,46	15,40	15,43	15,41	15,39	15,48	15,47	15,51	15,50	15,36	15,42	15,38	15,47
	CaB	1,81	1,85	1,82	1,81	1,77	1,82	1,77	1,77	1,74	1,80	1,75	1,81	1,78	1,80	1,80
	NaB	0,05	0,03	0,05	0,08	0,09	0,08	0,12	0,06	0,10	0,03	0,07	0,04	0,06	0,03	0,08
	NaA	0,33	0,23	0,34	0,28	0,32	0,29	0,28	0,37	0,36	0,40	0,38	0,27	0,31	0,30	0,35
	KA	0,12	0,09	0,13	0,13	0,11	0,12	0,11	0,12	0,11	0,11	0,12	0,09	0,11	0,08	0,12

Table D.7 EPMA results of mica minerals from Edremit field

	Sample No.	EDR-912													EDR-994				
		1/1			1/2					3/1					1/1				
		1/1			1/2					3/1					1/1				
		1	4	5	1	2	3	4	5	1	3	5	6	7	1	2	3	4	5
Mica	Spot No.																		
	SiO ₂	35,38	34,52	34,47	35,97	35,07	34,33	35,96	34,77	34,90	33,66	33,20	33,93	33,18	34,44	34,42	35,43	35,31	34,62
	TiO ₂	4,70	4,69	3,74	4,20	4,43	4,50	4,54	4,59	4,76	4,19	4,73	4,57	4,57	4,62	4,65	4,50	3,62	4,02
	Al ₂ O ₃	15,28	14,17	14,52	14,96	14,50	13,88	14,83	14,14	13,90	13,00	13,47	13,72	13,65	13,75	13,80	14,53	14,21	13,88
	FeO	24,56	24,94	24,12	23,44	23,35	23,24	23,08	22,99	26,91	25,66	26,83	27,82	28,25	22,87	22,63	23,24	23,21	23,27
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	9,21	8,75	9,29	10,38	10,23	9,72	10,37	9,98	8,45	9,52	7,95	7,68	7,34	10,35	10,35	10,47	10,65	10,26
	CaO	0,14	0,06	0,09	0,02	0,04	0,06	0,02	0,02	0,09	0,14	0,07	0,08	0,08	0,09	0,08	0,09	0,12	0,13
	Na ₂ O	0,24	0,18	0,22	0,20	0,16	0,17	0,12	0,11	0,15	0,09	0,13	0,14	0,13	0,17	0,21	0,20	0,21	0,23
	K ₂ O	8,73	9,22	8,77	9,71	9,51	9,79	9,86	9,94	9,55	8,10	9,46	9,48	9,38	9,58	9,58	9,66	9,70	9,44
	Cr ₂ O ₃	0,03	0,01	0,02	0,02	0,03	0,02	0,03	0,03	0,02	0,004	0,02	0,002	0,002	0,00	0,003	0,01	0,00	0,001
	SO ₃	0,08	0,07	0,07	0,05	0,06	0,08	0,05	0,04	0,10	0,07	0,06	0,09	0,08	0,09	0,11	0,12	0,12	0,14
	Total	98,34	96,60	95,32	98,95	97,37	95,79	98,85	96,60	98,82	94,42	95,92	97,51	96,65	95,96	95,83	98,24	97,16	95,99
	Formula																		
	Si	5,36	5,38	5,41	5,41	5,38	5,38	5,41	5,38	5,37	5,38	5,30	5,33	5,29	5,37	5,37	5,38	5,43	5,40
	Al-iv	2,64	2,60	2,59	2,59	2,62	2,56	2,59	2,58	2,52	2,45	2,53	2,54	2,56	2,53	2,54	2,60	2,57	2,55
	Al-vi	0,10	0,00	0,10	0,07	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
	Ti	0,54	0,55	0,44	0,48	0,51	0,53	0,51	0,53	0,55	0,50	0,57	0,54	0,55	0,54	0,55	0,51	0,42	0,47
	Cr	0,003	0,001	0,002	0,002	0,004	0,002	0,003	0,003	0,002	0,001	0,002	0,00	0,00	0,00	0,00	0,001	0,00	0,00
	Fe ⁺²	3,12	3,25	3,17	2,95	2,99	3,05	2,90	2,98	3,46	3,43	3,58	3,66	3,76	2,98	2,95	2,95	2,99	3,04
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	2,08	2,03	2,17	2,33	2,34	2,27	2,33	2,30	1,94	2,27	1,89	1,80	1,74	2,41	2,41	2,37	2,44	2,39
	Ca	0,02	0,01	0,01	0,004	0,01	0,01	0,003	0,004	0,02	0,02	0,01	0,01	0,01	0,02	0,01	0,01	0,02	0,02
	Na	0,07	0,05	0,07	0,06	0,05	0,05	0,04	0,03	0,05	0,03	0,04	0,04	0,04	0,05	0,06	0,06	0,06	0,07
	K	1,69	1,83	1,75	1,86	1,86	1,96	1,89	1,96	1,87	1,65	1,93	1,90	1,91	1,91	1,91	1,87	1,90	1,88
	Total	15,61	15,71	15,72	15,75	15,76	15,81	15,72	15,79	15,78	15,73	15,85	15,83	15,86	15,80	15,80	15,77	15,84	15,82
	Fe/Fe+Mg	0,60	0,62	0,59	0,56	0,56	0,57	0,56	0,56	0,64	0,60	0,65	0,67	0,68	0,55	0,55	0,55	0,55	0,56
	Fe+Mn+Ti	3,65	3,80	3,61	3,42	3,50	3,58	3,42	3,51	4,01	3,93	4,15	4,20	4,31	3,52	3,50	3,47	3,41	3,51
	Mg-Li	2,08	2,03	2,17	2,33	2,34	2,27	2,33	2,30	1,94	2,27	1,89	1,80	1,74	2,41	2,41	2,37	2,44	2,39

Table D.7 EPMA results of mica minerals from Edremit field (cont'd)

Mica	Sample No.	EDR-994												EDR-1008						
	Region/Mineral	1/1				1/2							2/1	1/1						
	Spot No.	6	7	8	9	1	2	3	4	5	6	7	2	2	3	4	5	6	7	
	SiO ₂	35,04	34,22	35,11	34,53	35,70	35,45	34,63	35,08	35,42	35,56	33,41	34,72	34,08	33,91	34,02	33,45	33,54	33,67	
	TiO ₂	4,34	4,34	4,37	4,33	3,34	3,80	4,07	4,17	4,32	4,42	4,09	4,39	4,37	4,33	4,44	4,06	3,47	4,61	
	Al ₂ O ₃	14,17	13,84	14,08	13,91	14,27	14,08	13,32	13,49	13,77	13,56	12,89	13,55	13,39	13,60	13,40	13,24	13,41	13,33	
	FeO	23,45	23,48	23,37	23,12	22,57	22,68	22,99	22,80	22,62	22,24	20,58	22,93	23,07	22,98	23,05	22,98	22,67	23,09	
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	MgO	10,30	9,98	10,30	10,21	11,32	11,18	10,68	10,86	11,14	11,27	10,64	10,46	10,43	10,40	10,34	10,31	10,75	10,25	
	CaO	0,09	0,10	0,12	0,14	0,03	0,03	0,07	0,10	0,05	0,10	0,06	0,04	0,06	0,09	0,03	0,05	0,10	0,04	
	Na ₂ O	0,35	0,23	0,21	0,24	0,19	0,17	0,30	0,17	0,16	0,20	0,16	0,13	0,25	0,24	0,30	0,26	0,43	0,33	
	K ₂ O	9,54	9,60	9,53	9,53	10,05	9,99	9,93	9,87	9,97	9,99	9,33	9,71	9,66	9,67	9,62	9,91	9,75	9,75	
	Cr ₂ O ₃	0,01	0,00	0,00	0,00	0,007	0,01	0,006	0,002	0,02	0,002	0,007	0,003	0,00	0,003	0,002	0,00	0,00	0,007	
	SO ₃	0,13	0,10	0,09	0,11	0,06	0,07	0,06	0,14	0,10	0,11	0,08	0,07	0,10	0,11	0,09	0,10	0,47	0,13	
	Total	97,42	95,88	97,17	96,11	97,54	97,45	96,06	96,67	97,57	97,45	91,24	96,00	95,41	95,34	95,29	94,35	94,60	95,21	
	Formula																			
	Si	5,38	5,36	5,40	5,38	5,45	5,43	5,41	5,43	5,42	5,44	5,44	5,41	5,37	5,34	5,36	5,35	5,36	5,33	
	Al-iv	2,57	2,56	2,55	2,56	2,55	2,54	2,45	2,46	2,48	2,45	2,48	2,49	2,49	2,53	2,49	2,49	2,52	2,49	
	Al-vi	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Ti	0,50	0,51	0,51	0,51	0,38	0,44	0,48	0,49	0,50	0,51	0,50	0,51	0,52	0,51	0,53	0,49	0,42	0,55	
	Cr	0,001	0,00	0,00	0,00	0,001	0,001	0,001	0,00	0,002	0,00	0,001	0,00	0,00	0,00	0,00	0,00	0,00	0,001	
	Fe ⁺²	3,01	3,08	3,01	3,01	2,88	2,90	3,00	2,95	2,89	2,84	2,80	2,99	3,04	3,03	3,04	3,07	3,03	3,06	
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Mg	2,36	2,33	2,36	2,37	2,58	2,55	2,49	2,51	2,54	2,57	2,58	2,43	2,45	2,44	2,43	2,46	2,56	2,42	
	Ca	0,01	0,02	0,02	0,02	0,005	0,005	0,01	0,02	0,01	0,02	0,01	0,01	0,01	0,02	0,005	0,01	0,02	0,01	
	Na	0,11	0,07	0,06	0,07	0,06	0,05	0,09	0,05	0,05	0,06	0,05	0,04	0,08	0,07	0,09	0,08	0,13	0,10	
	K	1,87	1,92	1,87	1,89	1,96	1,95	1,98	1,95	1,95	1,95	1,94	1,93	1,94	1,94	1,94	2,02	1,99	1,97	
	Total	15,82	15,84	15,78	15,82	15,89	15,87	15,92	15,85	15,84	15,83	15,81	15,81	15,88	15,89	15,88	15,97	16,02	15,91	
	Fe/Fe+Mg	0,56	0,57	0,56	0,56	0,53	0,53	0,55	0,54	0,53	0,53	0,52	0,55	0,55	0,55	0,56	0,56	0,54	0,56	
	Fe+Mn+Ti	3,52	3,59	3,51	3,52	3,27	3,34	3,48	3,44	3,39	3,35	3,31	3,50	3,56	3,54	3,57	3,56	3,45	3,60	
	Mg-Li	2,36	2,33	2,36	2,37	2,58	2,55	2,49	2,51	2,54	2,57	2,58	2,43	2,45	2,44	2,43	2,46	2,56	2,42	

Table D.7 EPMA results of mica minerals from Edremit field (cont'd)

	Sample No.	EDR-1032																	
		1/1							1/2					2/1			2/2		
		Region/Mineral							Spot No.					1			2		
		1	2	4	5	6	10	11	1	2	3	4	5	1	2	3	1	2	3
Mica	SiO ₂	36,03	36,16	34,48	36,00	36,80	36,07	35,10	34,94	34,53	35,27	34,59	36,97	35,01	35,72	35,23	34,82	35,00	35,68
	TiO ₂	4,31	4,35	3,94	4,51	4,62	3,82	3,88	4,26	4,38	4,53	4,18	3,73	4,36	4,41	4,08	4,09	3,98	3,55
	Al ₂ O ₃	14,53	14,46	14,41	14,22	14,39	14,63	14,43	13,96	13,81	14,14	14,11	14,97	14,05	14,64	14,07	14,12	14,07	14,40
	FeO	21,88	22,18	22,69	21,91	21,58	21,79	22,24	22,16	21,72	21,57	22,20	21,73	21,04	21,22	20,98	20,99	20,88	20,44
	MnO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	MgO	11,51	11,48	11,62	11,28	11,46	11,86	11,93	11,13	10,88	10,99	11,29	12,01	11,22	11,58	11,62	11,55	11,59	12,19
	CaO	0,05	0,04	0,09	0,04	0,05	0,03	0,08	0,03	0,09	0,53	0,03	0,05	0,03	0,03	0,02	0,03	0,03	0,02
	Na ₂ O	0,13	0,12	0,10	0,14	0,16	0,15	0,17	0,10	0,11	0,17	0,11	0,09	0,25	0,14	0,16	0,18	0,17	0,15
	K ₂ O	9,82	9,85	8,74	10,08	9,81	9,79	9,28	9,72	9,84	9,21	9,48	9,84	9,90	9,97	9,93	9,91	10,04	10,22
	Cr ₂ O ₃	0,00	0,004	0,003	0,00	0,00	0,007	0,00	0,001	0,01	0,01	0,01	0,00	0,005	0,00	0,01	0,00	0,01	0,004
	SO ₃	0,07	0,06	0,06	0,07	0,05	0,07	0,10	0,04	0,06	0,10	0,06	0,06	0,07	0,05	0,06	0,07	0,07	0,05
	Total	98,34	98,70	96,13	98,23	98,92	98,22	97,20	96,35	95,43	96,51	96,06	99,44	95,94	97,76	96,15	95,74	95,83	96,71
	Formula																		
	Si	5,42	5,43	5,33	5,44	5,48	5,43	5,36	5,40	5,39	5,41	5,36	5,48	5,41	5,40	5,43	5,39	5,41	5,45
	Al-iv	2,58	2,56	2,62	2,53	2,52	2,57	2,60	2,54	2,54	2,56	2,58	2,52	2,56	2,60	2,55	2,58	2,57	2,55
	Al-vi	0,00	0,00	0,00	0,00	0,01	0,03	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,01	0,00	0,00	0,00	0,04
	Ti	0,49	0,49	0,46	0,51	0,52	0,43	0,45	0,49	0,51	0,52	0,49	0,42	0,51	0,50	0,47	0,48	0,46	0,41
	Cr	0,00	0,00	0,00	0,00	0,00	0,001	0,00	0,00	0,001	0,002	0,002	0,00	0,001	0,00	0,001	0,00	0,001	0,00
	Fe ⁺²	2,75	2,79	2,93	2,77	2,69	2,74	2,84	2,86	2,84	2,77	2,88	2,69	2,72	2,68	2,70	2,72	2,70	2,61
	Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mg	2,58	2,57	2,68	2,54	2,55	2,66	2,71	2,56	2,53	2,51	2,61	2,65	2,59	2,61	2,67	2,67	2,67	2,77
	Ca	0,01	0,01	0,01	0,01	0,01	0,004	0,01	0,01	0,02	0,09	0,01	0,01	0,005	0,005	0,004	0,01	0,005	0,003
	Na	0,04	0,03	0,03	0,04	0,05	0,04	0,05	0,03	0,03	0,05	0,03	0,03	0,08	0,04	0,05	0,05	0,05	0,05
	K	1,89	1,89	1,72	1,94	1,87	1,88	1,81	1,92	1,96	1,80	1,87	1,86	1,95	1,92	1,95	1,96	1,98	1,99
	Total	15,76	15,76	15,78	15,78	15,69	15,80	15,83	15,81	15,82	15,71	15,82	15,74	15,81	15,77	15,82	15,85	15,86	15,87
	Fe/Fe+Mg	0,52	0,52	0,52	0,52	0,51	0,51	0,51	0,53	0,53	0,52	0,52	0,50	0,51	0,51	0,50	0,50	0,50	0,48
	Fe+Mn+Ti	3,24	3,28	3,39	3,28	3,21	3,18	3,29	3,36	3,35	3,29	3,36	3,11	3,23	3,18	3,17	3,19	3,16	3,02
	Mg-Li	2,58	2,57	2,68	2,54	2,55	2,66	2,71	2,56	2,53	2,51	2,61	2,65	2,59	2,61	2,67	2,67	2,67	2,77

Table D.8 EPMA results of pyroxene minerals from Edremit field

Pyroxene	Sample No.	EDR-994	EDR-1032	
	Region/Mineral	2/1	1/1	
	Spot No.	1	1	3
	SiO ₂	48,95	48,18	48,39
	TiO ₂	1,27	1,53	1,62
	Al ₂ O ₃	7,25	6,97	7,29
	Cr ₂ O ₃	0,003	0,00	0,002
	FeO	17,46	15,96	15,63
	MnO	0,00	0,00	0,00
	MgO	13,58	14,05	14,15
	CaO	11,53	11,52	11,20
	Na ₂ O	1,24	1,27	1,38
	K ₂ O	0,68	0,64	0,67
	<i>Total</i>	<i>101,96</i>	<i>100,12</i>	<i>100,33</i>
	O	6	6	6
	Cation	4	4	4
	Formula			
	Si	1,82	1,82	1,81
	Ti	0,04	0,04	0,05
	Al	0,32	0,31	0,32
	Cr	0,00	0,00	0,00
	Fe	0,54	0,50	0,49
	Mn	0,00	0,00	0,00
	Mg	0,75	0,79	0,79
	Ca	0,46	0,47	0,45
	Na	0,09	0,09	0,10
	K	0,03	0,03	0,03
	End Members			
	Es	42,88	44,91	45,70
	Wo	26,18	26,47	25,99
	Fs	30,94	28,62	28,31
	<i>Total</i>	<i>100</i>	<i>100</i>	<i>100</i>

E. General Views of EPMA from two Samples of Akköy and Edremit

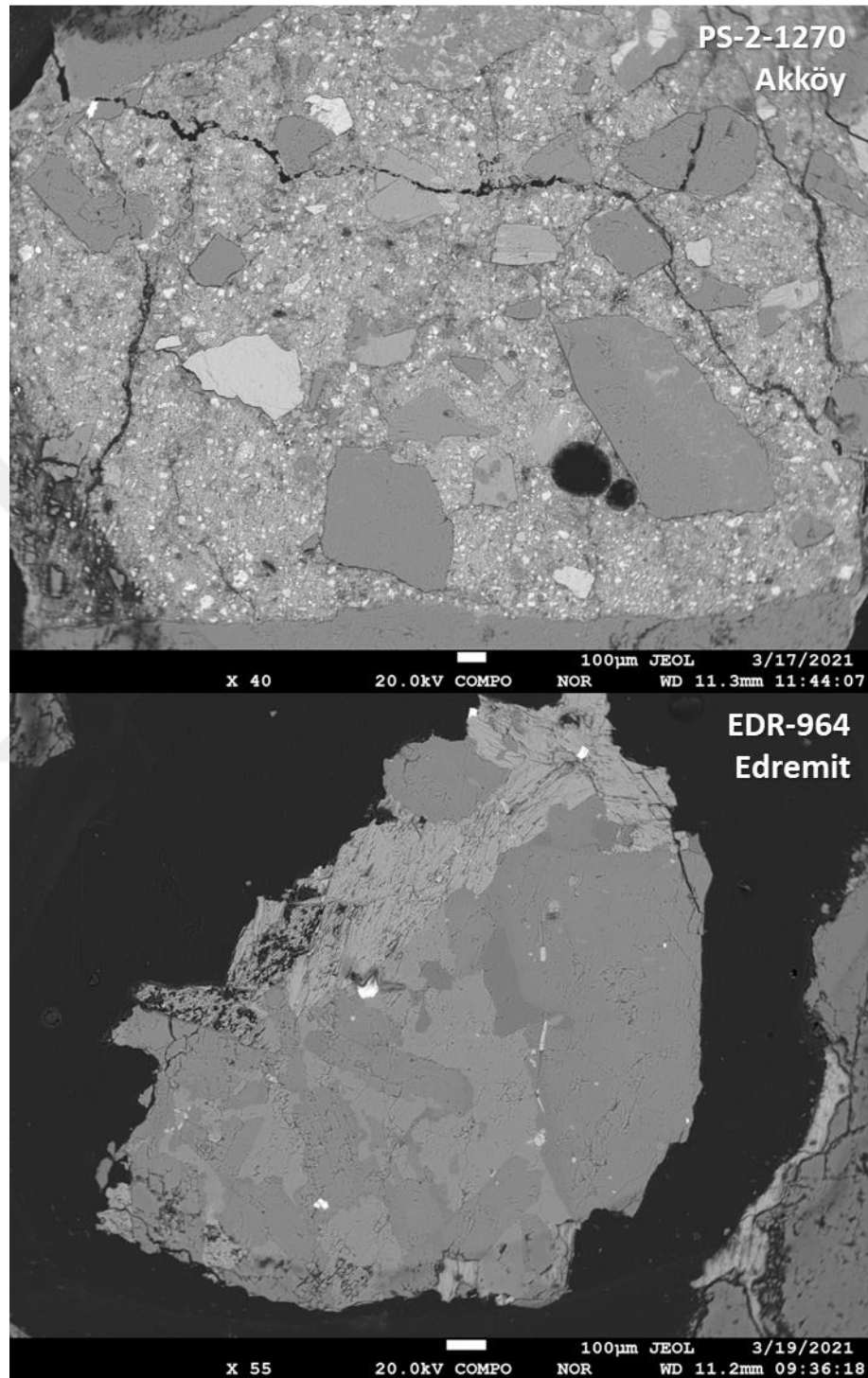


Figure E.1. EPMA views of two samples from Akköy and Edremit fields

F. XRF Analyses Results of Akköy and Edremit Fields

Table F.1 XRF analyses results of samples from Akköy field

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
ADK-PS1-1300	1300	0,058	4,94	14,19	55,63	0,0687	0,3646	0,0002	1,451	7,943	0,6226	0,0245	0,0978	0,0685	8,129	6,23	99,82
ADK-PS1-1305	1305	0,051	4,208	12,883	46,7	0,0724	0,3335	0,01627	1,273	12,26	0,4924	0,0224	0,0551	0,1925	12,55	8,62	99,73
ADK-PS1-1310	1310	0,31	2,7	14,69	61,89	0,0754	0,3904	0,0002	1,774	4,085	0,7459	0,0301	0,1065	0,0337	7,398	5,82	100,05
ADK-PS1-1315	1315	0,05	7,298	11,966	46,49	0,0637	0,3197	0,00324	1,15	14,55	0,4547	0,0178	0,0507	0,1186	7,827	8,92	99,28
ADK-PS1-1320	1320	0,13	3,965	13,66	59,81	0,0634	1,557	0,0002	1,411	6,699	0,6032	0,0329	0,1734	0,0366	6,169	5,99	100,30
ADK-PS1-1325	1325	0,05	4,498	10,17	58,44	0,0778	0,5638	0,00884	1,511	9,695	0,5815	0,0215	0,0899	0,0541	4,991	9,62	100,37
ADK-PS1-1330	1330	0,05	5,356	10,08	53,2	0,077	1,206	0,02224	1,443	10,88	0,5983	0,0233	0,0817	0,063	6,73	10,63	100,44
ADK-PS1-1335	1335	0,051	3,958	8,365	51,81	0,0629	0,5534	0,00249	1,236	10,56	0,4593	0,0191	0,0575	0,2109	9,626	12,84	99,81
ADK-PS1-1340	1340	0,049	4,429	7,744	59,44	0,0679	0,8012	0,0002	1,031	10,18	0,519	0,0184	0,2663	0,0659	5,285	10,83	100,73
ADK-PS1-1345	1345	0,053	5,39	9,158	54,83	0,0911	1,119	0,00014	1,072	11,22	0,6707	0,0235	0,0883	0,0615	6,038	10,44	100,26
ADK-PS1-1350	1350	0,049	4,221	9,835	53,5	0,0775	0,5187	0,00006	1,385	11,94	0,6247	0,0248	0,0749	0,0918	6,085	11,554	99,98
ADK-PS1-1355	1355	0,049	5,382	7,87	52,1	0,0586	0,5285	0,00139	1,122	12,91	0,4814	0,0182	0,1578	0,1106	6,651	12,53	99,97
ADK-PS1-1360	1360	0,053	5,282	8,6	59,42	0,0736	0,3231	0,01193	1,182	13,78	0,5163	0,0187	0,1013	0,1543	7,801	2,48	99,80
ADK-PS1-1365	1365	0,051	5,277	8,397	51,12	0,0655	0,2905	0,00551	1,213	12,86	0,5121	0,0186	0,1448	0,1021	7,043	12,99	100,09
ADK-PS1-1370	1370	0,052	4,06	9,006	53,25	0,0765	0,3209	0,00006	0,975	10,54	0,5952	0,0234	0,1753	0,1237	8,327	12,74	100,27
ADK-PS1-1375	1375	0,051	3,509	9,355	53,69	0,0831	0,3808	0,00006	1,217	11,96	0,6226	0,0221	0,0966	0,0677	5,791	13,85	100,70
ADK-PS1-1380	1380	0,052	4,578	8,295	48,08	0,0684	0,3555	0,00008	1,099	15,76	0,4709	0,0168	0,1019	0,1172	7,089	14,11	100,19
ADK-PS1-1385	1385	0,051	4,956	8,873	58,99	0,062	0,3818	0,00013	1,242	14,72	0,5022	0,0191	0,0859	0,0928	6,965	3,74	100,68
ADK-PS1-1390	1390	0,053	4,918	8,345	60,59	0,0675	0,4409	0,009	1,194	13,35	0,4712	0,0131	0,0831	0,104	6,782	3,24	99,66
ADK-PS1-1395	1395	0,051	6,013	6,832	59,16	0,057	0,2894	0,00075	0,9462	17,33	0,4399	0,0151	0,0572	0,098	5,578	3,29	100,16
ADK-PS1-1400	1400	0,049	5,787	7,352	60,35	0,0597	0,3227	0,00014	0,991	17,07	0,4613	0,0171	0,0596	0,1273	7,309	0,33	100,29
ADK-PS1-1405	1405	0,051	6,608	7,107	55,28	0,053	0,3365	0,00014	0,9115	17,39	0,4631	0,0189	0,0797	0,0759	5,117	6,24	99,73
ADK-PS1-1410	1410	0,052	4,947	8,657	51,08	0,0724	0,3873	0,0001	1,141	14,66	0,5387	0,0195	0,0807	0,087	5,752	12,55	100,02

