Konya Mühendislik Bilimleri Dergisi, c. 10, s. 4, 903-911, 2022
Konya Journal of Engineering Sciences, v. 10, n. 4, 903-911, 2022
ISSN: 2667-8055 (Electronic)
DOI: 10.36306/konjes.1124048

CONTACT METAMORPHISM OF LATE SILURIAN-EARLY CARBONIFEROUS METACARBONATES BY METAMAFIC DYKES AROUND LADIK AND ESIRAĞIL AREA (KONYA, CENTRAL TURKEY)

[1]Kerim KOÇAK, [2]Adnan DÖYEN

Konya Teknik University, Engineering and Natural Sciences Faculty, Geological Engineering Department, Konya, TÜRKİYE

[1]kkocak@ktun.edu.tr, [2]adoyen@ktun.edu.tr

ABSTRACT: In NNW Konya, mafic rocks form as dyke swarm or isolated linear dykes, which are cut by a series of normal faults that developed possibly by emplacement of the dyke-forming magma. Some anhydrous oxidized calcic skarn zones have ever been found out in Silurian-Early Carboniferous metacarbonates next to the Triassic metamafic dykes faulted, and in roof pendants within the intrusion. The metamafic rocks are suggested to have a low temperature and a small amount (or even absence) of the heat of crystallization, which causes the development of a restricted skarn zone. Mineralogical studies show that the skarn contains garnet, magnetite/hematite, chlorite, and sericite. The magnetite/hematite minerals form mostly as large euhedral crystals, up to 0.5 cm in length, which may be resorbed by chlorite and felsic minerals or rimmed by goethite. The garnet typically forms as spectacular euhedral large crystals, up to ~1.5 mm in size. The existence of chlorite and sericite, and the lack of hornblende, biotite and wollastonite in the region indicate that contact metamorphism took place under low pressure, relatively low temperatures (albite-epidote hornfels) and/or high CO_2 conditions in the area.

Keywords: *Skarn, Dyke Swarm, Garnet, Konya*

Ladik ve Esirağıl Alanı (Konya, Orta Anadolu) Yöresindeki Geç Silüriyen Erken Karbonifer Yaşlı Metakarbonatların Metamafik Dayklarla Kontak Metamorfizması

ÖZ: Konya'nın KKB'da dayk topluluğu veya muhtemelen dayk oluşturan magmanın yerleşimi ile gelişen bir dizi normal faylar tarafından kesilmiş izole çizgisel dayklar şeklinde mafik kayaçlar oluşur. Faylanmış Triyas yaşlı metamafik dayklara komşu Silüryen-Erken Karbonifer yaşlı metakarbonatlar ve sokulumdaki çatı askıları içerisinde, ilk kez su içermiyen oksitlenmiş Ca'ca zengin bazı skarn zonları belirlenmiştir. Metamafik kayaçların, sınırlı skarn zonunun gelişimine neden olan düşük sıcaklığa ve az miktarda (veya yok) kristalleşme sıcaklığına sahip olduğu ileri sürülmüştür. Mineralojik çalışmalar, skarnın granat, manyetit/hematit, klorit ve serisitten oluştuğunu gösterir. Manyetit/hematit mineralleri, klorit ve açık renkli mineraller tarafında kemirilebilen veya götit tarafından çevrilen, çoğunlukla 0.5 cm uzunluğa kadar gelişmiş özşekilli kristaller şeklinde oluşur. Granat tipik olarak ~1.5 mm boyuta kadar ulaşan harikulade özşekilli iri kristaller şeklinde oluşur. Bölgede klorit ve serisitin varlığı ve hornblend, biyotit ve vollastonitin yokluğu kontakt metamorfizmanın düşük basınç, nispeten düşük sıcaklık (albit-epidot hornfels) ve/veya yüksek CO_2 şartlarında yer aldığına işaret eder.

Anahtar Kelimeler: *Skarn, Dayk Topluluğu, Granat, Konya*

1. INTRODUCTION&GEOLOGICAL SETTING

The intrusion of igneous rocks into colder or to some extent heated country rocks at relatively shallow depths in the upper crust induces a sharp increase in temperature so that the geothermal gradient exceeds ~90 °C/km at contact with intruding magma, and results in contact metamorphism (Kerrick, 1991;

Reverdatto *et al.*, 2019). In comparison with regional metamorphism, contact metamorphism is typified by shorter heating and cooling time scales.

The term "contact metamorphism" was used first by (Delesse, 1857). Karl H. F. Rosenbusch defined first a zonal contact aureole in