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
ADK-PS1-1415	1415	0,051	5,011	7,421	53,58	0,0433	0,2931	0,00182	0,962	19,73	0,4598	0,0164	0,0654	0,0844	5,012	7,98	100,71
ADK-PS1-1420	1420	0,049	5,918	6,676	56,85	0,06	0,5154	0,00013	0,8236	17,34	0,4301	0,0182	0,063	0,0932	5,573	6,03	100,44
ADK-PS1-1425	1425	0,14	4,811	8,705	52,47	0,0598	0,3385	0,00005	1,057	15,57	0,55	0,0169	0,0946	0,0586	4,525	11,44	99,84
ADK-PS1-1430	1430	0,049	5,21	7,994	57,7	0,0627	0,2812	0,0001	1,035	17,24	0,4885	0,0189	0,0537	0,0854	4,854	4,82	99,89
ADK-PS1-1435	1435	0,047	6,199	7,919	56,57	0,0651	0,2093	0,0001	0,878	16,95	0,5251	0,0211	0,101	0,0753	4,604	5,86	100,02
ADK-PS1-1440	1440	0,051	5,568	8,512	58,76	0,0589	0,2239	0,00008	1,032	15,26	0,5081	0,0199	0,0654	0,0834	5,728	4,53	100,40
ADK-PS1-1445	1445	0,05	5,433	8,474	58,13	0,0613	0,232	0,0001	1,105	15,69	0,5378	0,0202	0,0881	0,0886	5,357	4,27	99,54
ADK-PS1-1450	1450	0,049	5,937	6,843	53,26	0,0485	0,3473	0,01101	0,9105	17,95	0,4367	0,0219	0,0984	0,0852	5,067	9,72	100,79
ADK-PS1-1455	1455	0,05	5,311	7,1	56,24	0,0542	0,4349	0,0001	0,8923	18,92	0,4854	0,0176	0,1098	0,0935	4,854	6,82	101,38
ADK-PS1-1460	1460	0,048	4,252	5,789	52,75	0,0505	0,3168	0,00336	0,7162	22,3	0,3752	0,0178	0,1041	0,1507	5,736	7,83	100,44
ADK-PS1-1465	1465	0,05	3,975	5,489	40,26	0,0495	0,3344	0,00949	0,6353	24,1	0,3702	0,0141	0,1109	0,1576	6,244	18,93	100,73
ADK-PS1-1470	1470	0,05	4,939	7,082	45,15	0,0615	0,2884	0,00342	0,8918	18,51	0,4674	0,0146	0,0858	0,1199	5,795	17,33	100,79
ADK-PS1-1475	1475	0,049	3,951	7,581	48,31	0,0576	0,2696	0,00007	0,8849	17,49	0,4686	0,0164	0,0916	0,121	5,553	15,39	100,23
ADK-PS1-1480	1480	0,049	2,796	8,964	56,07	0,062	0,3568	0,00125	0,8366	13,87	0,5965	0,024	0,1289	0,0866	5,016	11,54	100,40
ADK-PS1-1485	1485	0,05	2,376	7,849	44,99	0,0659	0,6395	0,00919	0,9724	22,36	0,4992	0,0201	0,0828	0,0775	4,64	16,03	100,66
ADK-PS1-1490	1490	0,051	2,672	9,568	49,71	0,0739	0,9109	0,0002	1,3	17,39	0,5761	0,023	0,0903	0,0567	4,624	12,57	99,62
ADK-PS1-1495	1495	0,05	2,912	8,706	47,29	0,0539	0,6962	0,00007	1,127	18,22	0,5157	0,0157	0,0765	0,0599	4,518	15,58	99,82
ADK-PS1-1500	1500	0,05	3,836	8,122	48,6	0,0621	0,5361	0,00011	1,042	16,58	0,5438	0,0223	0,1021	0,0915	5,541	14,55	99,68
ADK-PS1-1505	1505	0,05	3,903	9,109	49,75	0,0569	0,5241	0,1047	1,095	15,43	0,5587	0,0222	0,096	0,0657	4,884	14,64	100,29
ADK-PS1-1510	1510	0,049	3,111	11,07	54,55	0,0674	0,6096	0,00004	1,243	12,86	0,6131	0,021	0,1432	0,0615	4,976	10,37	99,74
ADK-PS1-1515	1515	0,052	3,679	8,733	51,56	0,0693	0,7455	0,00006	1,078	14,8	0,5591	0,0204	0,087	0,1079	6,353	12,58	100,42
ADK-PS1-1520	1520	0,051	4,792	7,72	58,24	0,0714	0,3928	0,00305	0,9309	17,86	0,4384	0,0185	0,0914	0,2249	5,327	3,73	99,89
ADK-PS1-1525	1525	0,051	3,642	9,067	50,13	0,0785	0,6291	0,00004	1,163	16,7	0,5337	0,0229	0,0915	0,1639	5,727	12,88	100,88

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS1-1300	1300	76,4	663,3	31,8	65,3	14,5	1,9	10,5	0,3	0,4	62,7	296,1	17,1	125,9	13,2	4	0,8	0,7
ADK-PS1-1305	1305	96	599	20,6	121,5	11,6	2,2	5,7	0,3	1,4	57,9	378	23,6	126	12,6	3,8	1,3	0,8
ADK-PS1-1310	1310	87,7	661,8	40,8	60,9	18,3	1,7	11,4	0,3	0,2	76,2	288,3	19,3	165,2	14,2	3,9	0,8	0,8
ADK-PS1-1315	1315	53,9	451	27,3	74,8	12,6	1,3	7,6	0,3	0,8	52,2	398,1	17	111,5	7,9	3,1	0,9	0,8
ADK-PS1-1320	1320	95	896	32,5	46	16,2	1,9	66,5	0,5	0,5	56,2	272,9	15,2	126,5	13,6	8	0,8	0,9
ADK-PS1-1325	1325	48,2	453,9	22,9	49,7	14,4	1,4	16,6	0,3	0,7	65,1	338,5	18,9	177,7	11,5	2,7	0,8	0,7
ADK-PS1-1330	1330	68,3	469,2	22,4	63,1	14,9	1,7	16,7	0,3	0,3	59,1	319	19	129,7	13	3,1	0,8	0,7
ADK-PS1-1335	1335	89	701,7	19,8	76,3	10,7	1,1	9,6	0,3	0,5	53,8	272	16,8	100,3	16,3	3,5	0,9	0,9
ADK-PS1-1340	1340	69,3	555,1	20,6	52	10,2	1,6	11,6	0,3	0,6	40,4	273	14,6	136	11,1	2,9	0,8	0,8
ADK-PS1-1345	1345	94	652,9	30,6	51,1	11,6	1,3	13,9	0,3	0,3	42,5	483,7	17,4	121,5	11,8	3,4	0,9	0,8
ADK-PS1-1350	1350	79,1	498,5	25,6	51,4	15,8	1,2	12	0,3	0,8	57,4	313,5	16,4	132	9,3	3	0,8	0,8
ADK-PS1-1355	1355	44,2	524,2	21,1	52,6	9,9	2	9,5	0,3	0,3	46,6	367,9	14,6	127,5	12,4	3,4	0,9	0,8
ADK-PS1-1360	1360	63,1	486	20,6	62,7	12,2	0,8	6,5	0,4	0,8	50,1	375,8	18	155	12,9	4	0,9	0,8
ADK-PS1-1365	1365	62,6	492,6	19,7	55,5	12,3	1,3	5,4	0,3	0,6	51,4	346,8	17,3	153,4	17,6	4,5	0,9	0,9
ADK-PS1-1370	1370	87	855	29,9	64,4	11,1	1,2	7,9	0,3	0,2	40,7	279,3	17,4	128,2	5,8	3	0,8	0,8
ADK-PS1-1375	1375	38,6	513,9	20,4	43,7	13,6	0,5	10,3	0,3	0,2	49,3	287,5	17,9	135,3	10,9	3,5	0,8	0,8
ADK-PS1-1380	1380	66,6	616,9	26,5	54,6	11,6	0,6	20,7	0,3	0,7	46,3	343,4	17,9	109,6	13,6	3,4	0,9	0,9
ADK-PS1-1385	1385	97	570,8	20,8	56,1	11,8	2,2	9,3	0,3	0,6	55	348,4	17,6	121,3	10,7	3,5	0,9	0,8
ADK-PS1-1390	1390	68,4	528,5	20,8	53,4	12,6	1,5	14,2	0,3	0,8	49,7	303,3	15	118,2	10,8	6,4	2	1
ADK-PS1-1395	1395	70,1	437,8	19	45,5	9,1	0,6	5,2	0,3	0,7	39,2	372,1	15,8	105,3	6,7	2,6	0,8	0,7
ADK-PS1-1400	1400	56,8	476	19,9	60,2	10,8	0,6	7,2	0,3	0,7	43,4	338,8	16,6	97,4	3,2	2,8	0,8	0,8
ADK-PS1-1405	1405	77,3	440,9	20,1	44,3	10,4	0,5	7,2	0,3	1,1	39,8	449,2	13,5	98,8	9,9	5	0,8	0,8
ADK-PS1-1410	1410	66,4	508,4	19,8	43,3	11,6	1,8	11,6	0,3	0,6	49,9	352	17,8	125	11,7	4,5	0,9	0,9

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS1-1300	1300	1,8	0,8	0,4	3,3	7	181,2	30,6	51,2	3,4	5,1	18,2	0,9	0,9	13,2	1	1,1	8,3
ADK-PS1-1305	1305	1,1	1	1,2	2,3	5,4	237,5	29,6	42,1	3,4	5,4	5,6	1,1	1	19	0,7	4,1	14,9
ADK-PS1-1310	1310	1,4	0,8	1,2	2,2	10,3	209	23,7	61,7	4,1	5,2	15	0,8	0,9	16,1	0,4	5,1	7
ADK-PS1-1315	1315	1,8	0,9	1,2	8,4	8,9	176,9	23,6	32,1	3,2	4,7	12,2	0,9	0,9	15,7	0,6	3,6	6,9
ADK-PS1-1320	1320	1,5	0,9	1,1	2,9	9	172,5	31,1	51,4	3,2	5,5	38,8	1	1,3	14,4	0,7	1,2	7,4
ADK-PS1-1325	1325	1,9	0,9	1,1	2,1	6,3	298,3	40,6	68,5	3,3	4,5	27,1	0,9	0,9	19,7	0,6	7,9	7,1
ADK-PS1-1330	1330	0,9	0,9	1,1	2,1	5	250,8	34,6	42,2	2,5	4,5	21,1	1	0,9	16,8	1,6	3,5	7,9
ADK-PS1-1335	1335	0,8	0,9	1,2	2,6	7,5	270,7	23,8	46,4	3,3	5,1	28,5	1	1	13,6	0,6	0,7	8,2
ADK-PS1-1340	1340	1,3	0,8	1,1	1,9	3	159,1	33,4	24,5	2,2	4,6	50,2	1	0,7	10,9	0,6	1,7	6,3
ADK-PS1-1345	1345	0,6	0,8	1,3	2,3	3,8	860,6	16,9	41,8	3,1	5,1	26,5	0,9	0,9	13,3	0,6	0,5	7,8
ADK-PS1-1350	1350	0,9	1	1,2	2,1	4,7	245,7	20	45,6	3	4,6	31	0,9	0,9	16,5	0,7	2,7	8,5
ADK-PS1-1355	1355	1,3	0,9	1,3	2	6,8	162,5	27,7	35,4	3,7	5,1	23,6	1	0,9	11,9	0,6	1	7,9
ADK-PS1-1360	1360	1,6	0,9	1,2	2,5	9,6	173,8	23,8	29	3	4,7	21	1	0,9	14,8	0,6	4	7,8
ADK-PS1-1365	1365	1,7	1,2	1,2	2,1	8,7	177,9	32,1	51,7	2,9	4,5	43	1,1	0,9	14,7	0,6	4,5	9,9
ADK-PS1-1370	1370	0,9	0,8	1,1	2	6,8	183,6	23	38,3	3,1	5,6	23,3	1	1,3	11,9	0,6	0,6	7,7
ADK-PS1-1375	1375	1,6	1	1,1	2,1	3,6	285,7	23,9	42,6	2,7	4,4	34	0,9	0,8	11,8	0,6	0,5	7,5
ADK-PS1-1380	1380	1,9	0,9	1,3	2,2	3,8	501,5	24,9	20,6	3,4	5	37,2	1	1	13,1	0,6	0,6	8,9
ADK-PS1-1385	1385	1,4	0,9	1,1	5,3	6,2	234,9	23,2	31,8	3,1	4,7	25,1	1	0,9	14	0,6	2,8	7,3
ADK-PS1-1390	1390	0,8	0,9	1,3	2,3	3,8	876,5	15,1	10	3,1	4,5	34,8	1	0,9	11,9	1,2	1,5	10
ADK-PS1-1395	1395	1,6	0,8	1,1	2,4	6,3	229,8	27,8	25,2	2,9	4,4	43,2	1	0,9	13,9	1,1	0,6	8,2
ADK-PS1-1400	1400	0,7	0,9	0,5	2,9	5,3	240,1	25,3	23	2,9	4,6	21,8	0,7	0,9	13	0,6	1	7,5
ADK-PS1-1405	1405	2,2	0,9	1,1	3,9	3,4	330	20,6	27,9	2,9	4,4	29,2	0,9	0,8	10	0,6	1,5	7,7
ADK-PS1-1410	1410	1	0,9	1,2	2,1	7	211,6	28,2	29,7	2,8	4,6	38,9	1,1	0,8	12,6	0,6	2	7,6

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS1-1415	1415	40,1	387,2	15,9	40,6	10,6	0,8	4	0,3	0,4	44,4	412	12,9	97	9,3	3,6	0,9	0,8
ADK-PS1-1420	1420	70,6	497,8	19,8	44,3	9,4	1,6	14,6	0,3	0,8	35,7	370,7	14,8	83,7	3,5	2,7	0,8	0,8
ADK-PS1-1425	1425	55,6	565	24,2	40	10,7	0,8	4,1	0,3	1	44,8	396,8	12,2	122	11,3	2,9	0,8	0,8
ADK-PS1-1430	1430	57,6	414,8	18,5	38,4	10,2	1,1	6,8	0,3	0,9	44,1	400,7	15,4	97,8	10,2	2,9	0,8	0,7
ADK-PS1-1435	1435	43	375,4	26,1	39,6	11,3	0,5	4,8	0,3	1,3	38,5	437,1	13,6	101,1	10,9	2,9	0,8	0,8
ADK-PS1-1440	1440	53,6	442,9	25,4	51,6	12	0,6	6	0,3	0,9	45,7	388,2	15,2	128,8	9,3	2,1	0,8	0,7
ADK-PS1-1445	1445	29,6	367,9	25,4	44,1	11,3	0,5	4	0,3	1	48,4	410,5	14,9	108,8	3,4	3	0,8	0,8
ADK-PS1-1450	1450	68,4	338	18,3	39,8	9,2	0,6	2,9	0,3	1	40,1	429,8	13,2	101,1	3,2	2,7	0,8	0,8
ADK-PS1-1455	1455	48,9	406,8	19,7	38,5	11,5	1	15	0,3	1,2	37,5	427,3	13,4	109	10,5	3	0,8	0,8
ADK-PS1-1460	1460	49,4	379,8	12,1	45	7,6	0,7	4,5	0,3	0,7	30,7	434,9	11,3	92,5	3,5	3,3	0,9	0,9
ADK-PS1-1465	1465	45,8	417,6	16,2	46,7	7,7	0,9	4,3	0,3	0,9	26,9	450,4	11,4	100,5	6,4	3,6	0,9	0,8
ADK-PS1-1470	1470	49,1	384,5	15,5	43,8	10,3	0,6	3,7	0,3	1	38,1	373,1	14,8	100,9	8,1	3,3	0,9	0,7
ADK-PS1-1475	1475	26,7	431,8	21,4	39,7	11,9	0,6	3,4	0,3	0,6	38,5	371,8	14,2	85,2	7,7	2,7	0,8	0,7
ADK-PS1-1480	1480	74	565,2	29,4	42,3	11,9	1,8	6,6	0,3	0,9	34	295,3	12,1	98	6,4	2,9	0,8	0,7
ADK-PS1-1485	1485	49,1	436,6	14,8	42,2	9,7	2,8	10,7	0,3	2,6	42,2	362,9	13,6	123,6	7,8	3,3	0,8	0,8
ADK-PS1-1490	1490	73,7	586,1	22,2	52,6	12,6	3,2	17,6	0,7	1,7	55,7	386,8	15,3	124,8	10,6	5,2	0,9	0,8
ADK-PS1-1495	1495	42,9	480,9	20,8	45	11,6	1,5	10,6	0,7	1,2	50,9	336,8	12,8	108,2	11,5	4,3	0,8	0,8
ADK-PS1-1500	1500	75,1	531,7	19,8	49,4	11,4	1,5	7,9	0,3	1	45,4	298,4	15	120,5	9,7	3,5	0,8	0,8
ADK-PS1-1505	1505	50,5	544,2	34,1	50,8	13,1	1,2	6,9	0,5	0,9	50,1	332,7	13,1	116,5	8,1	3	0,8	0,8
ADK-PS1-1510	1510	58,6	549,5	27,4	50,6	14,9	1,7	7,8	0,3	0,9	58,7	350,4	15	132,9	9	3,4	0,8	0,8
ADK-PS1-1515	1515	74,9	551,2	20,8	51,5	12,6	1,4	8,8	0,3	0,8	48,3	334,2	14,3	94,6	7,1	3,9	0,8	0,7
ADK-PS1-1520	1520	41,2	450	28,6	52,4	10,3	0,5	4,8	0,3	0,3	41,2	307,5	18,1	85,9	3,5	2,6	0,8	0,8
ADK-PS1-1525	1525	57,4	549,5	28	51,5	12,2	0,5	7,8	0,3	0,9	49	330	17,7	112,3	3,6	3,2	0,8	0,9

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS1-1415	1415	0,9	0,9	1,2	3,5	7,6	322,4	23	30,5	3	4	15,1	0,9	0,6	9,5	0,6	2,3	8,5
ADK-PS1-1420	1420	0,9	0,9	0,9	2	3,4	179,5	30,2	33,7	2,4	4,5	36,9	1,1	0,4	9,7	0,6	0,6	7,6
ADK-PS1-1425	1425	1,5	0,9	1,2	2,2	3,6	194,8	16,9	34,9	4,4	4,7	43,7	1	0,8	11,6	0,6	0,5	7,7
ADK-PS1-1430	1430	1	0,8	1,2	5,2	3,6	371,8	16,2	27,4	2,9	4,2	23,1	0,9	0,8	11,1	0,6	1,5	7,1
ADK-PS1-1435	1435	2,5	0,8	1,2	7,7	3,6	212,6	28,3	41,6	3,1	4,5	22,7	0,8	0,8	9,9	0,6	2,5	7,6
ADK-PS1-1440	1440	1,7	0,9	0,8	3,7	3,5	182,8	28,2	41,2	3	4,6	36,5	1	0,8	11,6	0,6	1,8	8,1
ADK-PS1-1445	1445	1,9	0,9	1,2	3,3	3,6	206,9	24	25,6	6,5	4,3	20,1	0,9	0,8	11,3	0,6	1,2	7,5
ADK-PS1-1450	1450	0,9	0,8	1,1	4,3	3,7	290,3	20,4	18,6	3	4,1	34,1	1	0,8	10,5	0,6	0,9	7,5
ADK-PS1-1455	1455	1,8	0,8	1,1	5,5	7,1	226,7	26	20,5	2,8	4,3	32,2	1	0,9	10,6	0,6	1,3	11,6
ADK-PS1-1460	1460	1	1,1	1,2	2,2	3,6	190,6	29,3	20,5	4,9	4	32,6	1,1	0,9	7,9	0,6	0,6	8,7
ADK-PS1-1465	1465	1,8	1	1,5	5,5	5,7	185,8	20,2	27,2	3	4,5	35,2	1,1	0,9	6,5	0,6	0,6	17,2
ADK-PS1-1470	1470	0,5	0,9	1,1	2,1	4,3	390,3	23,3	22,2	2,9	4,4	26,6	1	0,9	10,6	0,6	1	10,9
ADK-PS1-1475	1475	0,9	0,9	1,1	3,3	3,5	191,4	24,6	41,3	2,9	4,4	39,6	1,1	0,8	8,4	0,6	0,6	7,3
ADK-PS1-1480	1480	0,8	1	1,1	4,3	3,4	268,2	18,3	22,1	3,1	5	37,6	1	0,8	5,4	0,6	0,5	6,6
ADK-PS1-1485	1485	1,9	0,9	1,2	6,5	5,3	258,3	27,4	27,8	2,8	4,4	31,3	1,1	0,9	8,5	0,6	0,6	10,5
ADK-PS1-1490	1490	1,5	0,9	1,2	2,1	5,1	262,6	26,7	48,2	2,9	4,8	19,5	1	0,9	12,2	0,6	1,6	8,6
ADK-PS1-1495	1495	1,6	2,4	1,1	7,6	8,6	235,2	26,6	39,8	2,4	4,5	40,3	1,1	0,5	10,1	0,5	2	8,1
ADK-PS1-1500	1500	0,4	0,8	1,1	2	8,1	222	18,4	36,2	3	4,7	34,6	1	0,8	11,6	0,6	1,3	8,1
ADK-PS1-1505	1505	0,9	1	0,4	2	7,2	185,3	22,8	30,7	2,8	4,8	24	0,9	0,8	10,5	0,8	0,5	7,9
ADK-PS1-1510	1510	1,2	1,7	1,2	2,1	3,7	464,1	25,8	32,1	3,8	4,7	9,9	0,8	0,8	10,2	0,6	0,8	8,5
ADK-PS1-1515	1515	1,4	0,9	1,2	2,1	5,5	326,5	28,5	28	2,3	4,7	38	1,1	0,5	11,8	0,4	0,6	7,9
ADK-PS1-1520	1520	0,9	0,8	1,1	2,1	10,3	190,2	21,2	30,3	2,6	4,9	28,3	1	0,8	7	0,5	0,6	8,1
ADK-PS1-1525	1525	1,2	1	1,2	2,1	3,7	299,3	20,1	40,5	3,1	4,9	20,8	0,9	0,6	8,6	0,6	0,6	8,4

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
ADK-PS2-755	755	0,05	4,756	5,445	31,46	0,0435	0,3899	0,03953	0,9845	23,82	0,3559	0,0117	0,0673	0,0593	3,895	28,63	100,01
ADK-PS2-760	760	0,046	1,879	6,051	38,38	0,0657	0,2728	0,01788	1,271	23,91	0,3485	0,0074	0,0374	0,053	2,596	24,99	99,93
ADK-PS2-765	765	0,051	2,257	7,675	37,95	0,0808	0,2482	0,01624	1,571	20,86	0,4451	0,0116	0,0343	0,0482	3,487	24,87	99,61
ADK-PS2-770	770	0,05	1,492	4,718	33,47	0,0506	0,3494	0,0287	0,962	27,86	0,2956	0,0068	0,0439	0,041	1,876	28,73	99,97
ADK-PS2-775	775	0,17	1,555	4,589	36,24	0,0584	0,449	0,04128	0,9907	26,09	0,3116	0,0057	0,0421	0,0442	1,673	28,05	100,31
ADK-PS2-780	780	0,13	2,4	7,428	38,28	0,0625	1,114	0,01799	1,46	21,26	0,4568	0,015	0,05	0,045	2,844	24,53	100,09
ADK-PS2-785	785	0,053	1,733	4,901	30,84	0,0585	1,504	0,02429	0,9953	29,11	0,3172	0,0081	0,0441	0,0419	1,921	27,89	99,44
ADK-PS2-790	790	0,051	1,321	3,209	25,58	0,0403	0,9951	0,02407	0,7338	35,8	0,2125	0,0062	0,0321	0,0406	1,208	30,62	99,87
ADK-PS2-795	795	0,049	1,821	4,978	35,14	0,0688	0,3079	0,01836	1,066	25,83	0,2977	0,0093	0,0338	0,0405	2,131	28,91	100,70
ADK-PS2-800	800	0,052	1,23	4,21	34,87	0,0533	0,4969	0,02619	1,013	27,69	0,2709	0,0088	0,0406	0,0385	1,659	28,51	100,17
ADK-PS2-805	805	0,15	1,319	5,092	39,93	0,0886	0,273	0,04066	1,03	24,25	0,4097	0,011	0,0819	0,0431	1,808	24,88	99,41
ADK-PS2-810	810	0,049	1,575	5,839	37,95	0,0796	0,3221	0,03415	1,21	24,05	0,3781	0,0115	0,0476	0,0713	2,573	25,87	100,06
ADK-PS2-815	815	0,048	2,701	10,29	47,1	0,1118	0,7558	0,0196	1,883	17,46	0,5514	0,0164	0,0395	0,0808	5,309	14,05	100,42
ADK-PS2-820	820	0,05	2,694	11,75	51,66	0,1192	0,5445	0,01952	2,134	12,82	0,5763	0,016	0,0438	0,0944	6,104	11,63	100,26
ADK-PS2-825	825	0,29	2,603	10,01	47,81	0,1022	1,001	0,02184	1,906	17,78	0,5383	0,0191	0,0357	0,0681	5,108	12,55	99,84
ADK-PS2-830	830	0,051	1,861	7,443	32,03	0,0921	1,373	0,02239	1,543	25,91	0,4393	0,0149	0,0324	0,0516	3,572	25,52	99,96
ADK-PS2-835	835	0,29	2,626	10,69	49,93	0,1071	1,18	0,01621	2,03	16,35	0,5848	0,0198	0,0383	0,0702	5,083	10,63	99,65
ADK-PS2-840	840	0,049	2,621	11,91	51,84	0,1118	0,632	0,01523	2,212	13,37	0,5933	0,0192	0,0465	0,0751	5,709	10,77	99,97
ADK-PS2-845	845	0,052	1,513	5,862	42,1	0,0729	1,261	0,03448	1,175	28,31	0,3819	0,0091	0,0451	0,0449	2,392	16,53	99,78
ADK-PS2-850	850	0,051	1,366	5,081	27,48	0,0615	1,075	0,02768	1,067	31,93	0,3239	0,0105	0,0307	0,0486	2,183	29,73	100,47
ADK-PS2-855	855	0,048	0,57	1,685	18,84	0,0464	0,9691	0,0078	0,4273	47,49	0,1153	0,0027	0,012	0,042	1,238	28,95	100,44
ADK-PS2-860	860	0,05	0,437	2,021	15,18	0,038	0,8162	0,009	0,4604	46,61	0,1811	0,0035	0,0238	0,0494	1,424	32,62	99,92
ADK-PS2-865	865	0,05	1,17	4,868	22,96	0,0614	0,9911	0,00934	0,9872	37,6	0,3215	0,0102	0,0309	0,0539	2,581	28,96	100,65
ADK-PS2-870	870	0,047	0,295	1,457	21,32	0,0594	1,107	0,00995	0,4385	41,61	0,107	0,0046	0,0104	0,0581	0,9935	32,73	100,25
ADK-PS2-875	875	0,05	1,805	8,171	39,74	0,0875	1,034	0,02934	1,616	21,64	0,4989	0,0141	0,0386	0,0563	3,435	21,74	99,96
ADK-PS2-1255	1255	0,047	6,691	6,013	39,86	0,058	0,2563	0,00788	0,7825	22,99	0,378	0,0144	0,0482	0,0847	3,996	18,93	100,16
ADK-PS2-1260	1260	0,05	8,098	6,486	41,65	0,0522	0,3945	0,00458	0,8685	19,45	0,4021	0,0159	0,0687	0,1269	5,675	16,73	100,07
ADK-PS2-1265	1265	0,052	4,99	6,127	39,4	0,0714	0,2505	0,00736	0,7899	23,04	0,3972	0,0145	0,0489	0,2313	9,652	14,88	99,95
ADK-PS2-1270	1270	0,049	3,83	8,058	44,83	0,0597	0,2955	0,00081	1,111	19,85	0,4802	0,0208	0,0789	0,104	7,059	14,72	100,55
ADK-PS2-1275	1275	0,052	4,087	6,682	38,19	0,051	0,4555	0,00812	0,8652	19,71	0,3844	0,0167	0,047	0,2445	12,92	16,53	100,24
ADK-PS2-1280	1280	0,052	3,768	8,247	45,19	0,0642	0,7556	0,01379	1,177	19,47	0,4907	0,0164	0,0716	0,101	7,093	13,64	100,15
ADK-PS2-1285	1285	0,051	2,536	8,128	42,84	0,0695	0,7002	0,01155	1,233	20,62	0,4617	0,0183	0,0537	0,1136	7,776	15,88	100,49

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
ADK-PS2-1290	1290	0,051	2,561	7,144	41,55	0,0721	0,7962	0,02113	1,035	24,22	0,405	0,0108	0,0492	0,115	6,504	15,62	100,15
ADK-PS2-1295	1295	0,053	3,579	7,118	40,25	0,0637	0,6777	0,01348	1,077	23	0,4294	0,02	0,0561	0,1362	8,941	14,92	100,33
ADK-PS2-1300	1300	0,054	3,694	6,642	38,7	0,0607	0,6058	0,01466	0,8663	20,61	0,3924	0,0182	0,0466	0,26	12,63	14,36	98,95
ADK-PS2-1305	1305	0,05	3,142	4,907	36,76	0,0616	0,5247	0,01414	0,744	29,48	0,3051	0,0127	0,0768	0,1152	5,664	18,37	100,23
ADK-PS2-1310	1310	0,048	4,864	1,856	19,97	0,0228	0,1954	0,01159	0,2895	35	0,1777	0,0089	0,0709	0,1095	3,961	34,28	100,87
ADK-PS2-1315	1315	0,051	4,708	4,129	24,07	0,0451	0,286	0,0113	0,6727	29,26	0,2734	0,0103	0,0969	0,1184	5,969	30,62	100,32
ADK-PS2-1320	1320	0,051	4,674	3,79	24,22	0,0353	0,2336	0,01205	0,595	30,19	0,2536	0,0096	0,0834	0,1007	4,831	30,51	99,59
ADK-PS2-1325	1325	0,05	4,883	3,625	22,24	0,0342	0,2541	0,01453	0,5916	31,94	0,2333	0,011	0,1035	0,0835	4,504	31,73	100,30
ADK-PS2-1330	1330	0,051	5,058	4,061	22,01	0,0374	0,3293	0,01346	0,6187	31,21	0,2561	0,0087	0,0575	0,093	4,544	31,48	99,83
ADK-PS2-1335	1335	0,052	4,095	5,537	36,33	0,0496	0,6643	0,01581	0,7682	25,42	0,3251	0,0163	0,0654	0,1723	9,363	17,83	100,70
ADK-PS2-1340	1340	0,049	8,14	4,135	30,19	0,0247	0,2106	0,00941	0,5597	28,37	0,2315	0,0104	0,0616	0,0722	4,104	23,62	99,79
ADK-PS2-1345	1345	0,051	9,276	3,158	37,33	0,0217	0,3331	0,01382	0,3934	29,55	0,1868	0,0087	0,0402	0,1014	4,854	14,82	100,14
ADK-PS2-1350	1350	0,054	2,425	5,055	27,18	0,0739	0,3024	0,01777	0,5977	30,47	0,6055	0,0138	0,0725	0,1081	5,114	27,53	99,62
ADK-PS2-1355	1355	0,052	2,237	3,452	25,62	0,0508	0,2484	0,01033	0,4467	32,72	0,3544	0,0115	0,0535	0,1012	3,521	32,93	101,81
ADK-PS2-1360	1360	0,054	2,071	4,674	31,31	0,1021	0,1511	0,01801	0,5471	27,9	0,7085	0,0154	0,0648	0,1258	5,162	27,82	100,72
ADK-PS2-1365	1365	0,053	2,324	6,354	31,88	0,1	0,1384	0,00376	0,9688	24,32	0,5579	0,0134	0,0643	0,1289	6,953	25,921	99,78
ADK-PS2-1370	1370	0,053	4,379	3,899	29,73	0,0717	0,1078	0,00821	0,3403	27,98	0,411	0,012	0,0647	0,1404	4,476	28,83	100,50
ADK-PS2-1375	1375	0,051	5,14	4,477	30,4	0,0689	0,4832	0,01371	0,5781	26,34	0,294	0,0133	0,0622	0,1698	5,181	26,99	100,26
ADK-PS2-1380	1380	0,051	4,945	4,814	30,08	0,0674	0,1566	0,01213	0,4924	26,02	0,386	0,0171	0,0979	0,1746	6,006	26,73	100,05
ADK-PS2-1385	1385	0,055	1,869	1,418	10,2	0,0083	0,1048	0,02071	0,148	49,14	0,1493	0,0063	0,0376	0,0813	1,981	34,88	100,10
ADK-PS2-1390	1390	0,052	1,456	1,43	12,7	0,0054	0,161	0,01933	0,192	46,73	0,1633	0,004	0,0224	0,0713	2,136	34,28	99,42
ADK-PS2-1395	1395	0,053	0,314	0,607	3,784	0,0027	0,0637	0,0198	0,0053	57,29	0,0857	0,0062	0,0119	0,029	0,8574	36,73	99,86
ADK-PS2-1400	1400	0,054	2,109	0,85	7,685	0,0069	0,0687	0,02105	0,1084	48,99	0,0932	0,0121	0,0243	0,0404	1,137	39,03	100,23
ADK-PS2-1405	1405	0,054	2,026	1,286	10,13	0,017	0,0893	0,02278	0,162	47,78	0,1544	0,0067	0,0441	0,0689	1,748	36,82	100,41
ADK-PS2-1410	1410	0,053	2,367	0,817	6,25	0,0029	0,0734	0,01877	0,1286	51,32	0,07	0,007	0,0198	0,0385	1,032	31,65	93,85
ADK-PS2-1415	1415	0,051	0,042	1,378	3,966	0,0027	0,0596	0,01813	0,4311	56,8	0,0903	0,0014	0,0092	0,0176	0,5032	36,83	100,20
ADK-PS2-1420	1420	0,05	0,115	0,506	1,859	0,0026	0,0629	0,02083	0,1437	55,02	0,0437	0,0014	0,005	0,01228	0,3152	41,48	99,64
ADK-PS2-1425	1425	0,05	0,327	0,283	1,362	0,0026	0,0807	0,0226	0,0045	55,05	0,0189	0,0012	0,00295	0,01264	0,4424	42,48	100,14
ADK-PS-2-1665	1665	0,047	1,066	0,838	4,8	0,0027	0,1864	0,02895	0,131	55,42	0,0686	0,006	0,005	0,0215	0,7437	35,73	99,09
ADK-PS-2-2100	2100	0,053	1,618	4,797	26,91	0,0537	0,4222	0,01449	0,8931	31,9	0,4313	0,0074	0,00594	0,0456	3,655	29,73	100,54
ADK-PS-2-2195	2195	0,054	1,984	6,35	31,65	0,0749	0,6386	0,04333	1,144	27,52	0,5106	0,0155	0,00622	0,0619	4,611	25,82	100,48

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS2-755	755	40,2	261,1	11,3	33	8,6	0,6	5,7	0,3	2,1	46,1	776,4	10	125,1	7,9	3,3	0,8	0,8
ADK-PS2-760	760	26,5	120	6,5	29,3	8,6	1,8	8,3	0,4	1,9	47,5	661,8	14,2	124,3	11,1	3	0,8	0,8
ADK-PS2-765	765	32,5	143,6	13	38,9	10,6	1,3	9,1	0,3	1,4	63,6	708	14,3	139,6	14,9	3,4	0,9	0,8
ADK-PS2-770	770	30,5	84	5	18,4	7,2	0,7	5	0,3	0,8	37,7	639,6	11,5	130,5	10,4	6,2	0,8	0,9
ADK-PS2-775	775	22,6	79	3,7	16,7	7,4	0,9	5,2	0,4	1,7	35,7	706,6	10,4	162,3	7,7	3,4	0,8	0,8
ADK-PS2-780	780	32,1	160,7	10,5	35,7	9,9	0,7	10	0,3	0,9	60	775,4	16,7	173,8	11,3	2,7	0,9	0,8
ADK-PS2-785	785	20,8	90,3	3,9	19,7	7,7	0,5	15,8	0,3	1,3	38,1	789,9	12,1	177,1	10,7	2,9	0,8	0,8
ADK-PS2-790	790	25,7	49	2,8	11,4	6,3	0,7	25,3	0,4	1,5	27,8	866,6	7,3	139,9	3,6	3,6	0,9	0,9
ADK-PS2-795	795	23,5	100	5,5	20,6	6,4	1,1	8,2	0,3	1,7	40,3	674	9,3	131,4	3,9	3,9	1,7	0,9
ADK-PS2-800	800	19,9	62,8	2,7	16,9	5,6	0,8	9,9	0,4	1,7	36,4	693,1	8	124,5	8	2,7	0,8	0,8
ADK-PS2-805	805	11,4	82,4	4,7	20,5	6,9	0,8	7,1	0,4	0,6	35,5	495,7	14,7	254,5	9,4	3,1	0,8	0,7
ADK-PS2-810	810	38	119,6	4,3	28,7	9,5	0,7	11,4	0,4	1	48,5	528,9	14,5	220,9	8,9	3,2	0,9	0,8
ADK-PS2-815	815	47,1	245,1	24,4	55,7	15,9	1,5	24,8	0,3	1,5	87,8	896,9	19,7	153,5	13,4	3,1	0,9	0,4
ADK-PS2-820	820	43,2	251,2	24,3	65,6	16,3	0,8	25,9	0,3	1,4	98,3	633,7	21,7	200,6	17,5	3,4	1,8	0,9
ADK-PS2-825	825	45,1	246	22,9	59,2	15,1	0,4	17,5	0,3	1,2	89,8	1179	16,4	145,2	13,7	3	0,9	0,8
ADK-PS2-830	830	35,8	160,9	13,6	42,3	10,6	1,4	17,4	0,3	1,4	64	1250	14	149,1	14,2	3,9	0,8	0,8
ADK-PS2-835	835	49,2	225,2	21,7	62,9	16,1	0,5	21,6	0,3	1,3	87,6	830,5	21,5	162,6	3,8	3,2	0,8	0,8
ADK-PS2-840	840	36,5	258,5	25,6	68,3	16,5	0,8	18,8	1	1,1	102,6	805,8	22,6	175,8	12,6	3,2	0,9	0,8
ADK-PS2-845	845	21,1	95,8	7,2	29,1	8,4	0,6	12,8	0,3	1,3	46,3	895,6	10,6	152,6	10,9	3,7	0,9	0,8
ADK-PS2-850	850	14,6	98,6	9,1	25,4	7,6	0,6	8,8	0,3	1,6	45,6	1055	8,3	122,2	7,1	3,3	0,9	0,8
ADK-PS2-855	855	19,3	76,2	1,2	9	3,5	0,5	6,5	0,3	1,6	18,6	1082	0,7	26,7	6,2	3,7	0,9	0,9
ADK-PS2-860	860	24	45,7	1	10,1	4,4	0,8	5,6	0,4	1,2	17,2	840,5	4,9	86,5	4,2	6,1	0,5	1
ADK-PS2-865	865	15,6	104,3	6	23,9	8,5	1,1	10,1	0,6	1,3	42,1	893,5	9,1	82,3	11,6	3,7	0,9	0,9
ADK-PS2-870	870	15,6	27,3	1	4,5	3,4	0,8	5	0,4	0,3	15,7	579,4	3,4	50,6	3,5	3,2	0,9	0,8
ADK-PS2-875	875	36	179,8	15,2	40,9	14	0,6	10,8	0,3	1,1	73,2	754	16,8	173,4	12,5	3	0,9	0,8
ADK-PS2-1255	1255	28,8	237,7	11,7	33,3	9	0,4	2,3	0,3	1,4	33	308,2	14,5	87,2	9,1	3	0,9	0,8
ADK-PS2-1260	1260	61,9	515,3	18,8	51,3	10,6	1,9	4	0,3	2,6	36,6	703,2	13,3	81,5	8,9	2,9	0,8	0,8
ADK-PS2-1265	1265	93	587,5	25,3	82,2	6,7	0,6	1,8	0,3	0,3	33,4	401,2	22,8	106,4	9,7	4,2	1	0,8
ADK-PS2-1270	1270	43,8	405,9	22,3	51,7	11,8	1,6	3,2	0,3	1	50,6	326,3	17,8	108,2	11,5	3,3	0,9	0,8
ADK-PS2-1275	1275	119	684,3	28	96,2	9,2	0,6	1,3	0,3	1,2	43	346,7	20,3	81,3	11,3	5,8	1	0,9
ADK-PS2-1280	1280	48,8	403,6	20,4	57,1	10,8	1,5	6,4	0,3	0,5	55	384,2	18,3	101,1	16,2	5,4	0,9	0,8
ADK-PS2-1285	1285	67,2	454,8	23	62,6	13	0,4	4	0,3	0,3	62	415,1	16,4	118,2	11,5	3,9	0,9	0,8

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS2-755	755	1	1,5	1,2	8,3	5	239	20,5	38,9	2,7	3,8	39,6	1,1	0,8	10,9	0,9	3,3	8,4
ADK-PS2-760	760	0,9	0,9	1,2	3,5	4,1	287,9	24	31,1	2,7	3	109,3	1,3	0,9	14,1	0,6	5,8	8,8
ADK-PS2-765	765	1	0,9	1,2	4,2	3,7	321	29,8	35	2,6	3,2	42,9	1,1	0,8	17,8	0,6	5,7	8,5
ADK-PS2-770	770	0,9	0,9	1,2	4,3	3,5	235,8	24,6	39,9	2,8	2,8	91,6	1,2	0,8	10,9	0,6	4,5	7,7
ADK-PS2-775	775	0,9	1,5	1,2	2,3	3,5	243,6	21,2	41,3	3,5	2,8	152,8	1,5	0,7	11,6	0,6	5,1	8,6
ADK-PS2-780	780	0,9	0,9	1,1	2,4	3,6	306,5	23	42,6	2,7	3,2	52,1	1,1	0,8	15,7	0,6	7,2	8,3
ADK-PS2-785	785	0,9	1,9	1,1	4,9	3,5	253,2	20,8	25,7	2,8	2,8	69,2	1,2	0,9	12,1	1	5,8	7,5
ADK-PS2-790	790	0,9	1	0,8	4,4	3,6	225,1	21,2	28,2	2,7	2,6	82,9	1,2	0,8	8	0,7	4	9,4
ADK-PS2-795	795	0,7	1	1,2	4,3	4,7	225,6	26,5	29,8	4,7	2,8	75,2	1,2	0,9	11,8	0,4	5,5	14,6
ADK-PS2-800	800	1,1	1,7	1,2	5	3,5	302	18,4	34,2	1,4	2,5	99,9	1,2	0,8	11,1	0,6	4,9	6,9
ADK-PS2-805	805	2,1	0,9	1,7	2,9	3,6	224,8	19,8	18,5	3,7	3,3	112	1,3	0,8	11,1	0,6	5,6	7,7
ADK-PS2-810	810	1,3	0,9	1,1	2,1	3,5	266,2	26,3	46,7	2,6	2,2	98,4	1,3	0,8	13,5	0,6	7,8	12
ADK-PS2-815	815	3,2	2,6	1,2	2,1	6,2	363	30,9	61,9	2,9	4	6,8	0,9	0,7	22,7	0,4	9,7	7,8
ADK-PS2-820	820	3,9	3,6	1,3	2,2	3,5	386,1	38	78,2	5,1	3,9	14,6	0,9	0,6	27,5	0,7	10,3	14,8
ADK-PS2-825	825	2,1	1,8	1,2	1,7	3,2	363,5	20,6	35,8	3,1	4,1	7	0,9	0,9	25,2	0,7	9,2	8,3
ADK-PS2-830	830	1,9	0,9	1,2	2,4	3,7	319,6	28,5	37,6	4,2	3,5	14,4	0,9	0,4	15,8	0,7	7,5	8,2
ADK-PS2-835	835	1	1	1,2	2,6	6,8	382	35,5	49	4,5	3,9	13,5	0,9	1	25,6	0,7	9,6	11,9
ADK-PS2-840	840	2,7	1,6	1,2	2,2	3,7	416	33,3	60,6	4,8	4	10,5	0,5	0,8	25,3	0,4	10,5	12,6
ADK-PS2-845	845	1,4	0,6	1,2	2,1	6,6	260,7	22,9	41,3	2,6	2,9	43,2	1	1,2	12,9	0,6	6,9	8,6
ADK-PS2-850	850	3,9	1,5	1,2	2,1	7,5	275,6	14,7	26	2,4	3,1	27,9	0,9	0,9	12,5	0,6	5,1	9,4
ADK-PS2-855	855	1	0,9	1,2	2	3,4	101,1	7,2	9,9	2,9	3,1	2,9	0,9	0,9	5,4	0,7	2,7	14,8
ADK-PS2-860	860	1,1	1	1,3	2,1	3,6	139,9	24,2	10	3,5	2,7	38,5	1,1	0,5	6,1	0,6	2,4	9,5
ADK-PS2-865	865	1,1	1,2	1,2	5,9	3,6	199,7	14,4	30,5	2,1	3,2	14,4	1	0,4	11,7	0,7	4,8	16,5
ADK-PS2-870	870	1	1	1,2	2,1	5,4	131,7	7,4	17,2	2,6	2,3	91,2	1,3	0,8	4,8	0,5	2,4	9,7
ADK-PS2-875	875	2,7	2,7	1,2	2,2	5,5	393,8	25	53,2	3,2	3,5	28	1	0,9	18,4	0,6	10,5	8,3
ADK-PS2-1255	1255	0,9	0,9	0,7	9	3,6	230,1	24	26,3	1,9	3,5	25,4	0,9	0,8	10,1	0,7	2,2	10
ADK-PS2-1260	1260	1,5	0,9	1,2	10	3,5	184,1	19,4	29,5	2,9	4,5	6,1	0,9	0,7	12,1	0,6	0,6	8
ADK-PS2-1265	1265	1,5	1	1,2	4,4	3,5	128,3	28,7	45,2	3,7	5,5	9,3	1	0,8	16,4	0,7	0,7	19,7
ADK-PS2-1270	1270	1,4	1	0,7	2	12,6	163,2	7,5	39,4	3,1	4,5	9,1	1	0,9	13,3	0,6	3,1	12,7
ADK-PS2-1275	1275	1,1	0,9	0,6	7,2	11,4	135,9	37,3	38,4	4	6,3	6,4	1,2	1,1	17,1	0,8	1	9,6
ADK-PS2-1280	1280	2,5	1	1,2	2,1	4,5	259,9	25,4	39,1	3,2	4,6	12,1	1	0,9	15,4	0,7	2,6	9,2
ADK-PS2-1285	1285	2,6	1	1,2	4,8	10,9	223,5	35,1	36,3	3,2	4,8	9,3	1	1	18,3	0,7	4,8	9

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS2-1290	1290	70	358,4	18,9	57,8	11,1	0,6	7	0,3	1,3	49,4	376,2	18,3	99,3	3,8	3,5	0,9	0,9
ADK-PS2-1295	1295	31,3	502,4	20,9	64,6	10,4	0,6	5,8	0,3	1,4	51	368,7	17,2	98,7	10,6	13,6	0,9	0,9
ADK-PS2-1300	1300	94	686,3	19	94,5	8,1	0,6	5	0,3	0,3	42,1	337,8	19,6	103,5	4,5	4,3	2,2	1
ADK-PS2-1305	1305	38	426,9	16,4	46	8,7	0,6	4,6	0,3	0,7	35,8	330,5	12	97	6,3	3,7	0,9	0,9
ADK-PS2-1310	1310	32,1	316,9	10,3	27,6	4,3	0,8	3,7	0,4	0,8	12,6	204,5	6,8	58,1	5,7	3,5	0,9	0,8
ADK-PS2-1315	1315	70	553,2	10,7	37,7	6,3	0,5	5,2	0,6	0,3	31,2	273,4	10,8	67,9	3,4	9	0,9	0,8
ADK-PS2-1320	1320	54,3	482,2	15,2	34,9	7,1	0,7	4,9	0,3	1,7	30,8	305,2	11,2	77,7	8,3	10,1	0,9	0,9
ADK-PS2-1325	1325	55,3	487	15,3	32,8	5,2	0,6	5,3	0,3	1,6	29,9	273,9	9,1	79,9	4,6	3,5	0,9	0,9
ADK-PS2-1330	1330	45	398,9	9,5	33,8	6,2	0,6	3,4	0,3	1,4	28,9	268,4	8,4	70,5	3,3	5,2	0,9	0,9
ADK-PS2-1335	1335	80	578,1	21,1	69,9	9,7	0,8	5	0,4	0,9	37,6	299	15,7	84,3	8,4	4,2	0,9	0,9
ADK-PS2-1340	1340	35,1	350	5,8	31,2	5,3	0,6	3,7	0,3	1	26,5	235,1	8,1	64	4,7	3	0,8	0,7
ADK-PS2-1345	1345	63,3	313,5	11,3	34,1	4,7	0,6	5	0,3	1,5	19,8	228,2	8,9	51,4	3,1	3,1	0,9	0,8
ADK-PS2-1350	1350	41,4	291,3	14	35,6	9,6	1,3	4,7	0,3	0,3	37,9	242,2	16,6	93,6	16,5	3,8	0,4	0,9
ADK-PS2-1355	1355	26,7	206	9,3	24,4	6	0,8	3	0,3	0,3	25,3	236,5	14,1	62,6	9,5	3,3	0,9	0,8
ADK-PS2-1360	1360	51,2	280,1	19,2	37,5	7,9	1	4,5	0,4	0,3	30,5	159,6	20,1	101,4	23,1	4	2,6	1
ADK-PS2-1365	1365	53,2	560,6	21,7	58,9	9,6	0,7	4	0,4	0,7	51,3	305,1	15,4	103,2	4,1	3,6	1	0,9
ADK-PS2-1370	1370	35,9	289,4	16,1	42,3	5,4	0,7	2,7	0,4	0,9	15,9	189	21	51,6	11,7	3,4	0,9	0,8
ADK-PS2-1375	1375	34,6	313	26,2	36,5	5,8	0,7	5,4	0,3	0,9	25	226,6	15,4	54,4	2,7	3,2	0,8	0,8
ADK-PS2-1380	1380	49,4	352,4	48,4	46,4	8,2	0,6	3,5	0,3	0,7	27,9	223,8	14,5	70,5	10	3,6	0,9	0,9
ADK-PS2-1385	1385	21,5	120,9	9,9	13,5	2,5	0,6	2,3	0,3	0,3	8	332,5	6,9	25	3,9	3,2	1	0,9
ADK-PS2-1390	1390	11,8	133,3	25,4	13,1	3,4	0,6	4,3	0,3	1,4	9,2	295,2	5,6	21,7	3,5	3,4	1	0,9
ADK-PS2-1395	1395	15,8	34,1	0,9	4,1	2,3	0,5	1	0,3	0,7	4,9	184	3,5	9,9	3,6	3,4	1	0,8
ADK-PS2-1400	1400	17,3	73	4,4	7,6	2,7	0,5	1,3	0,3	0,3	7,3	198,9	3,5	14,6	3,2	3	0,9	0,8
ADK-PS2-1405	1405	16,4	109,4	5,7	10,5	3,9	0,6	1,9	0,3	1	7,4	193,6	6,7	19,5	3,5	3,3	0,9	0,9
ADK-PS2-1410	1410	15,5	62,2	1,4	8,1	1,6	0,5	0,9	0,3	0,3	5,5	187,1	4,2	9,4	3,5	4,9	0,9	0,9
ADK-PS2-1415	1415	27,9	18,1	6,5	3,7	3,6	0,6	1,5	0,3	0,3	16,4	156,5	4,5	15,5	3,4	3	0,8	0,9
ADK-PS2-1420	1420	16,3	16,6	1	4,4	2	0,6	1,6	0,3	0,6	6,7	163,8	2,8	15,3	3,8	3,3	1	0,8
ADK-PS2-1425	1425	24,6	2,7	1,2	0,6	2,6	0,5	0,4	0,3	0,3	1,9	132,6	1,3	5,5	3,3	3,1	0,9	0,9
ADK-PS-2-1665	1665	21,5	38,1	49,1	4	2	0,6	1,8	0,3	0,3	5,6	150,4	1,2	17	3,4	3,2	0,9	0,8
ADK-PS-2-2100	2100	34,3	21,9	13,9	36,9	7,8	1	2,3	0,5	0,3	31,6	165,1	12,6	80,5	4,9	3,3	0,8	0,8
ADK-PS-2-2195	2195	38,5	40,5	20	57,5	7,7	1,1	4,6	0,4	0,7	36,9	170,9	16,1	122,7	10,2	3,4	0,9	0,8

Table F.1 XRF analyses results of samples from Akköy field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
ADK-PS2-1290	1290	1,3	1	1,2	2,2	3,6	400,2	21,2	45,5	3,2	4,5	27,6	1,1	1	18,3	0,7	3,6	19,2
ADK-PS2-1295	1295	1,5	2,9	0,9	1,7	5,4	297,9	27,9	45,1	3,5	5,1	11,2	1	1,1	17,8	0,7	2,2	8,5
ADK-PS2-1300	1300	1,1	0,9	0,9	6,7	3,6	252,8	29,1	51,9	3,5	5,9	7,1	1,2	1,2	15,8	0,7	0,9	25
ADK-PS2-1305	1305	0,7	1	1,2	4,9	3,6	261	17,7	26,8	3,1	4,6	18,5	0,7	1	13,3	0,7	0,5	9,6
ADK-PS2-1310	1310	1	1	1,2	3,3	3,5	68,4	18,1	10	3	4	74,6	1,3	0,9	7	0,6	0,6	8,7
ADK-PS2-1315	1315	1	0,6	1,2	5,7	3,5	195,4	24,2	16,8	3	4,7	12,8	1,1	0,9	10,7	0,6	0,6	8,1
ADK-PS2-1320	1320	0,9	1,5	1,2	4,7	3,6	163,7	23,4	22,5	3	4,6	34,7	1,1	0,9	10,4	0,5	0,6	8,3
ADK-PS2-1325	1325	0,4	0,9	1,2	6,8	8,2	172,5	21,2	24,7	2,9	4,6	26,4	1,1	0,9	11,4	0,6	0,5	8,3
ADK-PS2-1330	1330	1	1	1,2	5,7	4,3	154,3	21,8	20,8	2,8	4,1	17,2	1	0,8	9,1	0,6	0,5	9,2
ADK-PS2-1335	1335	1,7	1,8	1,2	2,1	3,8	149,1	22,8	32,3	3,4	5,5	33	1,2	1,1	13,7	0,5	0,7	9,5
ADK-PS2-1340	1340	1,3	1	1,1	2	3,5	177,6	15,8	13,2	2	3,9	17,2	0,9	0,8	6,7	0,6	0,4	6,1
ADK-PS2-1345	1345	1	0,9	1,1	7,2	3,5	121,3	7,4	20,7	2,9	4	26,3	1	0,8	7,5	0,6	0,5	8,1
ADK-PS2-1350	1350	1	1,6	1,2	2	11,1	126,9	39,7	23,8	2,9	4,1	37,4	1,1	1	8,4	0,7	0,4	11,2
ADK-PS2-1355	1355	1,1	0,9	1,2	3,9	3,5	81,7	26,2	24	2,7	3,7	77,6	1,2	0,9	7,6	0,6	1,5	19,5
ADK-PS2-1360	1360	1	1	1,3	2,1	6	64,9	25,9	32,8	3,2	4,2	88,1	1,3	0,5	11,9	0,6	2	17,1
ADK-PS2-1365	1365	1,1	0,8	1,2	2,1	7,3	237,1	29	55,4	3,3	5,2	59,4	1,2	1	13,7	0,6	0,6	17
ADK-PS2-1370	1370	1	0,9	1,2	3,7	7,2	61,6	20	35,8	2,8	4,2	80,8	1,2	0,8	9,3	0,6	0,5	9,7
ADK-PS2-1375	1375	0,9	0,9	1,2	1,9	4,4	152,2	28,3	24,4	3,2	4,5	42,6	1,1	0,9	8	0,5	0,6	8,4
ADK-PS2-1380	1380	0,9	0,9	1,2	3,3	3,6	102,4	17,8	40,1	4	5,2	39,3	1,1	0,9	7,5	0,6	0,6	13,1
ADK-PS2-1385	1385	1	1	1,2	2	6,8	37	15,5	16,3	3,4	3,6	22,6	1	0,9	5,3	0,7	1,3	10
ADK-PS2-1390	1390	1	0,9	1,2	2	3,5	49,3	7,4	23,5	3,5	4,2	34,4	1,1	0,9	6,7	0,6	0,8	9,9
ADK-PS2-1395	1395	1	1	1,2	2	3,5	31,2	7,4	10	3	2,8	9,2	0,9	0,9	3,5	0,7	1	9
ADK-PS2-1400	1400	0,9	0,9	1,1	2	3,5	35,8	15,5	10	2,8	2,9	15,8	0,9	0,8	3,9	0,6	1,6	9,2
ADK-PS2-1405	1405	0,9	0,9	1,2	2	4,5	42,6	14,2	10	2,9	3,1	20,1	1	0,6	6,6	0,6	1,3	8,1
ADK-PS2-1410	1410	1	0,9	1	3,9	3,5	41,7	15,4	15,6	2,7	2,8	20	0,9	0,8	6,8	0,6	0,8	7,2
ADK-PS2-1415	1415	0,9	1,9	1,1	2	3,5	45,5	27,9	12,3	2,9	3,1	16	0,9	0,8	8,7	0,6	3	9,5
ADK-PS2-1420	1420	1	1	1,2	2	3,5	27,9	7,4	10	3	3,8	21,8	1	0,8	5,4	0,6	2,6	9,8
ADK-PS2-1425	1425	1,8	1	2	2	3,5	28,4	23,7	12,1	2,8	2,3	15	0,9	0,7	3	0,6	1,9	9,5
ADK-PS-2-1665	1665	1	0,9	1,1	2	3,4	50,7	13,3	17,2	4,3	4,9	14,2	0,9	0,8	2,5	0,7	1,2	9,4
ADK-PS-2-2100	2100	0,9	0,9	1,1	2	3,4	179,3	24,5	26,8	2,6	2,7	160,3	1,6	1,1	4,4	0,6	6	9,1
ADK-PS-2-2195	2195	1	0,9	1,1	1,3	3,4	218,8	19,4	33,8	2,5	3,4	118,5	1,5	0,9	6,1	0,6	5,7	7,9

Table F.2 XRF analyses results of samples from Edremit Field

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
EDR-900	900	1,82	1,359	9,82	75,5	0,0729	1,131	0,0002	2,846	3,881	0,3038	0,0094	0,00458	0,082	2,606	0,82	100,26
EDR-902	902	1,49	1,426	9,863	72,52	0,0737	1,013	0,0002	2,84	4,019	0,3021	0,01	0,00625	0,0756	2,617	3,22	99,48
EDR-904	904	1,8	1,329	9,604	75,32	0,0774	1,132	0,0002	2,843	3,74	0,3008	0,0135	0,00388	0,0803	2,69	1,55	100,48
EDR-906	906	1,68	1,565	10,05	74,53	0,074	1,052	0,0002	2,844	4,112	0,3086	0,0127	0,00316	0,0847	2,659	1,76	100,74
EDR-908	908	1,81	1,007	8,556	76,49	0,0617	0,6829	0,0002	2,712	5,459	0,2055	0,0097	0,00339	0,0636	1,983	0,35	99,39
EDR-910	910	1,76	1,316	8,674	74,81	0,0713	0,6922	0,0002	2,59	4,789	0,2264	0,0085	0,00441	0,0952	2,212	2,55	99,80
EDR-912	912	1,93	1,368	8,861	74,92	0,0663	0,6838	0,0002	2,697	4,442	0,2303	0,0062	0,0053	0,0936	2,277	2,71	100,29
EDR-914	914	1,72	1,308	9,703	73,03	0,0944	1,024	0,0002	2,591	5,575	0,3171	0,0148	0,00268	0,1072	3,012	1,64	100,14
EDR-916	916	1,6	1,277	9,806	73,06	0,0794	0,8162	0,0002	2,608	6,307	0,3215	0,0094	0,00519	0,1056	2,883	1,85	100,73
EDR-918	918	1,51	1,399	9,73	70,59	0,081	1,077	0,0002	2,731	7,064	0,3197	0,0114	0,00435	0,113	3,105	2,56	100,30
EDR-920	920	1,48	1,319	9,483	71,79	0,0898	0,8812	0,0002	2,751	7,221	0,3114	0,0084	0,00472	0,1033	2,832	1,86	100,14
EDR-922	922	1,42	1,37	9,09	73,03	0,0831	0,6532	0,0002	2,565	8,358	0,2852	0,0118	0,00438	0,1027	2,544	0,13	99,65
EDR-924	924	1,22	1,448	9,836	67,43	0,0935	0,893	0,0002	2,312	10,75	0,3599	0,0101	0,00795	0,1492	3,64	1,56	99,71
EDR-926	926	1,33	1,53	9,707	65,68	0,1028	0,8991	0,0002	2,349	11,04	0,3459	0,0138	0,0042	0,1557	3,652	3,82	100,63
EDR-928	928	1,01	1,322	9,453	67,2	0,0984	0,878	0,0002	2,15	12,17	0,3115	0,0101	0,0131	0,1407	3,612	1,35	99,72
EDR-930	930	2,26	0,96	8,301	76,77	0,062	0,5424	0,0002	1,829	3,811	0,177	0,0066	0,00412	0,0463	1,787	3,21	99,77
EDR-932	932	1,69	0,907	8,258	76,71	0,056	0,5647	0,0002	1,877	3,808	0,1625	0,0067	0,0383	0,0536	1,946	3,95	100,03
EDR-934	934	1,83	0,644	6,392	82,44	0,0363	0,3446	0,0002	1,849	3,497	0,0909	0,0047	0,0026	0,0381	1,123	1,55	99,84
EDR-936	936	1,47	0,803	7,463	76,59	0,0381	0,47	0,0002	1,95	6,147	0,1457	0,0078	0,0024	0,0506	1,518	3,44	100,10
EDR-938	938	0,85	0,613	7,015	79,94	0,0383	0,3496	0,0002	2,004	6,413	0,1077	0,0027	0,00195	0,0352	1,333	1,54	100,24
EDR-940	940	1,85	0,669	6,938	79,49	0,0404	0,357	0,0002	2,037	6,221	0,0923	0,0061	0,00417	0,0362	1,306	0,23	99,28
EDR-942	942	1,83	0,828	6,971	76,7	0,0348	0,4437	0,0002	2,016	6,104	0,1098	0,0046	0,00412	0,0492	1,581	3,42	100,10
EDR-944	944	1,68	0,735	6,979	82,34	0,0347	0,4839	0,0002	1,954	3,559	0,1074	0,0043	0,00148	0,0506	1,535	0,73	100,19
EDR-946	946	1,41	0,812	7,176	79,44	0,035	0,5191	0,0002	2,005	4,471	0,1152	0,0054	0,00141	0,0614	1,594	1,46	99,11
EDR-948	948	1,48	0,668	7,589	79,89	0,046	0,49	0,0002	2,952	3,252	0,1246	0,0037	0,00105	0,0436	1,42	2,57	100,53
EDR-950	950	1,62	0,635	7,37	81,03	0,0441	0,5709	0,0002	2,872	3,349	0,1065	0,0053	0,00221	0,0425	1,381	0,83	99,86
EDR-952	952	1,51	0,702	7,353	79,85	0,05	0,5547	0,0002	2,792	3,885	0,1257	0,0057	0,001	0,0552	1,507	1,56	99,95
EDR-954	954	1,37	0,721	7,397	80,77	0,0438	0,4907	0,0002	2,88	3,252	0,11	0,0038	0,00221	0,0459	1,326	1,75	100,16
EDR-956	956	1,53	1,113	8,255	78,94	0,0354	0,6716	0,0002	2,298	4,407	0,1512	0,0063	0,00482	0,0617	1,749	0,73	99,95
EDR-958	958	1,73	0,979	7,991	79,76	0,0537	0,6427	0,0002	2,313	4,07	0,1626	0,0038	0,00532	0,0479	1,51	0,88	100,15
EDR-960	960	1,82	0,979	7,768	79,1	0,0526	0,6339	0,0002	2,125	3,906	0,159	0,0054	0,00317	0,0473	1,521	1,45	99,57
EDR-962	962	1,48	1,098	8,097	78,03	0,0529	0,5926	0,0002	2,265	3,847	0,1816	0,0088	0,01035	0,0534	1,643	1,86	99,22
EDR-964	964	1,64	1,113	8,55	77,47	0,0593	1,066	0,0002	1,654	4,988	0,1807	0,0049	0,00236	0,0927	2,616	0,73	100,17
EDR-966	966	1,35	1,02	8,516	76,72	0,0791	1,277	0,0002	1,609	4,069	0,2172	0,0109	0,0259	0,0792	2,679	2,55	100,20
EDR-968	968	1,49	0,811	7,824	76,78	0,0674	1,127	0,0002	1,556	3,848	0,187	0,0082	0,00491	0,0783	2,266	3,02	99,07

Table F.2 XRF analyses results of samples from Edremit field (cont'd)

Element	depth	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃	LOI	Total
Sample No\Dimension	m	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
EDR-970	970	1,88	0,647	7,592	77,9	0,0365	0,8211	0,0002	1,677	2,735	0,1374	0,0075	0,00584	0,047	1,52	4,29	99,30
EDR-972	972	1,62	0,862	9,046	77,68	0,0616	0,6942	0,0002	2,428	3,585	0,1958	0,0082	0,00828	0,0557	2,12	1,85	100,21
EDR-974	974	1,59	0,837	8,781	77,4	0,053	0,6582	0,0002	2,515	3,37	0,167	0,0059	0,00343	0,052	1,765	2,57	99,77
EDR-976	976	1,63	1,982	16,79	65,24	0,0868	1,373	0,0002	3,644	3,234	0,4378	0,0149	0,00725	0,0778	3,753	1,96	100,23
EDR-978	978	1,6	1,861	16,58	64,91	0,0841	1,651	0,0002	3,664	3,199	0,4542	0,0153	0,00734	0,082	3,958	1,74	99,81
EDR-980	980	1,81	1,903	16,49	65,47	0,0842	1,467	0,0002	3,73	3,393	0,4395	0,0139	0,00387	0,0837	3,804	1,88	100,57
EDR-982	982	1,61	1,971	16,89	65,76	0,0839	1,544	0,0002	3,801	2,981	0,4569	0,0155	0,00799	0,0821	3,948	0,63	99,78
EDR-984	984	1,79	1,978	15,76	63,4	0,0863	1,615	0,00091	3,111	4,531	0,4615	0,0178	0,003	0,0909	4,255	2,77	99,87
EDR-986	986	2,11	1,872	14,97	66,38	0,1102	1,347	0,00293	2,522	5,18	0,4633	0,0152	0,0036	0,0955	4,093	0,83	99,99
EDR-988	988	2,37	1,845	14,88	63,87	0,1078	1,16	0,00412	2,585	6,943	0,4509	0,0146	0,0164	0,1006	4,088	1,57	100,01
EDR-990	990	2,74	1,865	14,72	66,54	0,116	1,366	0,0002	2,381	4,938	0,4183	0,0141	0,00119	0,0911	4,216	0,75	100,16
EDR-992	992	3,59	2,039	15,38	63,46	0,1561	0,9157	0,00942	2,072	6,358	0,4714	0,0148	0,00093	0,0944	4,686	0,66	99,91
EDR-994	994	3,11	2,054	15,19	63,47	0,1442	0,7229	0,01276	2,099	6,409	0,5182	0,013	0,00099	0,103	4,695	1,57	100,11
EDR-996	996	3,78	1,962	16,18	63,19	0,1366	0,6951	0,00951	2,167	6,036	0,4801	0,0185	0,00093	0,0921	4,633	0,73	100,11
EDR-998	998	3,34	2,04	15,1	64,78	0,1462	0,817	0,01464	2,143	5,522	0,4634	0,0185	0,00525	0,0907	4,85	0,86	100,19
EDR-1000	1000	3,19	1,916	14,43	65,03	0,1445	0,821	0,01199	2,097	5,609	0,4287	0,0159	0,00157	0,0839	4,474	1,84	100,09
EDR-1002	1002	2,47	2,064	13,26	63,9	0,1445	0,6144	0,01806	1,995	5,929	0,4359	0,0159	0,0247	0,0987	4,624	4,22	99,81
EDR-1004	1004	3,05	1,815	13,74	58,7	0,1409	0,4809	0,01476	2,068	5,618	0,4378	0,0163	0,00095	0,0842	4,256	9,73	100,15
EDR-1006	1006	3,2	1,989	14,92	65,75	0,1652	0,6714	0,02062	2,257	5,628	0,4688	0,0186	0,00714	0,0913	4,878	0,12	100,19
EDR-1008	1008	3,46	1,85	14,96	64,84	0,1506	0,5356	0,01605	1,927	6,224	0,4514	0,0141	0,001	0,0859	4,418	1,46	100,39
EDR-1010	1010	3,42	1,917	14,49	66,48	0,1432	0,5516	0,01088	2,045	5,876	0,4265	0,0159	0,00315	0,0933	4,33	0,53	100,33
EDR-1012	1012	3,67	1,861	15,62	63,87	0,1304	0,3895	0,01462	2,218	5,785	0,4377	0,0145	0,00161	0,0792	4,119	1,47	99,68
EDR-1014	1014	3,88	1,701	15,62	64,18	0,1386	0,4101	0,01137	2,191	6,022	0,4411	0,0151	0,00097	0,0792	4,195	1,35	100,24
EDR-1016	1016	3,46	1,824	15,53	64,8	0,1367	0,2941	0,01359	2,222	5,982	0,4354	0,0123	0,00097	0,0807	3,984	1,37	100,15
EDR-1018	1018	3,74	1,731	15,46	65,64	0,1317	0,3128	0,01058	2,191	5,983	0,4383	0,0172	0,00323	0,0788	4,137	0,18	100,05
EDR-1020	1020	3,73	1,7	15,16	64,72	0,1282	0,3475	0,01492	2,154	5,808	0,4307	0,0133	0,00336	0,0771	3,995	1,44	99,72
EDR-1022	1022	3,69	1,695	15,62	64,88	0,1518	0,4916	0,01091	2,162	6,158	0,4213	0,015	0,00229	0,0839	4,316	0,45	100,15
EDR-1024	1024	3,37	1,822	14,2	63,75	0,1572	0,589	0,00647	2,011	5,846	0,4208	0,0167	0,001	0,0893	4,67	3,72	100,67
EDR-1026	1026	3,55	1,853	14,8	63,21	0,1511	0,3545	0,00632	2,07	5,986	0,4378	0,0133	0,00135	0,1006	4,593	2,56	99,69
EDR-1028	1028	3,2	1,96	14,44	64,85	0,1702	0,3839	0,00889	2,046	5,977	0,4435	0,0173	0,00099	0,0963	4,633	1,85	100,08
EDR-1030	1030	3,87	1,742	14,95	65,41	0,1621	0,2721	0,00434	2,065	5,746	0,4283	0,0111	0,00096	0,0874	4,177	1,85	100,78
EDR-1032	1032	4,12	1,561	16,2	63,8	0,1366	0,2283	0,0002	2,245	5,758	0,3738	0,0162	0,00187	0,0756	3,887	1,83	100,23
EDR-1034	1034	3,75	1,493	15,47	65,71	0,1418	0,2827	0,0002	2,183	5,635	0,3779	0,0156	0,00094	0,0852	3,909	0,63	99,68
EDR-1036	1036	4,11	1,602	15,93	64,88	0,1568	0,2593	0,00075	2,298	5,68	0,4117	0,0119	0,001	0,0806	4,058	0,24	99,72
EDR-1038	1038	3,37	1,609	15,39	64,76	0,1642	0,3186	0,00173	2,16	5,827	0,3801	0,0136	0,0264	0,0776	4,035	1,55	99,68

Table F.2 XRF analyses results of samples from Edremit field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
EDR-900	900	60,2	14,8	28,5	180,5	13,2	1,3	67,8	0,6	0,5	91,9	181,9	16,5	127,9	12,2	14,1	0,8	0,8
EDR-902	902	40,5	14,6	27,7	269,7	12,2	1,2	5,7	0,5	0,5	89,3	183,5	16,9	103,5	6,1	2,9	0,8	0,8
EDR-904	904	55,9	16,6	25,2	211	14,2	1,6	6,5	0,7	0,7	92	183,8	16,4	109	8,2	3	0,7	0,7
EDR-906	906	49,1	16,8	113,2	133,9	12,9	1,4	7,4	0,5	0,9	86,8	199,1	15,9	117,6	7,7	3,2	0,8	0,7
EDR-908	908	60	16,9	15,7	53,1	10,1	1,2	13,1	0,6	0,9	80,2	172,3	11,9	86	9,8	5,7	0,6	0,8
EDR-910	910	72,3	12,1	19,4	47,4	11,3	1,6	5,8	0,7	0,8	76,8	225,8	13,4	89	2,9	3,9	0,8	0,7
EDR-912	912	58,6	18,1	28,1	38,3	12,6	1,5	14,4	0,6	1,2	76,9	226,8	13,7	90,7	5,8	5,1	0,8	0,8
EDR-914	914	59,6	15,8	23,9	40,9	14,2	1,5	8,5	0,6	0,7	78,9	255	16,9	98,8	3,1	3,9	0,8	0,8
EDR-916	916	46,6	16,5	22,7	39,9	13,8	1,3	5,9	0,5	0,6	79,3	259,7	15,9	98,7	6,7	3,1	0,7	0,7
EDR-918	918	58,2	16,8	31	177,8	14,1	1,6	8,4	0,6	0,5	84,3	292,3	17	91,9	9	3,3	0,7	0,8
EDR-920	920	47,5	13,2	41,2	102,9	13,9	1,1	8,3	0,5	0,9	85,2	302,4	16,3	101,4	11,7	3,3	0,8	0,9
EDR-922	922	55,3	14,2	21,2	58,3	10	1,5	5,9	0,6	0,6	78,9	319,4	17,4	106,1	4,9	3,1	0,8	0,8
EDR-924	924	50,7	18,8	29,6	147,4	13,3	1,2	6	0,5	0,3	75,4	372,8	17,3	112,3	7	3,5	0,8	0,8
EDR-926	926	44,8	22,4	28	243,5	14,2	1	9,6	0,4	0,5	76,5	369,7	17	109,6	10	8,1	0,8	0,7
EDR-928	928	55,2	32,7	31,5	157,6	13,6	1	4,9	0,5	1	69	401,2	17	111,6	3,3	13,1	0,8	0,9
EDR-930	930	43,9	13,4	17,5	93,6	10,3	1,5	2,2	0,6	0,7	51,8	217,4	8,4	72,9	6,4	2,8	0,8	0,8
EDR-932	932	64,8	11,8	18,9	91,3	9,7	1,5	2,4	0,6	0,7	50,3	211,4	8,8	72,3	4,4	4,5	0,8	0,8
EDR-934	934	104,9	11,9	7,3	52,1	10	2,2	2,7	1,7	1,6	43,3	153,6	9,2	72,2	6	2,2	0,7	0,8
EDR-936	936	44	13,5	9,3	42	10,4	1,3	2,1	0,5	0,8	45,4	185,8	10,3	95,9	7,5	3,4	0,8	0,9
EDR-938	938	68,4	6,7	6,5	67,5	10,2	1,8	1,5	0,6	1,1	44	175,5	9,2	74,3	3,8	2,6	0,7	0,8
EDR-940	940	73,1	7,3	8,5	32	9,6	1,7	1,9	0,7	1	44,7	167,2	9,2	72,3	8,5	6,7	0,7	0,8
EDR-942	942	46,8	13,1	12,9	36	10	1,3	2,8	0,5	0,2	45,9	182,1	9,6	82,8	6,5	2,9	0,8	0,7
EDR-944	944	97,5	7,4	9	34,9	11,8	2,2	3,4	0,9	1,7	46,9	177,3	10,7	86,7	2,8	2,7	0,8	0,7
EDR-946	946	65,6	7,9	23,4	30	10,3	1,8	27,4	0,7	1,1	52,1	181,6	9,7	69,4	4,7	2,3	0,7	0,7
EDR-948	948	81,9	11,8	4,9	116	9,9	1,6	1,9	0,8	1,4	78	168,4	9	85,8	6,4	5,8	0,7	0,7
EDR-950	950	122,8	11,4	22,2	200,2	11,8	2,5	3,3	1	1,8	75,4	168,3	8,6	93,8	2,7	3	0,7	0,7
EDR-952	952	83	9,6	19,2	113,2	11,9	2,1	3,4	1,8	1,5	73,7	171,1	9,3	88	6,5	2,9	0,7	0,8
EDR-954	954	99,8	7,3	26,5	72,2	11,7	2,2	3,2	2,1	1,7	74,6	162,9	9,9	91,1	5,4	5,8	0,7	0,8
EDR-956	956	72,6	10,5	12,1	85,6	10,8	1,8	6,1	0,7	1	56,2	240,2	9,4	87,2	2,7	2,8	0,7	0,7
EDR-958	958	64,3	11,8	13,2	69,1	11,6	1,9	5,9	0,5	1,4	56,7	252,7	10,9	87,2	5,2	4,1	0,7	0,7
EDR-960	960	55,3	7,1	13,5	38,6	11,4	1,5	5,5	0,6	0,7	51,4	217,7	9,3	89,6	8,3	3	0,8	0,8
EDR-962	962	54,7	8,3	11,7	38,7	11,1	1,5	5,4	0,6	0,8	57	225,6	10,3	111,1	4,7	2,9	0,7	0,7
EDR-964	964	79,4	7,3	31,9	49,6	12,9	1,6	4	0,6	0,8	43,7	232,2	11,6	100,8	9,4	3,9	1,8	0,8
EDR-966	966	56,4	6,4	20,6	45,1	11,8	1,2	2	0,5	0,6	43,2	194,7	13	96,8	5,7	2,6	0,8	0,7
EDR-968	968	64,8	6,6	12,4	39,8	12,2	1,7	1,9	0,7	0,8	44,3	193,9	12,3	105	4,9	2,7	0,8	0,7

Table F.2 XRF analyses results of samples from Edremit field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
EDR-900	900	2,2	0,8	1,1	2	2,8	411,3	19,7	33,3	2,6	8,1	682	2,5	1,7	8,1	1,7	6,5	7,6
EDR-902	902	2	0,8	1,1	2	5,3	433,8	20	26	2,5	5,1	365,8	1,8	1,4	8,6	0,5	5	7,1
EDR-904	904	0,8	0,8	1,1	1,9	3,4	424,6	14,7	25	2,5	5,4	763,9	2,6	1,7	8,4	2,3	6,9	7,1
EDR-906	906	2,6	0,8	1,2	2	3,6	431,3	23,1	39,4	4,1	5,3	542,7	2,2	0,9	12,9	1,5	5,5	7,3
EDR-908	908	1	0,8	0,9	2	3,5	468,4	16,5	22,9	2,1	8,7	693,5	2,4	1,7	8,9	0,6	5,4	10,2
EDR-910	910	0,9	0,8	1,1	2	3,6	497,5	18,2	40	2,2	7,8	785,7	2,6	1,3	8	0,9	6,7	6,3
EDR-912	912	1,5	0,8	0,4	2	3,5	488,9	20,5	31,6	2,5	3,4	635,2	2,3	1,1	8,8	1,3	8,2	8,5
EDR-914	914	1,6	0,8	1,2	2	3,5	489,1	18,8	40	2,5	5,2	586,8	2,3	1,2	9,9	1	7	6,6
EDR-916	916	0,9	0,8	1,1	2	3,5	495,3	7,2	45,7	2,4	7,2	448,3	2,1	1,7	8,5	0,8	8,1	6,3
EDR-918	918	0,9	0,8	1,1	2	3,5	483,1	11,8	36,9	2,8	3,5	443,4	2,1	1,7	9,2	1,6	7,1	6,8
EDR-920	920	1,7	0,8	1,1	2	3,5	491,6	22,4	27,8	3	3,7	448,5	2,1	1,7	7,8	0,8	7,4	10,4
EDR-922	922	2,1	0,8	1,1	2	4,2	452,4	16,3	27,6	2,5	8,2	590,5	2,4	1,5	7,8	0,6	7,1	9,1
EDR-924	924	2	0,9	1,1	2,1	4,2	436,4	21,1	43,1	2,8	6,9	337	1,9	1	8,6	0,9	7,5	6,7
EDR-926	926	1,9	0,8	1,2	2	6,2	458,1	22,8	28,1	2,8	5	240,3	1,7	1,4	10,2	1,1	6,5	6,4
EDR-928	928	2	0,9	1,2	2	6,7	411,4	20,4	41,9	3	4,9	329,7	1,9	1	8	0,6	8,7	8
EDR-930	930	1,5	0,8	1,1	2	3,5	624,7	7,2	21,6	2,2	6,3	685	2,3	1,1	8,3	1	5,1	8,3
EDR-932	932	1,1	0,8	1,2	2,1	3,6	628,1	13,7	36,8	2,2	3	644,1	2,3	1,6	10	0,8	4,2	6,3
EDR-934	934	0,7	0,8	1,1	2	4,2	538,9	17,6	24,4	1,9	3,2	1571	3,5	2	5,5	2	4,1	6,5
EDR-936	936	1	0,9	1,3	2,1	3,6	497,1	13,5	37,9	1,8	2,8	524,9	2	0,9	6,9	0,5	5	14,6
EDR-938	938	0,8	0,8	1,1	2	3,5	504,9	16,5	24	1,9	2,4	870,8	2,7	1,1	7,6	0,5	3,2	6,9
EDR-940	940	1,9	0,8	0,6	2	3,6	507	7,2	13,1	1,9	6,2	880,2	2,6	1,6	6,5	2,1	5,1	7
EDR-942	942	0,9	0,8	1,1	2	3,5	477	7,2	17,1	2	2,6	525,7	2,1	1,6	4,9	1,5	3,7	16,2
EDR-944	944	0,8	0,8	1,1	2	3,4	421,1	7	15,5	1,9	3,3	1623	3,6	1,7	6,2	2	4,3	9,8
EDR-946	946	1,4	0,8	1,1	1,9	3,4	419	17,5	39,1	2,4	4,2	927,9	2,8	2,3	5	2,2	5,5	5,5
EDR-948	948	0,8	0,8	1,1	2	3,4	533,2	13,9	15	1,7	9,7	1149	3	2,2	8,8	2,3	4,8	6,1
EDR-950	950	1,8	0,5	0,9	2	3,4	513,9	7,1	22,5	2,3	6,9	1873	3,8	2,3	7,3	1,8	4,8	6,6
EDR-952	952	0,8	0,8	1,1	2	3,4	503,8	16,7	29	2,2	3,4	1352	3,2	2,6	6,6	0,6	5,8	11,8
EDR-954	954	1,4	0,8	1,1	2	3,5	498,8	11	21,6	2,3	8,2	1525	3,4	1,9	6,6	2,1	3,8	6,5
EDR-956	956	1,5	0,8	1,1	2	3,5	527,3	13,7	19,2	2	7,5	944,6	2,8	1,4	7,5	2,4	4,7	6,4
EDR-958	958	0,8	0,8	1,1	2	3,5	516,2	20,7	34	2,1	3,1	1098	3	1,9	7,5	0,6	7,2	6,9
EDR-960	960	1	0,8	1,2	2	3,6	470,1	13,3	23,4	2,1	4,3	658	2,3	0,9	7,4	1,4	6,6	6,4
EDR-962	962	1,5	0,8	1,1	2	3,5	519	18,6	25,4	2	3,6	670,7	2,3	0,8	8,1	0,6	6,4	6,6
EDR-964	964	0,9	0,8	1,2	2	3,5	377,1	14,1	22,4	2,7	3,5	741,8	2,5	1,9	7	1,3	8,2	16,1
EDR-966	966	2,1	0,8	1,1	1,2	3,4	323,4	23,3	25	2,3	2,9	410,8	1,9	1,3	6,5	1,1	6,9	5,6
EDR-968	968	0,8	0,8	1,1	1,9	3,5	318	17,9	25,2	2	6	835,8	2,6	1,2	6,1	0,6	6,9	6,3

Table F.2 XRF analyses results of samples from Edremit field (cont'd)

Element	depth	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Rb	Sr	Y	Zr	Nb	Mo	Cd	In
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
EDR-970	970	35,6	6,9	10,6	34,2	10,9	1,3	1,5	0,5	1,4	46,7	157,9	8,4	74,7	5,4	2,6	0,7	0,7
EDR-972	972	57,3	24,4	18,3	72	12,2	1,7	3	0,7	0,9	65,7	190,6	13,5	100,6	5,7	8,6	0,7	0,7
EDR-974	974	75,1	12,8	18,1	66,6	12,6	1,9	1,9	0,7	1,1	68,7	180	11,8	99,5	2,8	2,7	1,2	0,7
EDR-976	976	45,1	16,2	39,6	44,8	23,9	1	20,3	0,5	0,2	102,3	170,7	23,5	194,6	20	5,5	2,4	0,9
EDR-978	978	52,4	19	28,9	61,3	22,2	1,4	21,7	0,5	0,4	103,5	170,9	25,9	175,8	12,2	7,5	0,8	0,8
EDR-980	980	48,7	17,2	34	59,1	22,1	2,5	25,6	0,6	1,2	105,2	162,9	25,7	198,5	16,2	4,4	0,8	0,8
EDR-982	982	38,2	18,6	35,4	48,3	21,6	1,3	21,1	0,6	0,8	106	168,2	23,4	195,3	13,1	5,4	0,8	0,8
EDR-984	984	17,8	19,4	65,7	38,4	22,1	1,8	51,2	0,4	0,6	93	228	21,3	192,2	15,9	4,5	0,8	0,8
EDR-986	986	50,5	14,7	57,6	46,6	17,9	1,4	20,6	0,6	0,3	77,1	284,1	17,4	165,8	3	8	0,8	0,8
EDR-988	988	54,5	13,7	53,9	70,2	20,3	1	23	0,4	0,6	77,4	297,4	16,7	154,3	12,9	8,8	0,8	0,8
EDR-990	990	61	13,2	52,3	41,4	18,2	1,9	19	0,6	0,8	68,1	313,3	18,4	145,8	8,6	3,1	0,8	0,8
EDR-992	992	50,9	8,7	52,3	56,5	17,9	1,4	39,1	0,6	0,3	56,4	443	15,4	105,8	2,9	6	0,8	0,7
EDR-994	994	47,9	6,7	35,7	126,8	19,1	1,2	14,9	0,5	0,4	60,4	455,8	15,6	128,3	5,1	4,2	0,8	0,8
EDR-996	996	79,3	12,7	41,3	112,6	21	1,5	9,3	0,6	0,7	63,5	453,6	14,3	138,1	3,1	3,6	0,8	0,8
EDR-998	998	50	11,5	53	41	19,1	1,3	8,4	0,5	0,2	65,4	418	20,7	135,5	3,2	3,4	0,8	0,8
EDR-1000	1000	41,3	5,2	54,9	41,7	18,6	0,9	11,9	0,4	0,7	64,8	406,4	17,7	121	3,2	3,2	0,9	0,8
EDR-1002	1002	35,2	9,5	49,1	36,2	17,1	0,7	9,8	0,3	0,2	64,4	406,5	18,8	119,2	10,1	7,7	0,9	0,8
EDR-1004	1004	57,4	5,7	36,1	41	18,1	1	4,5	0,4	0,2	62,2	408,8	18,9	156,1	6,7	3,3	0,8	1,1
EDR-1006	1006	63,2	5,8	54,2	47,2	19,5	1,9	5	0,5	1,1	66,3	406,8	18,7	140,6	12,7	3,2	0,8	0,8
EDR-1008	1008	37,5	7,7	77,6	38,5	18,6	1	10,8	0,4	0,2	64,1	483,4	16,4	142,6	4,2	4,9	0,9	0,8
EDR-1010	1010	35,1	7,1	49,5	47,5	16,6	1,1	5,2	0,5	0,5	64,3	418,7	18,9	140	7	3,7	1,8	1,8
EDR-1012	1012	39,4	9,1	30,9	48,3	18,1	1,2	3,5	0,5	0,9	68,1	476,4	14,7	131	9,4	2,3	0,8	0,9
EDR-1014	1014	61,2	8,9	36,6	45,7	18,8	1,5	9,4	0,9	0,5	69,1	489	13,9	125	6,3	5,5	0,7	0,8
EDR-1016	1016	54,7	7,7	27,5	47,8	18,4	1,4	3,1	0,9	0,9	66,9	481,2	14,6	133,8	3,5	3,7	0,8	0,8
EDR-1018	1018	55,3	9,2	24,8	77,2	18,5	1,5	1,7	0,6	0,6	69,4	474,3	15,5	123,9	2,6	3,4	0,8	0,8
EDR-1020	1020	56	6,5	25,7	47,3	15,9	1,2	5,9	0,5	0,3	65,8	476,4	14,6	103,1	10	9,1	0,8	0,8
EDR-1022	1022	55,7	9,2	37,5	59,8	19,1	1,7	13,8	0,6	1,1	63,6	475,7	15,4	120,6	8,4	5,7	1,4	2,1
EDR-1024	1024	58,2	4,2	27,8	43,6	15,6	1,4	3,2	0,6	0,5	60,5	443,4	17,4	125,8	3,1	3,3	0,8	0,8
EDR-1026	1026	55	5	32,6	45,8	16,5	2,6	5,3	0,5	0,2	65,3	450,7	19,7	127,7	7,4	2,9	0,8	0,8
EDR-1028	1028	51,5	6	33,3	46,4	16	1,2	4	0,5	0,4	63,7	442	20,5	164,7	5,8	3,5	0,9	0,9
EDR-1030	1030	47	6,1	20,1	51,6	17,4	1	2,3	0,4	0,2	61,9	467,1	17,7	133,5	3,3	3,3	0,8	0,8
EDR-1032	1032	51,1	8	15,1	68,7	18,3	1,6	4,1	0,5	1,1	65,3	502,8	13,9	116,6	2,9	3,3	0,8	0,8
EDR-1034	1034	48,1	6,8	21,6	48,8	17,5	1,4	4,3	0,6	1	64,2	483,7	15	125,6	4,4	5	0,8	0,8
EDR-1036	1036	62,1	3,9	18,1	44,8	17,4	1,4	2,9	0,6	0,2	67,1	496,2	14,5	131,2	7,8	5,3	1,5	1,5
EDR-1038	1038	63,3	6,8	20,5	44,2	18,9	1,3	4,4	0,5	0,7	63,8	500,1	14,4	112,8	6	3,1	0,8	0,7

Table F.2 XRF analyses results of samples from Edremit field (cont'd)

Element	depth	Sn	Sb	Te	I	Cs	Ba	La	Ce	Hf	Ta	W	Hg	Tl	Pb	Bi	Th	U
Sample No\Dimension	m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
EDR-970	970	1	0,8	1,1	1,9	3,4	263,4	11,1	26,8	1,9	2,6	515	2	0,5	8,2	0,5	5,6	5,7
EDR-972	972	0,8	0,8	1,1	2	3,4	404,7	25,4	40,6	2,1	6,2	826	2,6	2,1	8	3,5	7,2	8,7
EDR-974	974	1,8	0,8	1,1	2	3,4	382,9	15,6	22,3	2,1	4,4	1044	2,9	1,6	9,5	2,6	5	21,9
EDR-976	976	1	0,9	1,3	2,2	3,8	787,5	32,2	76,8	2,7	3,6	291,1	1,7	1,5	13,4	0,6	15,5	22,9
EDR-978	978	1,3	0,8	1,2	2,1	3,7	836,9	34,2	78	2,8	4,4	394,6	2	1,9	14,9	0,6	16,4	15,6
EDR-980	980	0,9	0,8	1,2	2,1	3,7	824,1	25,8	66,6	2,7	8,2	475,8	2,2	0,8	14,2	0,6	17,8	12,3
EDR-982	982	0,9	0,8	1,1	2,1	3,7	876,7	32,8	65,2	2,8	7,7	290,3	1,7	1,3	13,8	0,5	15,8	6,6
EDR-984	984	1,9	0,9	1,2	2,2	3,7	768,9	31,5	77,9	3,4	4,4	259	1,7	1,6	12,5	0,7	14,9	23,4
EDR-986	986	0,4	0,8	1,1	2,1	3,6	753,9	24,4	51,6	3,4	7,4	490	2,2	1,2	11,4	1,1	10,3	6,4
EDR-988	988	0,9	0,9	1,3	2,2	3,8	761,9	23,9	60,9	2,8	4	203,6	1,5	0,7	12,1	0,6	11,8	7,8
EDR-990	990	1,3	0,9	1,2	2	3,6	624,5	27,4	60,6	3,3	4,1	440,5	2,1	1,8	10,8	1,6	11	6,6
EDR-992	992	0,8	0,8	1,1	2	3,6	641,8	23	41,7	3,2	4,1	417,9	2,1	1,5	13,4	0,6	7,6	7,6
EDR-994	994	1,1	0,9	1,2	2,1	3,7	685,4	19,7	23,5	2,8	3,6	272,9	1,8	0,7	17,1	1,4	5,6	8,4
EDR-996	996	1,2	0,8	1,2	2,1	3,6	700,8	15,9	50,3	3,2	3,9	559,7	2,4	1,3	13	0,6	7,5	7
EDR-998	998	2,4	0,8	1,2	2,1	3,7	712	25,7	55,8	3,3	5,6	387,9	2	0,8	11,1	0,6	10,6	7,1
EDR-1000	1000	1,9	0,9	1,2	2,1	3,7	689,5	27,5	55,9	3,3	4,8	170,3	1,4	1,1	11,2	0,6	8,7	7,9
EDR-1002	1002	0,9	0,9	1,3	2,1	3,8	719,3	11	47,6	4,7	3,7	74,9	1,1	0,9	11,3	0,8	12,4	8,2
EDR-1004	1004	1,2	0,9	1,2	2,2	3,7	729,2	25,3	30	3,5	3,6	225,5	1,5	0,5	11,5	0,6	7,8	12,8
EDR-1006	1006	0,9	0,8	1,1	2,1	3,5	706,2	21,6	42,3	3,5	4,1	349	2	1,6	11,5	0,9	7,9	10,5
EDR-1008	1008	0,9	0,9	1,2	2,1	3,7	698,4	23,8	51,9	3,8	4,7	240,9	1,6	1,6	12,1	0,6	5,5	7,2
EDR-1010	1010	4,5	0,7	1,3	2,1	3,7	625,4	24,2	62,1	3,2	3,6	288	1,8	1,7	10,1	0,5	6,8	22,4
EDR-1012	1012	1,4	0,9	1,2	2,1	3,7	793,6	21,5	27,6	2,9	4,2	333,1	1,9	1	14	1,9	7,4	20,7
EDR-1014	1014	0,8	0,8	1,1	2	3,6	802	12,8	19,3	2,9	3,8	498,8	2,3	1,7	13,8	0,6	6,8	7,1
EDR-1016	1016	1	0,9	1,2	2,1	3,7	759,2	21,9	45,5	2,6	3,2	437,1	2,1	1,3	13,1	0,6	6,8	24,6
EDR-1018	1018	0,9	0,9	1,2	2,1	3,7	761,7	21,2	29,1	2,7	5,3	495	2,3	2,5	13,1	11,9	7,4	12,7
EDR-1020	1020	0,9	0,9	1,2	2,1	3,6	776,5	24,2	49,3	2,6	5,5	324,2	1,8	1,5	12,9	3,7	6,2	7,8
EDR-1022	1022	0,9	0,8	1,2	2,2	3,6	756,4	19,4	21,2	3	3,7	482	2,3	1,1	13,9	2,3	6,3	18,6
EDR-1024	1024	0,9	0,9	1,1	2,1	3,6	716,1	14,4	32,3	2,9	4,5	420,9	2,1	1,7	10,6	0,6	11,1	17
EDR-1026	1026	0,4	0,8	1,1	2,1	3,6	703,3	23,1	56,6	2,8	8	377,8	2	1,7	12,8	0,8	9,2	8
EDR-1028	1028	1,8	0,9	1,3	2,2	3,7	693,8	24,7	43,5	4,1	3,5	326,3	1,8	1,8	12,4	0,6	11,3	14,2
EDR-1030	1030	1,8	0,9	1,2	2,1	3,7	750,3	19,6	37,9	2,9	2,7	265,5	1,6	0,9	13,2	0,6	8,1	15,4
EDR-1032	1032	0,9	0,9	1,2	2,1	3,7	818,8	21,2	38,6	2,2	5	610,7	2,4	1	13,8	3	7	9,5
EDR-1034	1034	0,8	0,9	1,2	2,1	3,6	817,9	23	49,8	2,5	4,3	477,8	2,2	1,2	13,2	0,6	9,5	7
EDR-1036	1036	1,5	0,9	1,2	2,1	3,6	835,6	18	26,9	2,5	2,5	472,8	2,2	2,3	14,7	0,8	8,6	11,6
EDR-1038	1038	0,9	0,8	1,2	2,1	3,6	807,4	15,9	37,6	2,4	3,1	439,1	2,1	0,9	14,2	0,6	8,3	9,3

G. Reservoir Rock Mineralogy of the Representative Samples from Akköy and Edremit Fields Used in Modelling

Table G.1 Reservoir rock mineralogy of representative Akköy samples

Mineral	PS-1-1315		PS-1-1375		PS-1-1415		PS-1-1480		PS-1-1495		PS-1-1515*		PS-2-840*		PS-2-1280		PS-2-1355		PS-2-1380*	
	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)
Albite	2,5	7,17	-	-	-	-	7,9	22,65	-	-	13	37,27	6,7	19,21	-	-	10,8	30,97	-	-
Ankerite	-	-	-	-	-	-	12,4	45,31	-	-	-	-	-	-	16,5	60,29	-	-	-	-
Biotite	-	-	7,1	10,46	-	-	-	-	8	11,79	-	-	7,9	11,64	-	-	-	-	-	-
Calcite	-	-	13,6	102,47	26,6	200,41	17,3	130,34	25,3	190,62	16,3	122,81	22,8	171,78	27,2	204,93	55,6	418,91	46,8	352,61
Chlorite	-	-	-	-	-	-	-	-	13,4	29,57	12,9	28	-	-	-	-	-	-	16,3	35,97
Dolomite	40,7	166,45	8,9	36,40	22,4	91,61	-	-	7,2	29,44	8,3	34	-	-	-	-	7,9	32,31	7,6	31,08
Illite	13,4	26,32	13,6	26,72	7,1	13,95	-	-	7,8	15,32	-	-	12,4	24,36	8,1	15,91	-	-	-	-
Kaolinite	-	-	-	-	1	2,92	16	46,74	8,6	25,12	17,5	51	-	-	-	-	-	-	2	5,84
Muscovite	1,8	3,40	2,6	4,92	0,9	1,70	4,6	8,70	-	-	0,4	0,76	1,9	3,59	5,4	10,21	1,3	2,46	7,3	13,81
Orthoclase	-	-	17,1	46,33	-	-	-	-	-	-	-	-	13,7	37,12	-	-	-	-	-	-
Quartz	39	489,52	34,7	435,55	39,1	490,78	39,2	492,03	27,6	346,43	31,5	395,38	32,5	407,94	39,8	499,56	24,4	306,27	19,9	249,78
Smectite	2,5	4,81	2,4	4,62	2,9	5,58	2,7	5,19	2,1	4,04	-	-	2,2	4,23	3	5,77	-	-	-	-

*Simulated Samples

Table G.2 Reservoir rock mineralogy of representative Edremit samples

Mineral	EDR-912*		EDR-928		EDR-964		EDR-976		EDR-988*		EDR-994		EDR-1008*		EDR-1032	
	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)	Vol. (%)	Amount (mol)
Albite	-	-	21,7	43,11	-	-	-	-	25,6	50,86	-	-	-	-	-	-
Amphibole	-	-	-	-	-	-	-	-	-	-	5,8	3,63	-	-	-	-
Biotite	14,3	17,91	-	-	12	15,03	-	-	6,3	7,89	20,5	25,67	10,2	12,77	14,3	17,91
Bytownite	-	-	-	-	-	-	-	-	-	-	18	34,20	-	-	-	-
Calcite	1,2	6,26	4	20,88	-	-	-	-	5	26,1	-	-	-	-	1,2	6,26
Chlorite	-	-	-	-	-	-	-	-	12	18,35	-	-	-	-	-	-
Dolomite	3,2	9,07	1,1	3,12	-	-	-	-	2	5,67	4,9	13,88	-	-	3,2	9,07
Illite	-	-	10,7	14,56	8	10,89	12,2	16,60	-	-	3,1	4,22	11,4	15,52	-	-
Kaolinite	3	6,07	-	-	-	-	9,4	19,03	10,2	20,64	4,5	9,11	0,6	1,21	3	6,07
Labradorite	-	-	-	-	-	-	29,8	57,28	-	-	-	-	32,8	63,05	-	-
Orthoclase	50	93,86	14	26,28	20,5	38,48	-	-	-	-	22,4	42,05	23,2	43,55	50	93,86
Quartz	28,3	246,12	48,5	421,79	59,5	517,46	48,6	422,66	38,9	338,3	20,9	181,76	21,8	189,59	28,3	246,12

*Simulated Samples

H. Modelling Results of Samples PS-1-1315, PS-1-1375, PS-1-1415, PS-1-1480, PS-1-1495, PS-2-1280, PS-2-1355 from Akköy Field and EDR-928, EDR-964, EDR-976, EDR-994, EDR-1032 from Edremit Field

Table H.1 Equilibrium modelling results for sample ADK-PS-1-1315 from Akköy field (values are as moles)

Mineral	PS-1-1315		
	Initial	Final	Delta
Albite	7,17	0	-7,17
Ankerite	0	0	0
Biotite	0	0	0
Calcite	0	0	0
Chlorite	0	0	0
Dolomite	166,45	166,5	0,05
Illite	26,32	26,27	-0,05
Kaolinite	0	0	0
Muscovite	3,40	3,435	0,03
Orthoclase	0	0	0
Quartz	489,52	511,1	21,58
Smectite	4,81	4,808	0
Dawsonite	0	7,187	7,19
Magnesite	0	0	0
Siderite	0	0	0

Table H.2 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-1-1315 (Akköy field)

mol/L	initial	final
Al	7,48E-07	9,84E-06
Total C	0,02945	0,953
Ca	0,006629	0,0006575
Cl	0,002052	0,002356
Fe	6,27E-06	0,001186
K	0,003457	3,06E-09
Mg	0,002483	0,01319
Na	0,03068	0,01585
SO ₄	0,009349	0,01073
Si	0,0005351	0,001169

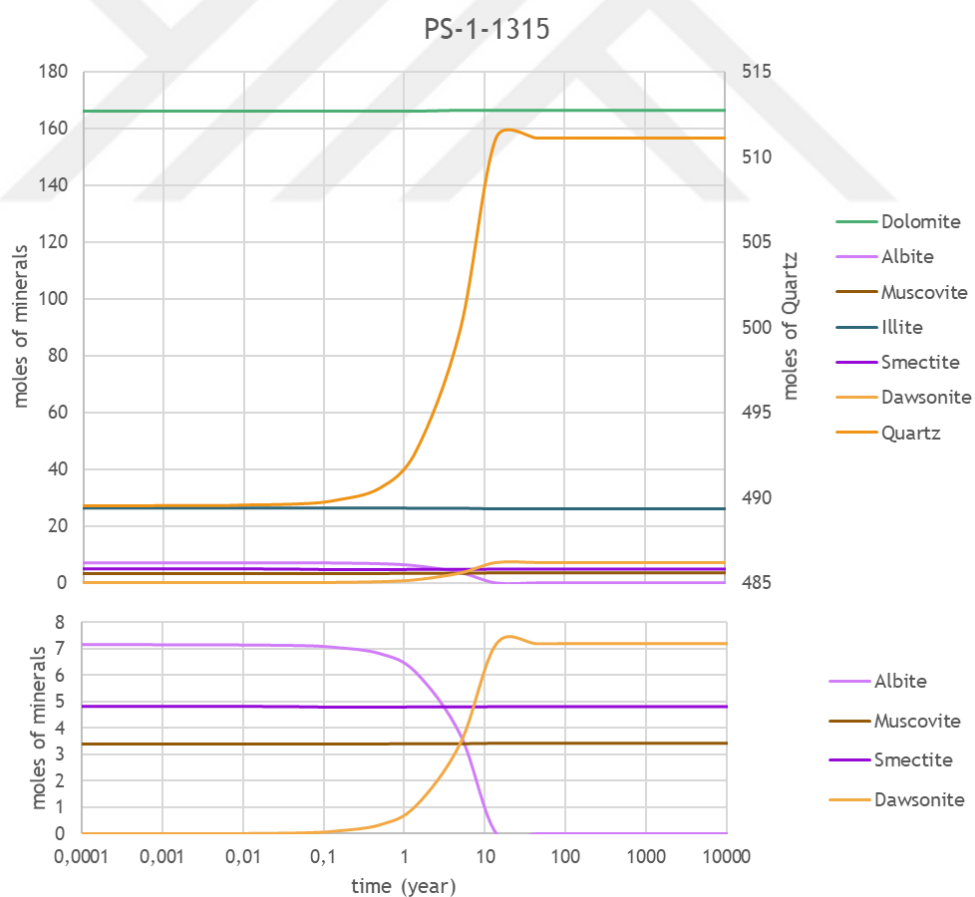


Figure H.1. Kinetic modelling results for sample ADK-PS-1-1315 from Akköy field

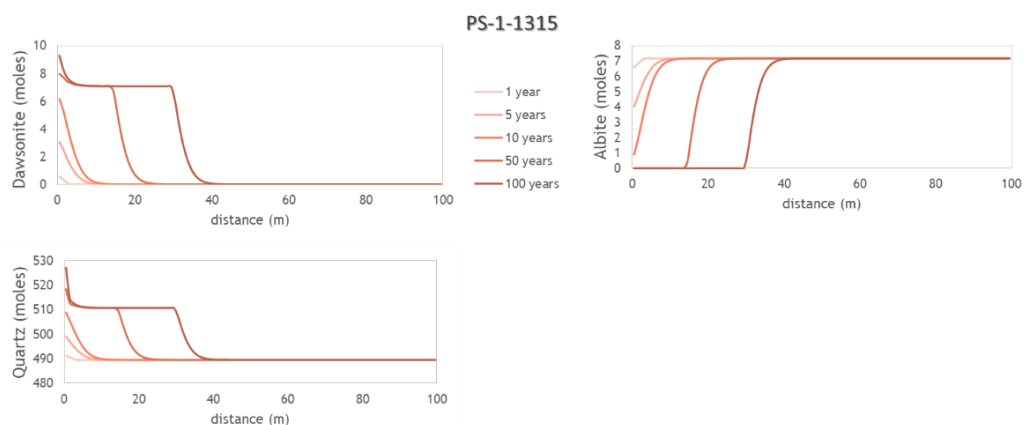


Figure H.2. Reactive transport modelling results for sample ADK-PS-1-1315 from Akköy field

Table H.3 Equilibrium modelling results for sample ADK-PS-1-1375 from Akköy field (values are as moles)

Mineral	PS-1-1375		
	Initial	Final	Delta
Albite	0	0	0
Ankerite	0	47,8	47,80
Biotite	10,46	0	-10,46
Calcite	102,47	58,27	-44,20
Chlorite	0	0	0
Dolomite	36,40	32,9	-3,50
Illite	26,72	0	-26,72
Kaolinite	0	0	0
Muscovite	4,92	30,07	25,15
Orthoclase	46,33	48,58	2,25
Quartz	435,55	495,6	60,05
Smectite	4,62	0	-4,62
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

Table H.4 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-1-1375 (Akköy field)

mol/L	initial	final
Al	7,48E-07	2,79E-07
Total C	0,02945	1,262
Ca	0,006629	1,27E-04
Cl	0,002052	0,001586
Fe	6,27E-06	1,26E-03
K	0,003457	0,01564
Mg	0,002483	4,37E-06
Na	0,03068	0,5594
SO ₄	0,009349	0,007227
Si	0,0005351	0,001186

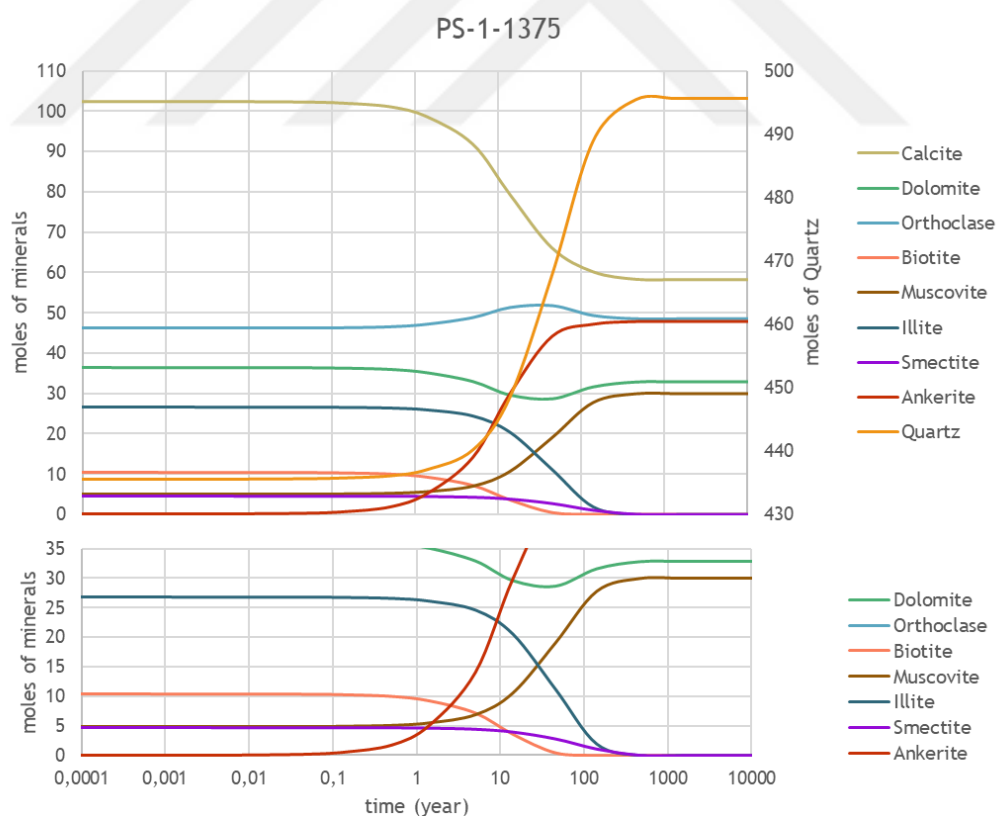


Figure H.3. Kinetic modelling results for sample ADK-PS-1-1375 from Akköy field

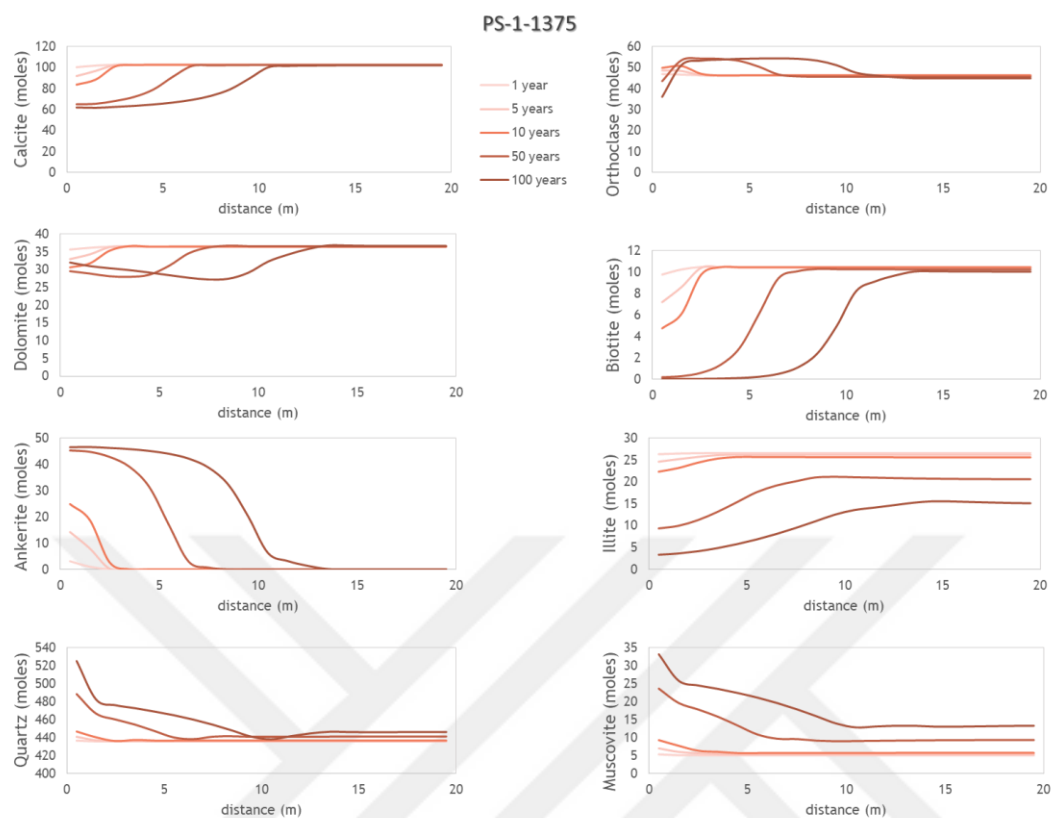


Figure H.4. Reactive transport modelling results for sample ADK-PS-1-1375 from Akköy field

Table H.5 Equilibrium modelling results for sample ADK-PS-1-1415 from Akköy field (values are as moles)

Mineral	PS-1-1415		
	Initial	Final	Delta
Albite	0	0	0
Ankerite	0	3,584	3,58
Biotite	0	0	0
Calcite	200,41	189,5	-10,91
Chlorite	0	0	0
Dolomite	91,61	99,05	7,44
Illite	13,95	0	-13,95
Kaolinite	2,92	7,905	4,98
Muscovite	1,70	11,19	9,49
Orthoclase	0	0	0
Quartz	490,78	522,1	31,32
Smectite	5,58	0	-5,58
Dawsonite	0	0,6252	0,63
Magnesite	0	0	0
Siderite	0	0	0

Table H.6 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-1-1415 (Akköy field)

mol/L	initial	final
Al	7,48E-07	3,21E-07
Total C	0,02945	1,281
Ca	0,006629	4,30E-04
Cl	0,002052	0,002076
Fe	6,27E-06	2,23E-03
K	0,003457	9,61E-04
Mg	0,002483	1,91E-05
Na	0,03068	0,2454
SO ₄	0,009349	0,00946
Si	0,0005351	0,001173

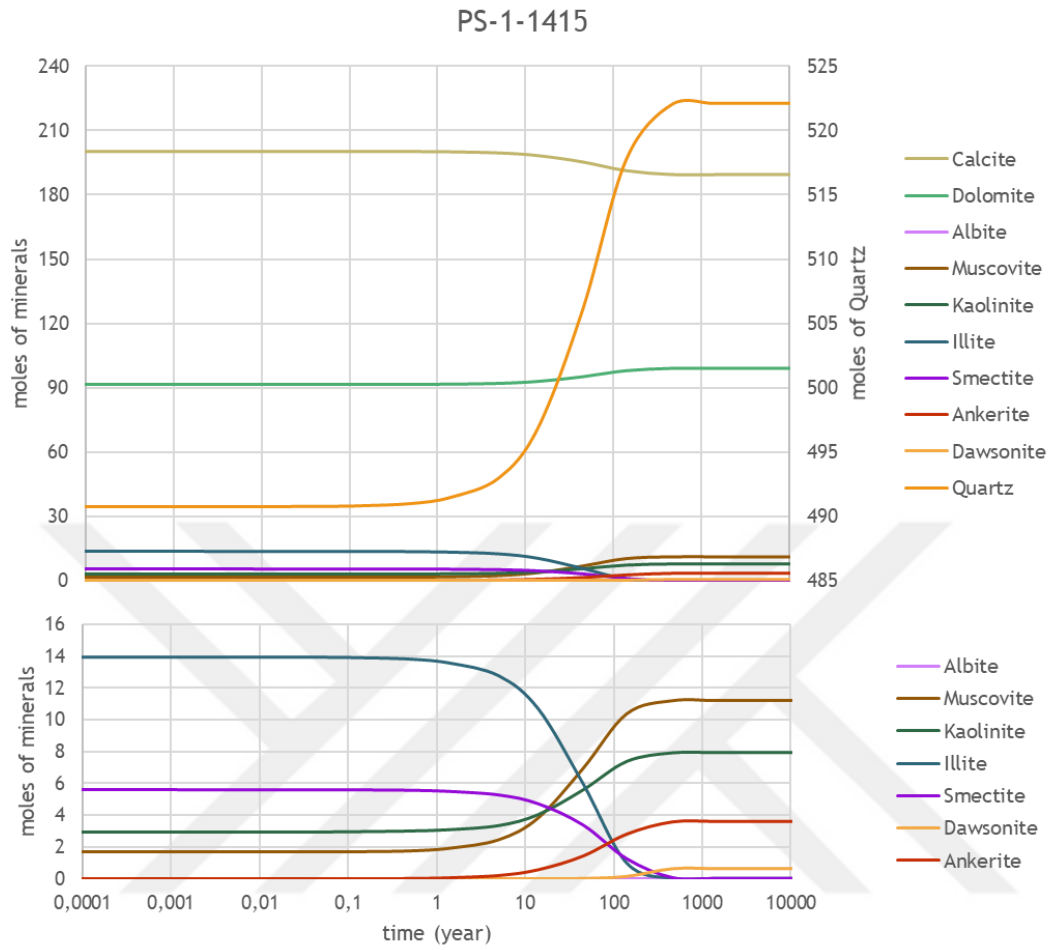


Figure H.5. Kinetic modelling results for sample ADK-PS-1-1415 from Akköy field

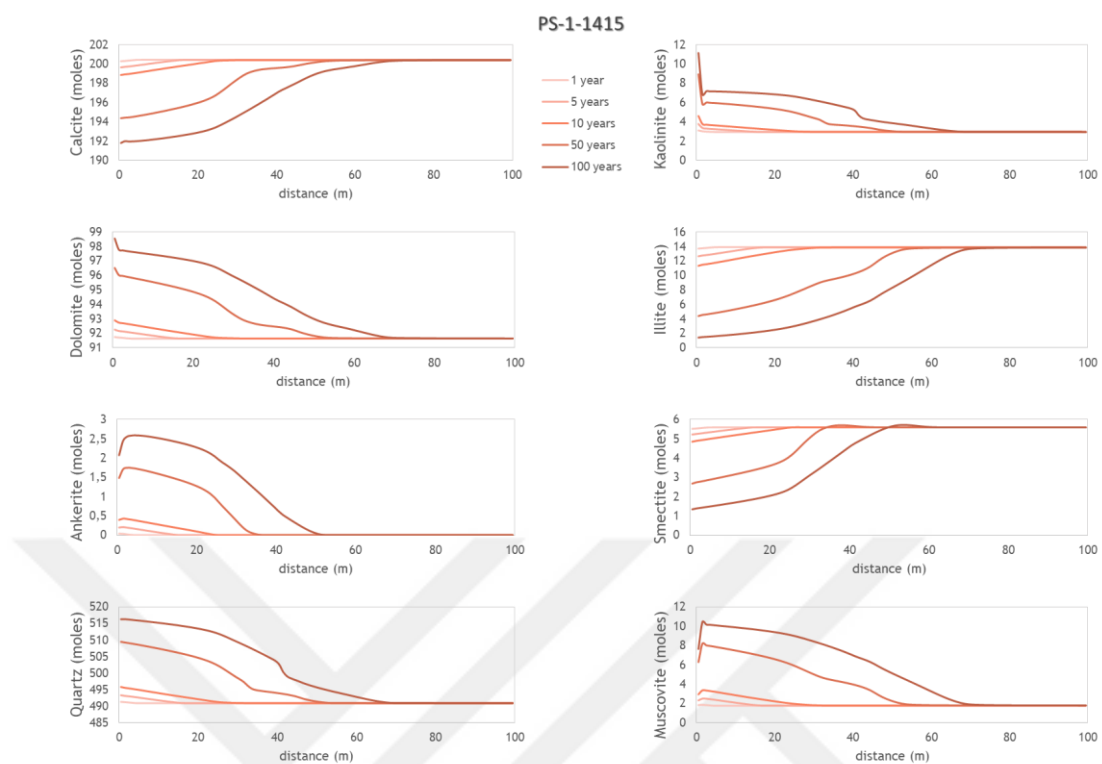


Figure H.6. Reactive transport modelling results for sample ADK-PS-1-1415 from Akköy field

Table H.7 Equilibrium modelling results for sample ADK-PS-1-1480 from Akköy field (values are as moles)

Mineral	PS-1-1480		
	Initial	Final	Delta
Albite	22,65	0	-22,65
Ankerite	45,31	48,64	3,33
Biotite	0	0	0
Calcite	130,34	123,4	-6,94
Chlorite	0	0	0
Dolomite	0	3,673	3,67
Illite	0	0	0
Kaolinite	46,74	48,09	1,35
Muscovite	8,70	9,741	1,04
Orthoclase	0	0	0
Quartz	492,03	573,6	81,57
Smectite	5,19	0	-5,19
Dawsonite	0	23,3	23,30
Magnesite	0	0	0
Siderite	0	0	0

Table H.8 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-1-1480 (Akköy field)

mol/L	initial	final
Al	7,48E-07	3,92E-07
Total C	0,02945	1,00E+00
Ca	0,006629	0,0003601
Cl	0,002052	0,003391
Fe	6,27E-06	0,002669
K	0,003457	7,85E-04
Mg	0,002483	1,85E-05
Na	0,03068	0,2551
SO ₄	0,009349	0,01545
Si	0,0005351	0,001173

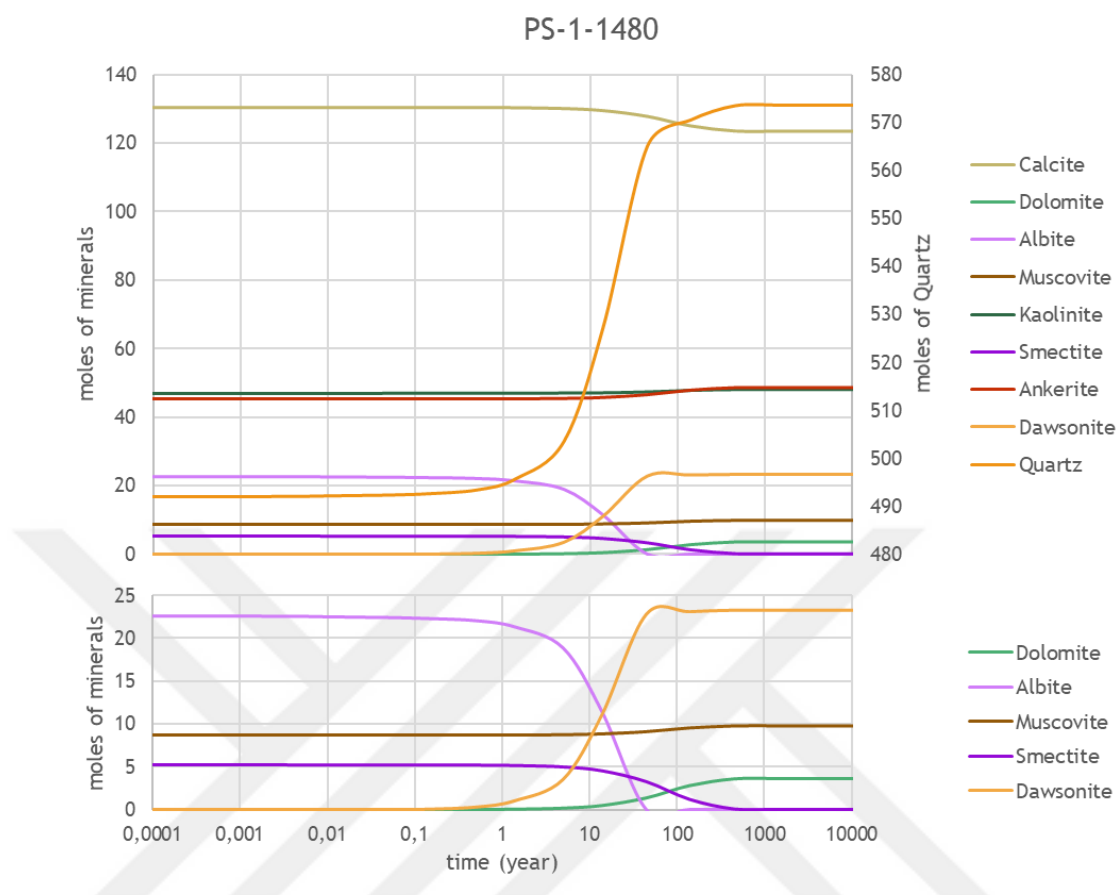


Figure H.7. Kinetic modelling results for sample ADK-PS-1-1480 from Akköy field

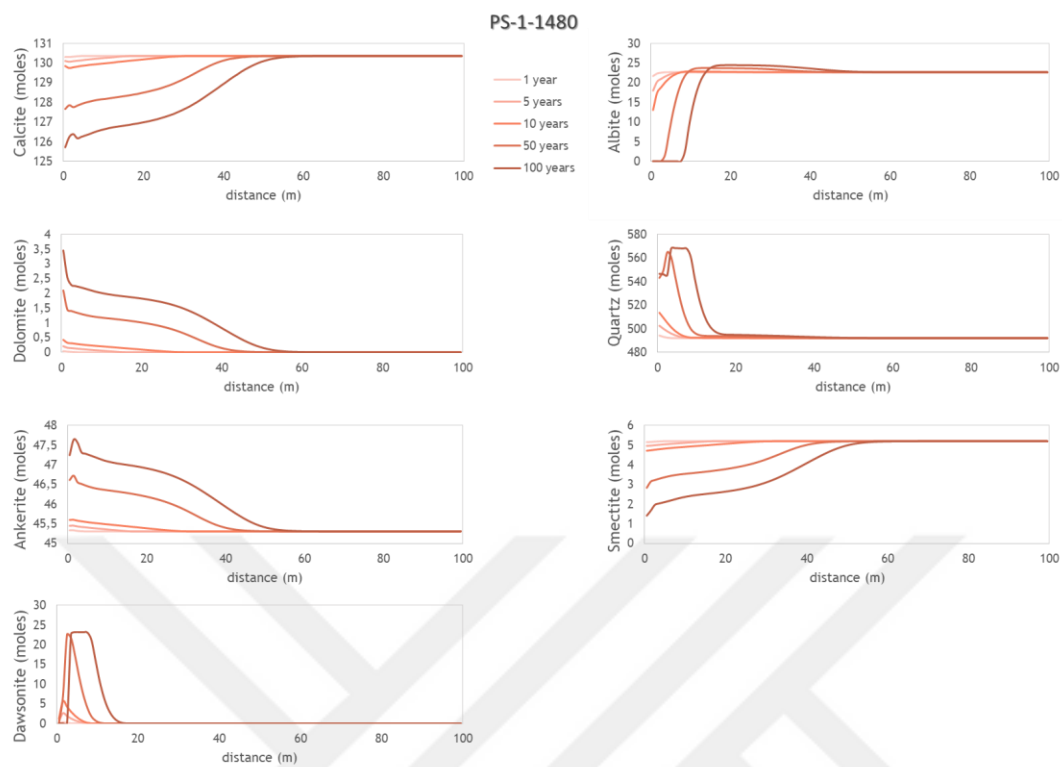


Figure H.8. Reactive transport modelling results for sample ADK-PS-1-1480 from Akköy field

Table H.9 Equilibrium modelling results for sample ADK-PS-1-1495 from Akköy field (values are as moles)

Mineral	PS-1-1495		
	Initial	Final	Delta
Albite	0	0,002503	0
Ankerite	0	23,14	23,14
Biotite	11,79	20,98	9,19
Calcite	190,62	170,6	-20,02
Chlorite	29,57	7,678	-21,89
Dolomite	29,44	26,32	-3,12
Illite	15,32	0	-15,32
Kaolinite	25,12	60,02	34,90
Muscovite	0	0	0
Orthoclase	0	0	0
Quartz	346,43	324,5	-21,93
Smectite	4,04	4,056	0,02
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

Table H.10 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-1-1495 (Akköy field)

mol/L	initial	final
Al	7,48E-07	4,79E-06
Total C	0,02945	0,006539
Ca	0,006629	0,0002712
Cl	0,002052	0,003198
Fe	6,27E-06	5,58E-07
K	0,003457	6,83E-06
Mg	0,002483	3,99E-05
Na	0,03068	0,04027
SO ₄	0,009349	0,01457
Si	0,0005351	0,001202

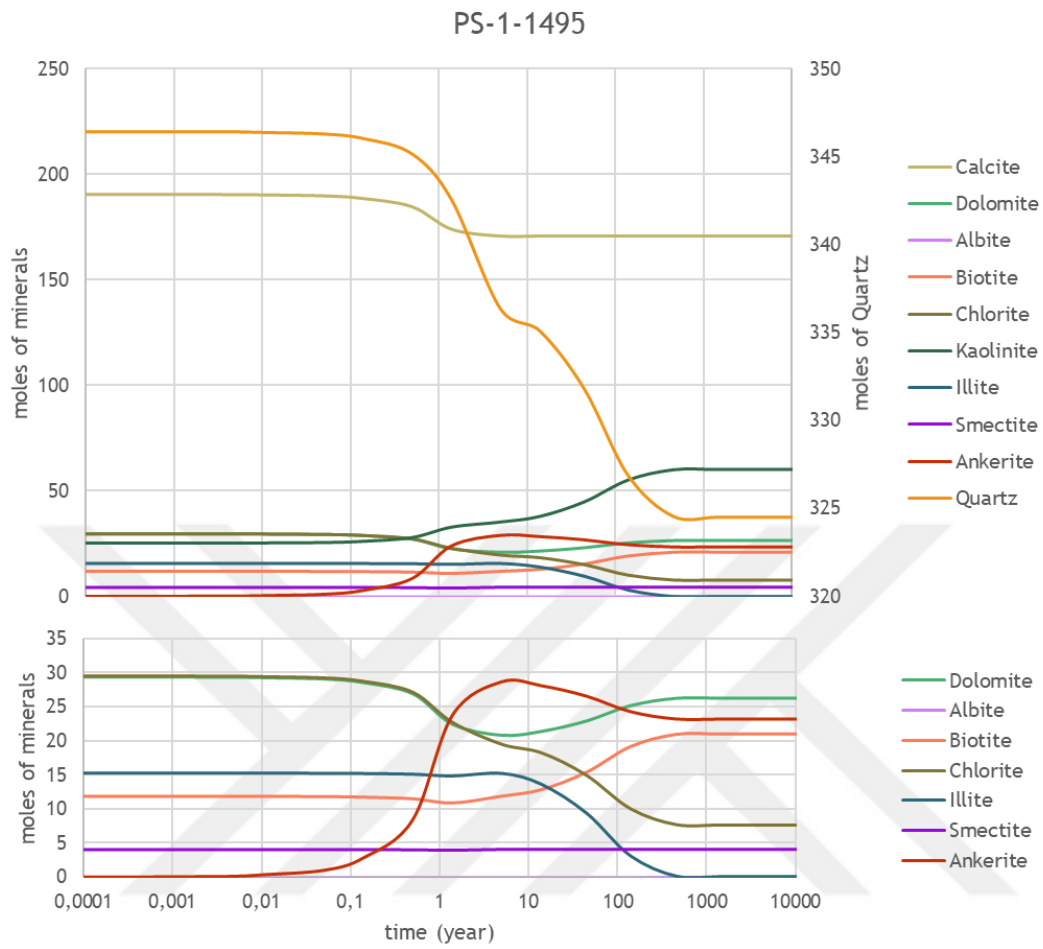


Figure H.9. Kinetic modelling results for sample ADK-PS-1-1495 from Akköy field

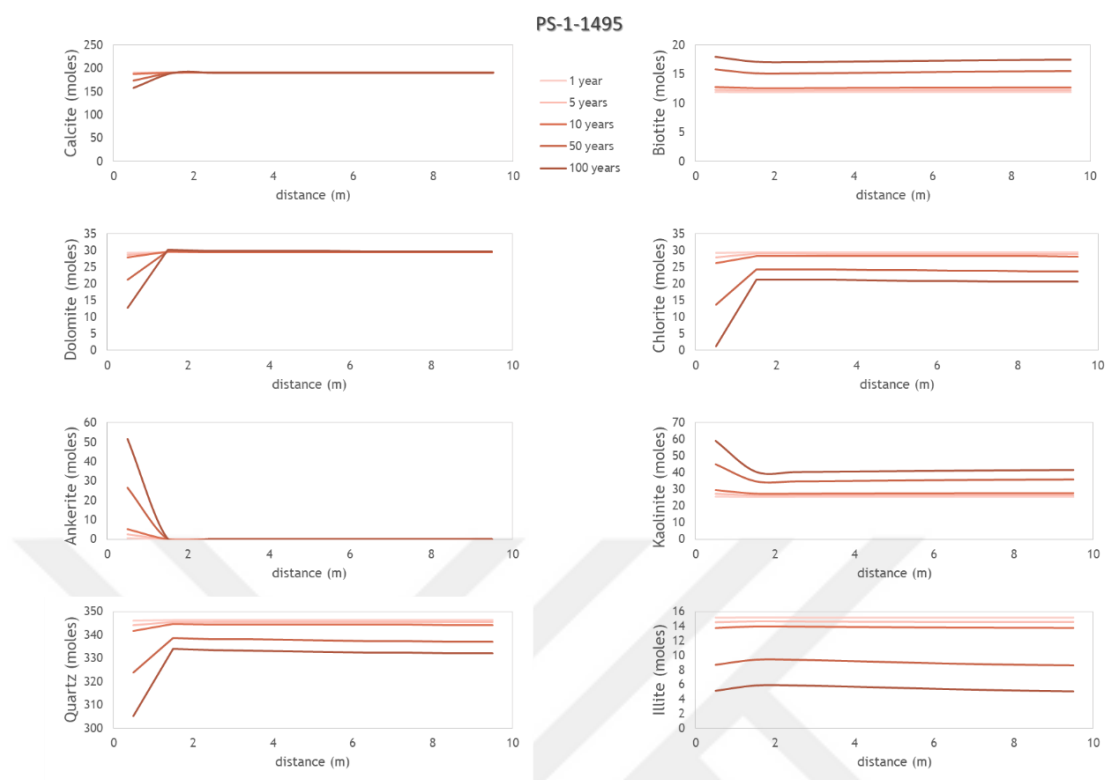


Figure H.10. Reactive transport modelling results for sample ADK-PS-1-1495 from Akköy field

Table H.11 Equilibrium modelling results for sample ADK-PS-2-1280 from Akköy field (values are as moles)

Mineral	PS-2-1280		
	Initial	Final	Delta
Albite	0	0	0
Ankerite	60,29	63,97	3,68
Biotite	0	0	0
Calcite	204,93	198,7	-6,23
Chlorite	0	0	0
Dolomite	0	2,667	2,67
Illite	15,91	21,61	5,70
Kaolinite	0	0	0
Muscovite	10,21	7,95	-2,26
Orthoclase	0	0	0
Quartz	499,56	508	8,44
Smectite	5,77	0	-5,77
Dawsonite	0	0,892	0,89
Magnesite	0	0	0
Siderite	0	0	0

Table H.12 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-2-1280 (Akköy field)

mol/L	initial	final
Al	7,48E-07	4,14E-05
Total C	0,02945	0,6607
Ca	0,006629	0,00756
Cl	0,002052	0,002001
Fe	6,27E-06	0,02123
K	0,003457	4,75E-11
Mg	0,002483	0,0006752
Na	0,03068	0,004066
SO ₄	0,009349	0,009115
Si	0,0005351	0,001169

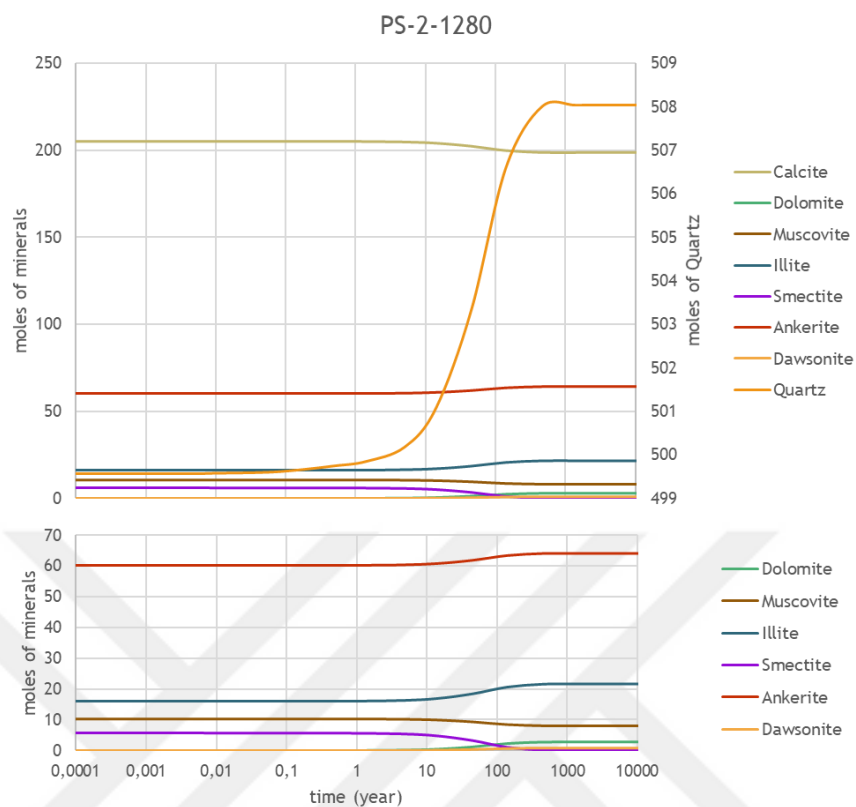


Figure H.11. Kinetic modelling results for sample ADK-PS-2-1280 from Akköy field

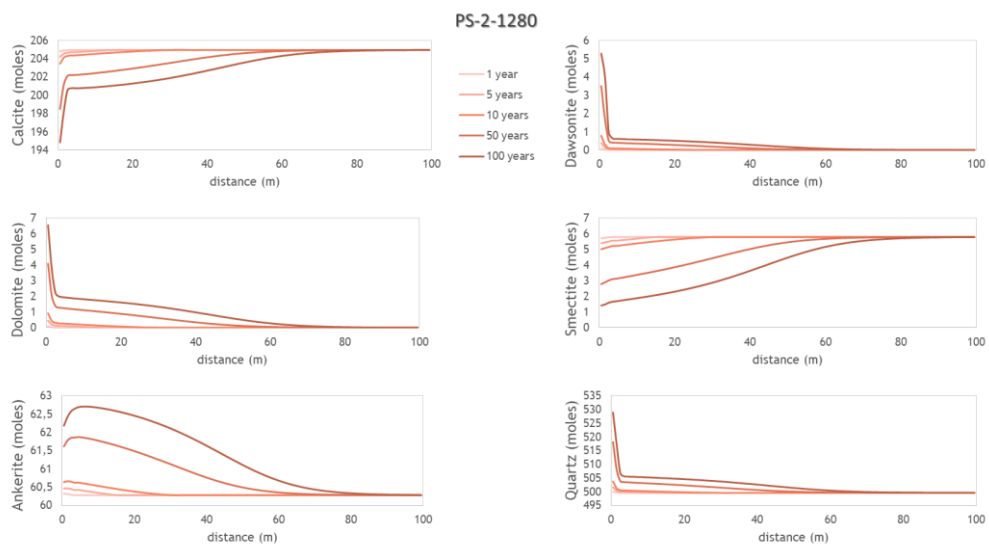


Figure H.12. Reactive transport modelling results for sample ADK-PS-2-1280 from Akköy field

Table H.13 Equilibrium modelling results for sample ADK-PS-2-1355 from Akköy field (values are as moles)

Mineral	PS-2-1355		
	Initial	Final	Delta
Albite	30,97	0,05782	-30,91
Ankerite	0	0	0
Biotite	0	0	0
Calcite	418,91	418,9	-0,01
Chlorite	0	0	0
Dolomite	32,31	32,31	0
Illite	0	0	0
Kaolinite	0	0	0
Muscovite	2,46	2,463	0
Orthoclase	0	0	0
Quartz	306,27	399	92,73
Smectite	0	0	0
Dawsonite	0	30,9	30,90
Magnesite	0	0	0
Siderite	0	0	0

Table H.14 Equilibrium modelling results of the water sample PS-1.2018 reacting with sample ADK-PS-2-1355 (Akköy field)

mol/L	initial	final
Al	7,48E-07	2,96E-06
Total C	0,02945	0,2687
Ca	0,006629	0,001271
Cl	0,002052	0,004627
Fe	6,27E-06	1,41E-05
K	0,003457	6,81E-07
Mg	0,002483	1,46E-04
Na	0,03068	0,09256
SO ₄	0,009349	0,02108
Si	0,0005351	0,001171

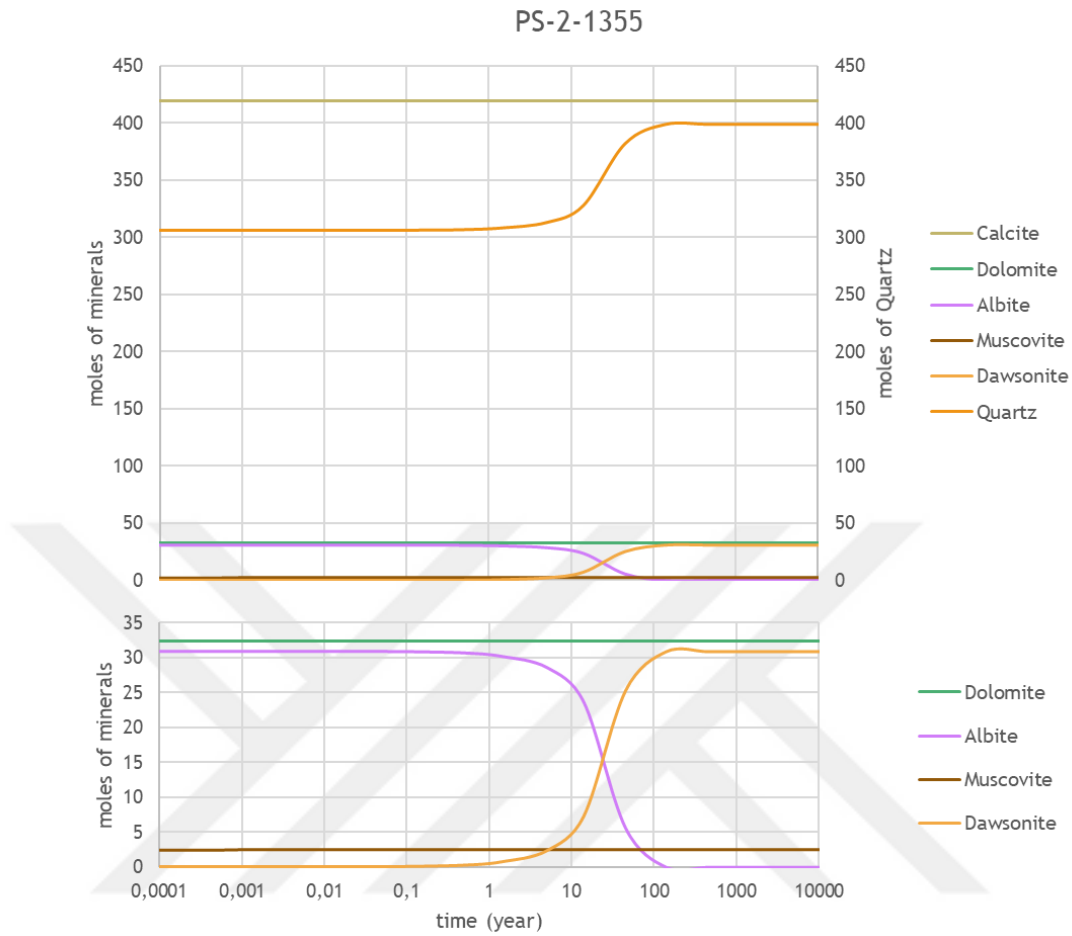


Figure H.13. Kinetic modelling results for sample ADK-PS-2-1355 from Akköy field

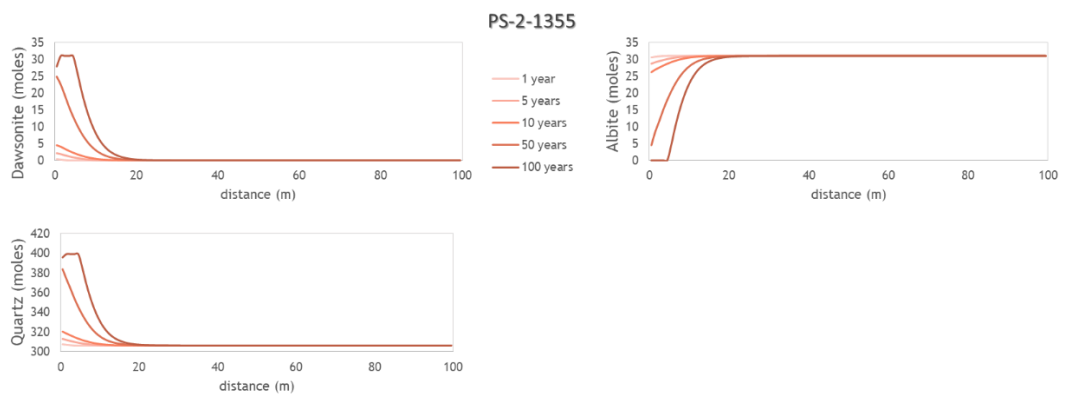


Figure H.14. Reactive transport modelling results for sample ADK-PS-2-1355 from Akköy field

Table H.15 Equilibrium modelling results for sample EDR-928 from Edremit field
(values are as moles)

Mineral	EDR-928		
	Initial	Final	Delta
Albite	43,11	43,03	-0,08
Amphibole	0	0	0
Biotite	0	0	0
Bytownite	0	0	0
Calcite	20,88	17,24	-3,64
Chlorite	0	0	0
Dolomite	3,12	6,76	3,64
Illite	14,56	0	-14,56
Kaolinite	0	12,42	12,42
Labradorite	0	0	0
Orthoclase	26,28	35,01	8,73
Quartz	421,79	422	0,21
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

Table H.16 Equilibrium modelling results of the water sample EDJ-7 reacting with
sample EDR-928 (Edremit field)

mol/L	initial	final
Al	3,26E-06	3,94E-06
Total C	6,07E-04	0,4418
Ca	9,74E-04	1,00E-04
Cl	0,001779	0,002185
Fe	1,42E-06	1,74E-06
K	1,46E-04	2,67E-03
Mg	4,12E-06	6,14E-06
Na	0,01071	0,1174
SO ₄	0,005211	0,006401
Si	0,0003739	0,001963

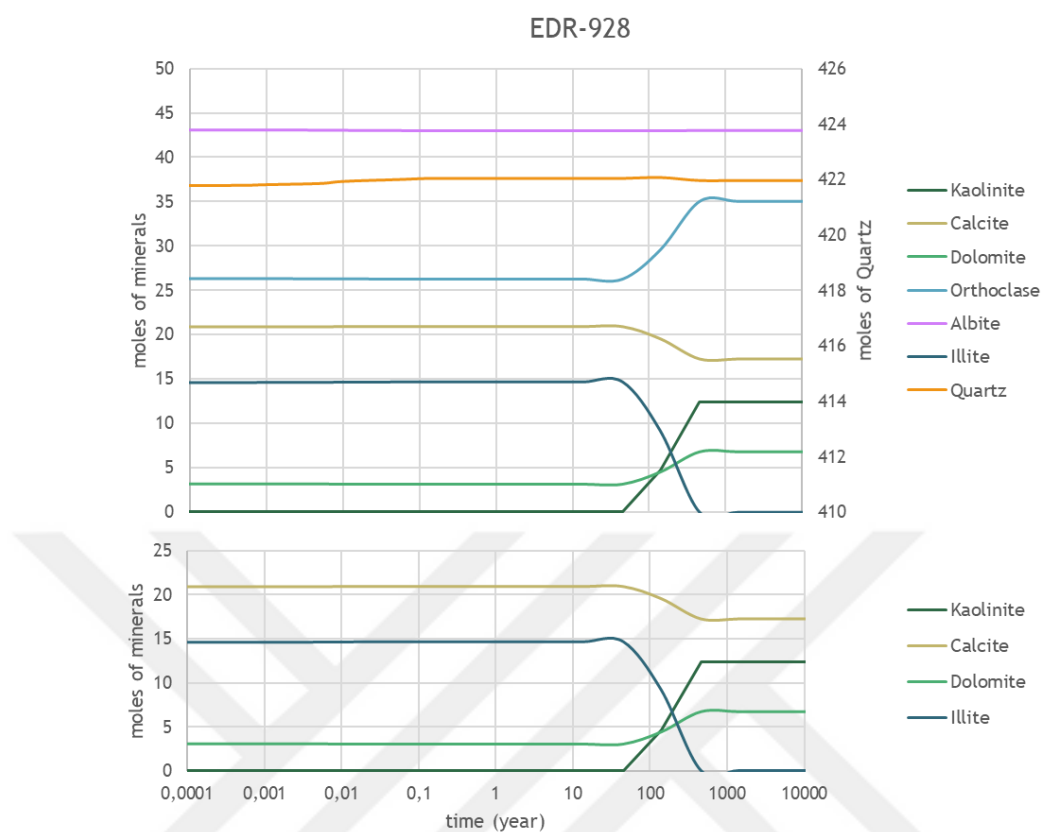


Figure H.15. Kinetic modelling results for sample EDR-928 from Edremit field

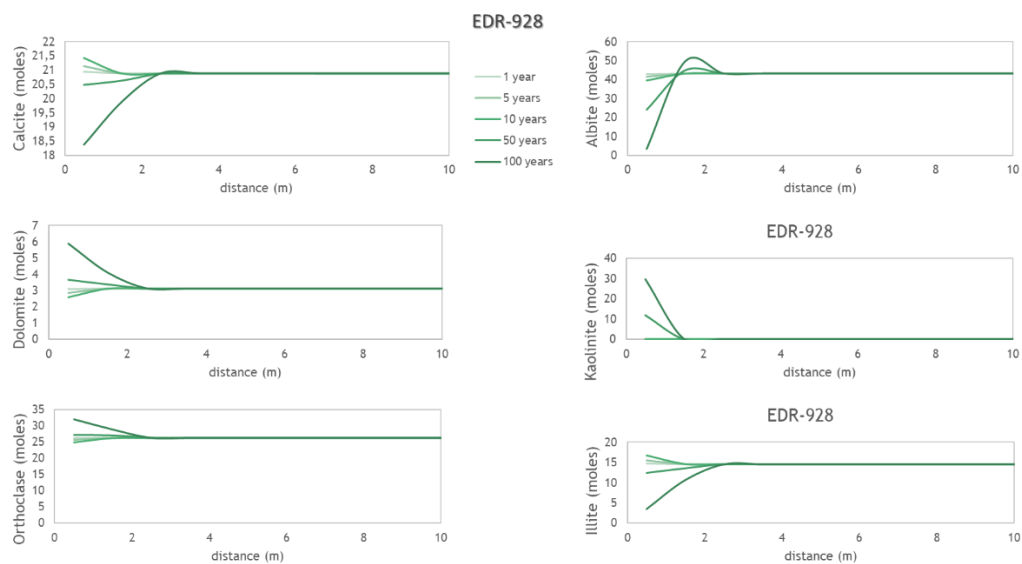


Figure H.16. Reactive transport modelling results for sample EDR-928 from Edremit field

Table H.17 Equilibrium modelling results for sample EDR-964 from Edremit field
(values are as moles)

Mineral	EDR-964		
	Initial	Final	Delta
Albite	0	0	0
Amphibole	0	0	0
Biotite	15,03	0	-15,03
Bytownite	0	0	0
Calcite	0	0	0
Chlorite	0	0	0
Dolomite	0	0	0
Illite	10,89	10,9	0,01
Kaolinite	0	0	0
Labradorite	0	0	0
Orthoclase	38,48	53,48	15,00
Quartz	517,46	517,5	0,04
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	45,08	45,08
Siderite	0	0	0

Table H.18 Equilibrium modelling results of the water sample EDJ-7 reacting with
sample EDR-964 (Edremit field)

mol/L	initial	final
Al	3,26E-06	5,75E-07
Total C	6,07E-04	0,7205
Ca	9,74E-04	1,15E-04
Cl	0,001779	0,0014
Fe	1,42E-06	1,12E-06
K	1,46E-04	1,69E-02
Mg	4,12E-06	1,78E-03
Na	0,01071	0,008432
SO ₄	0,005211	0,004102
Si	0,0003739	0,001949

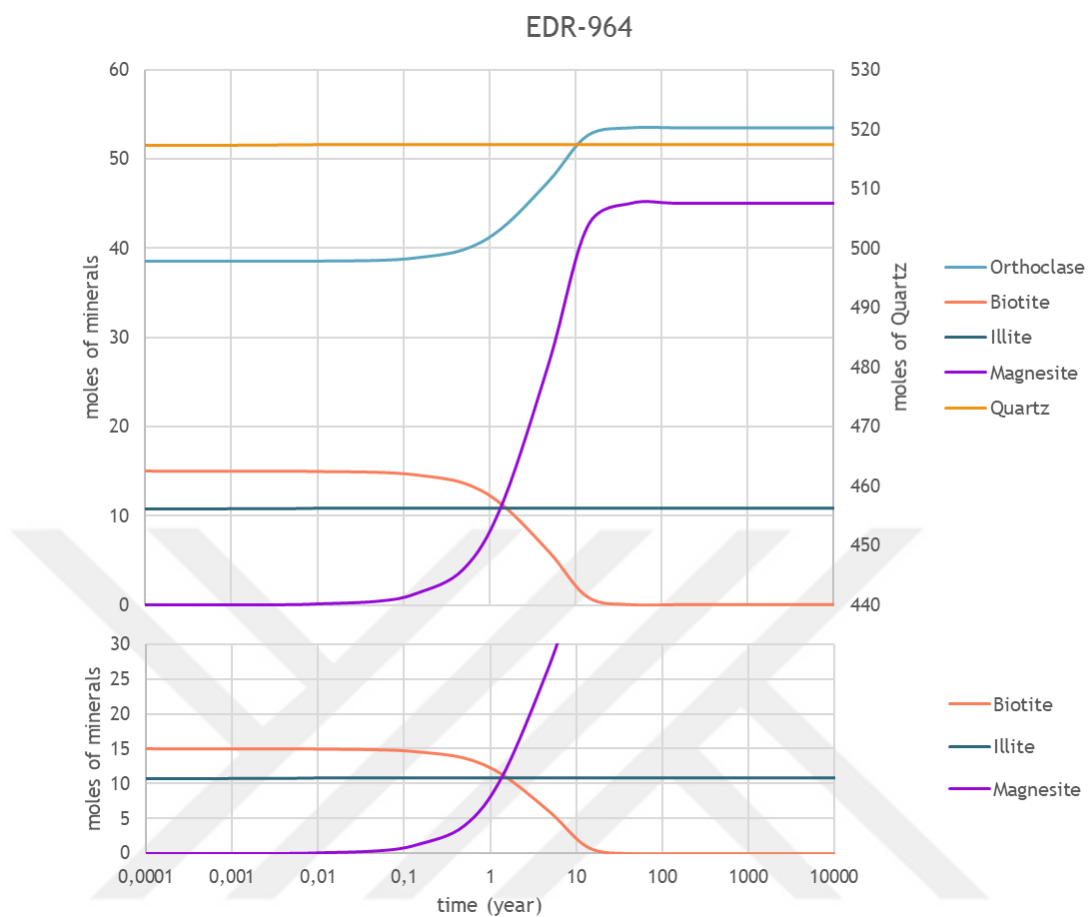


Figure H.17. Kinetic modelling results for sample EDR-964 from Edremit field

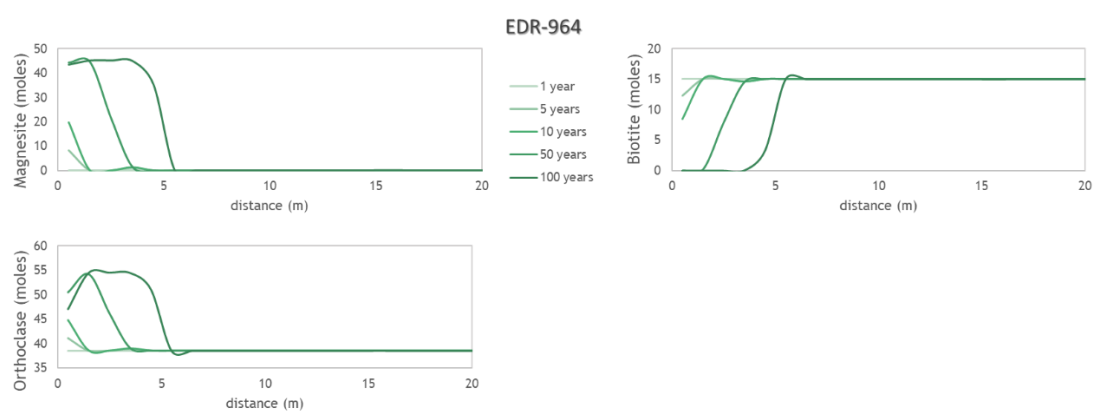


Figure H.18. Reactive transport modelling results for sample EDR-964 from Edremit field

Table H.19 Equilibrium modelling results for sample EDR-976 from Edremit field
(values are as moles)

Mineral	EDR-976		
	Initial	Final	Delta
Albite	0,00	18,01	18,01
Amphibole	0,00	0	0,00
Biotite	0,00	0	0,00
Bytownite	0,00	0	0,00
Calcite	0,00	27	27,00
Chlorite	0,00	0	0,00
Dolomite	0,00	0	0,00
Illite	16,60	16,6	0,00
Kaolinite	19,03	46,03	27,00
Labradorite	57,28	12,27	-45,01
Orthoclase	0,00	0	0,00
Quartz	422,66	422,6	-0,06
Ankerite	0,00	0	0,00
Dawsonite	0,00	0	0,00
Magnesite	0,00	0	0,00
Siderite	0,00	0	0,00

Table H.20 Equilibrium modelling results of the water sample EDJ-7 reacting with
sample EDR-976 (Edremit field)

mol/L	initial	final
Al	3,26E-06	4,23E-06
Total C	6,07E-04	4,32E-04
Ca	9,74E-04	1,43E-01
Cl	0,001779	0,06476
Fe	1,42E-06	5,16E-05
K	1,46E-04	5,73E-03
Mg	4,12E-06	3,25E-04
Na	0,01071	0,1492
SO ₄	0,005211	0,1897
Si	0,0003739	0,001964

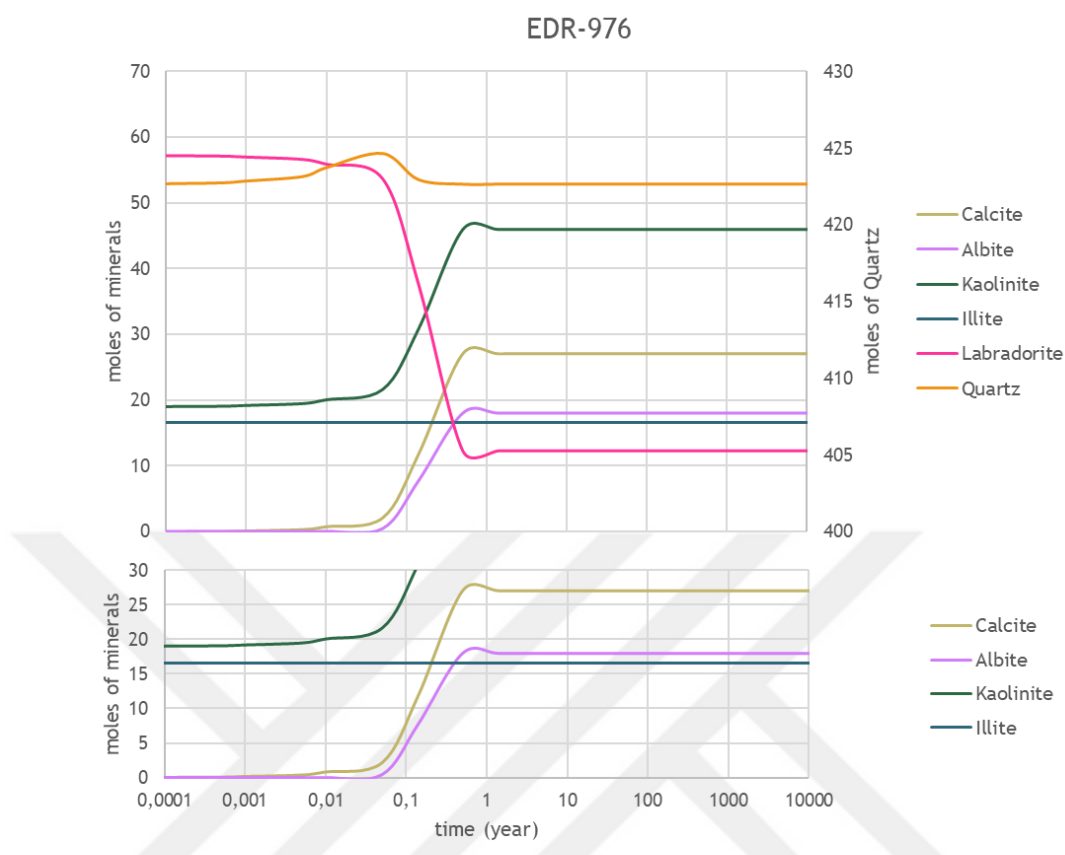


Figure H.19. Kinetic modelling results for sample EDR-976 from Edremit field

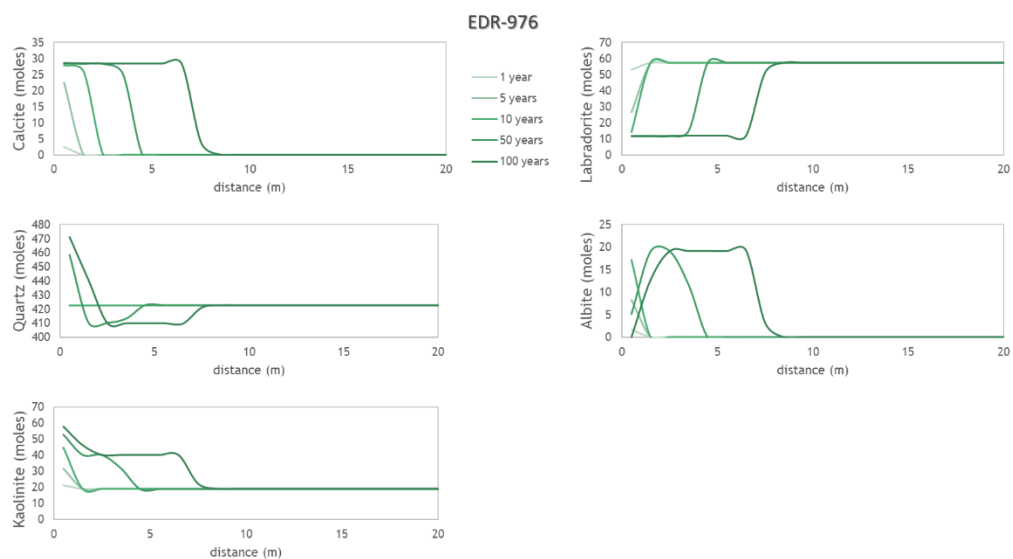


Figure H.20. Reactive transport modelling results for sample EDR-976 from Edremit field

Table H.21 Equilibrium modelling results for sample EDR-994 from Edremit field
(values are as moles)

Mineral	EDR-994		
	Initial	Final	Delta
Albite	0	10,46	10,46
Amphibole	3,63	0	-3,63
Biotite	25,67	15,12	-10,55
Bytownite	34,20	0	-34,20
Calcite	0	0,2528	0,25
Chlorite	0	0	0
Dolomite	13,88	48,25	34,37
Illite	4,22	51,4	47,18
Kaolinite	9,11	0	-9,11
Labradorite	0	0	0
Orthoclase	42,05	24,29	-17,76
Quartz	181,76	185,4	3,64
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	0	0
Siderite	0	0	0

Table H.22 Equilibrium modelling results of the water sample EDJ-7 reacting with
sample EDR-994 (Edremit field)

mol/L	initial	final
Al	3,26E-06	1,31E-05
Total C	6,07E-04	1,58E-02
Ca	9,74E-04	8,99E-05
Cl	0,001779	2,42E-03
Fe	1,42E-06	1,93E-06
K	1,46E-04	5,79E-04
Mg	4,12E-06	1,79E-05
Na	0,01071	0,025
SO ₄	0,005211	0,007102
Si	0,0003739	0,001992

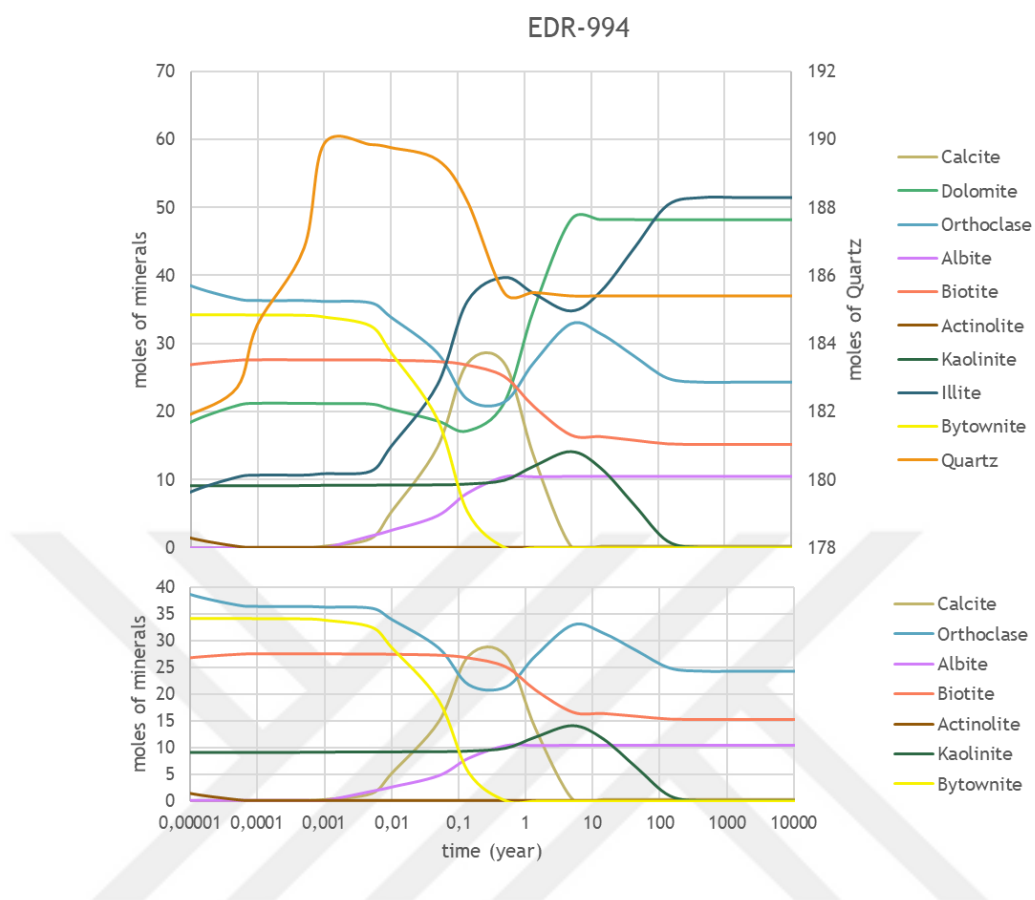


Figure H.21. Kinetic modelling results for sample EDR-994 from Edremit field

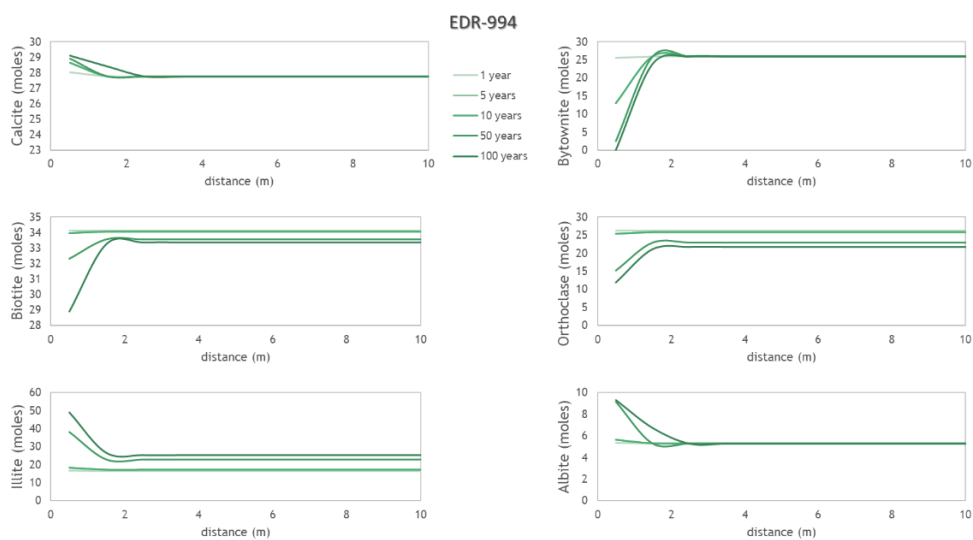


Figure H.22. Reactive transport modelling results for sample EDR-994 from Edremit field

Table H.23 Equilibrium modelling results for sample EDR-1032 from Edremit field
(values are as moles)

Mineral	EDR-1032		
	Initial	Final	Delta
Albite	0	0	0
Amphibole	0	0	0
Biotite	17,91	0	-17,91
Bytownite	0	0	0
Calcite	6,26	0	-6,26
Chlorite	0	0	0
Dolomite	9,07	15,33	6,26
Illite	0	0	0
Kaolinite	6,07	6,076	0
Labradorite	0	0	0
Orthoclase	93,86	111,8	17,94
Quartz	246,12	246,1	-0,02
Ankerite	0	0	0
Dawsonite	0	0	0
Magnesite	0	47,47	47,47
Siderite	0	0	0

Table H.24 Equilibrium modelling results of the water sample EDJ-7 reacting with
sample EDR-1032 (Edremit field)

mol/L	initial	final
Al	3,26E-06	8,25E-07
Total C	6,07E-04	2,06E-01
Ca	9,74E-04	8,00E-05
Cl	0,001779	1,35E-03
Fe	1,42E-06	1,07E-06
K	1,46E-04	9,62E-03
Mg	4,12E-06	1,55E-03
Na	0,01071	0,0081
SO ₄	0,005211	0,003941
Si	0,0003739	0,00195

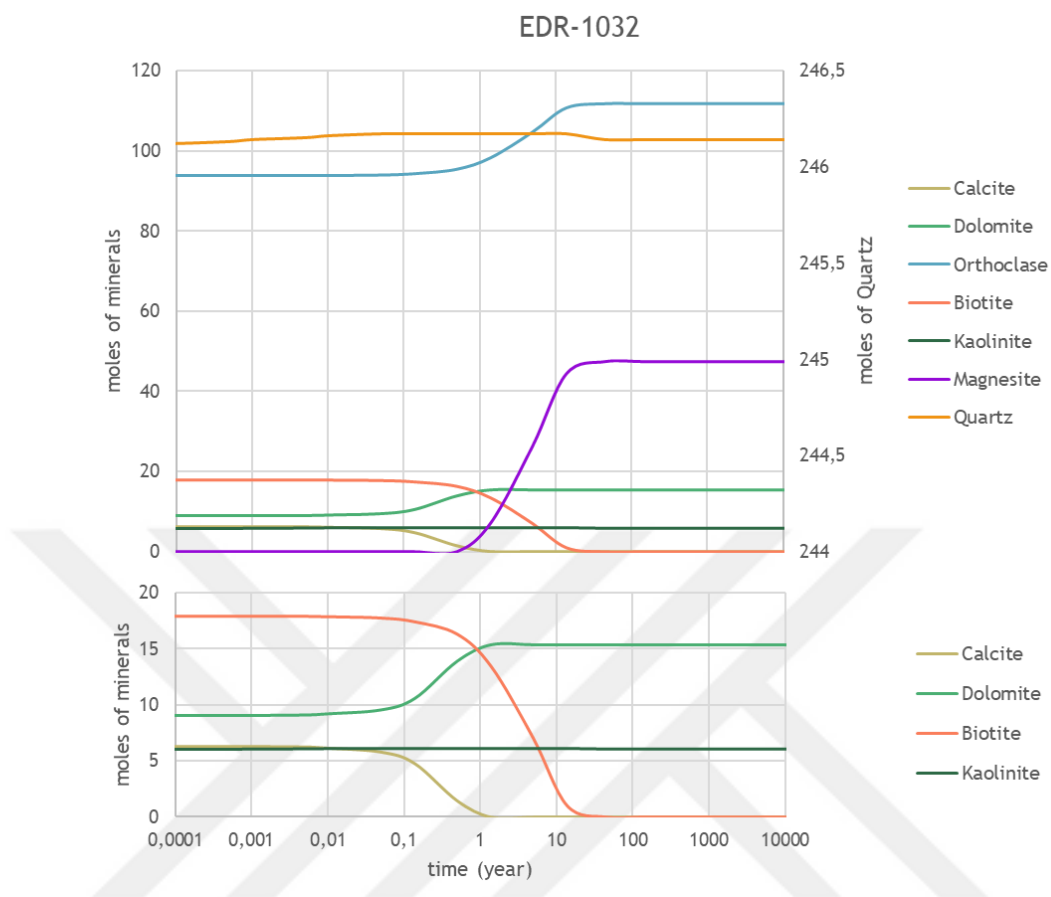


Figure H.23. Kinetic modelling results for sample EDR-1032 from Edremit field

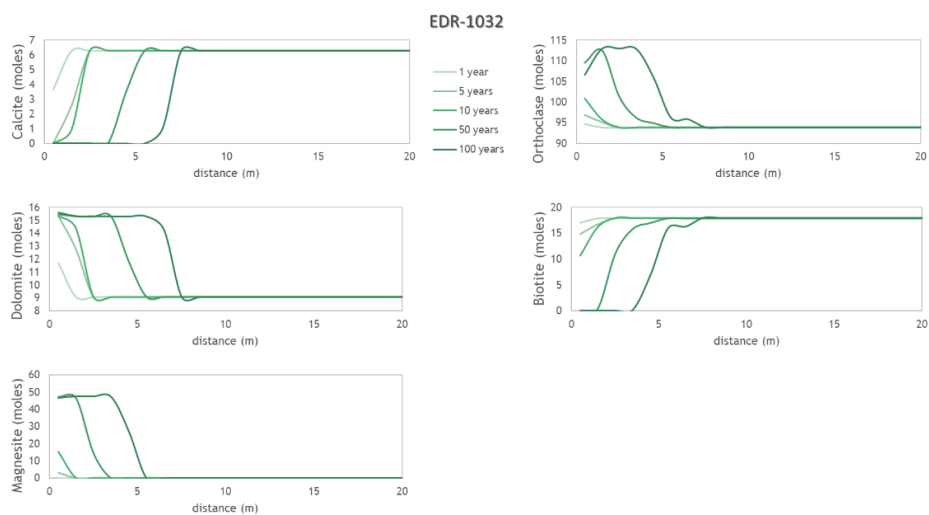


Figure H.24. Reactive transport modelling results for sample EDR-1032 from Edremit field

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EDUCATION

Degree	Institution	Year of Graduation
MS	METU Geological Engineering	2014
BS	METU Geological Engineering	2011
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FOREIGN LANGUAGES

Advanced English, Intermediate French, Intermediate Italian, Beginner Japanese

PUBLICATIONS

Journal Papers

1. Elidemir, S., Güleç, N., Deniz, K. and Kadioğlu, Y.K. (2022). Reservoir rock characterization in Edremit geothermal field: Geochemical implications for possible fault zones. *Applied Geochemistry* 143. DOI: <https://doi.org/10.1016/j.apgeochem.2022.105388>
2. Elidemir, S. and Güleç, N. (2018). Geochemical characterization of geothermal systems in western Anatolia (Turkey): implications for CO₂ trapping mechanisms in prospective CO₂-EGS sites. *Greenhouse Gases: Science and Technology* 8, 63–76. DOI: 10.1002/ghg.1747

Conference Papers

1. Elidemir, S., Güleç, N., Deniz, K., and Kadioğlu, Y. K. (2023) Implications for Possible Fault Zones Deduced from Lithogeochemical Characterization of Reservoir Levels of a Geothermal Field: Edremit Example, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-545, <https://doi.org/10.5194/egusphere-egu23-545>

2. Elidemir, S. and Güleç, N. (2021). Olası CO₂ Depolama Sahaları Olarak Akköy ve Edremit Jeotermal Sistemlerindeki Akışkan - Kayaç Etkileşimlerinin Jeokimyasal Modellemesi: Ön Çalışma Sonuçları/Geochemical Modelling of Fluid-Rock Interactions in Akköy and Edremit Geothermal Fields as Prospective CO₂ Storage Sites: Results of a Preliminary Study: *73rd Geological Congress of Turkey* (Online), 24-28 May 2021, Ankara, Turkey
3. Elidemir, S. and Güleç, N. (2020). Lithogeochemical Characterization of Akkoy and Edremit Geothermal Fields as Prospective CO₂ Storage Sites: A Preliminary Study: *EGU General Assembly 2020*, Online, 4-8 May 2020, EGU2020-452, DOI: 10.5194/egusphere-egu2020-452
4. Elidemir, S. and Güleç, N. (2020). Water-Rock Interactions in Geothermal Systems in the Framework of CO₂ Storage: *European Geothermal PhD Days-2020*, 24-26 February 2020, Denizli, Turkey
5. Elidemir, S. and Güleç, N. (2019). Geochemical Modelling of Fluid-Rock Interactions in Adaköy and Edremit Geothermal Fields as Prospective CO₂ Storage Sites: A Preliminary Study: *14th CO₂ GeoNet Open Forum*, 6-9 May 2019, Venice, Italy
6. Elidemir, S. and Güleç, N. (2017). Geothermal Systems as Natural Analogues for Geological Storage of CO₂: Implications for Trapping Mechanisms from Hydrogeochemistry of Western Anatolian Fluids (Turkey): *Goldschmidt 2017*, 13-18 August 2017, Paris, France (Goldschmidt Abstracts, 2017 1051)
7. Elidemir, S. and Güleç, N. (2016). Geochemical Characterization of Geothermal Systems in Turkey as Natural Analogues for Geological Storage of CO₂: *7th Geochemistry Symposium with International Participation*, 16-18 May 2016, Antalya, Turkey (Abstract Book p.213-214)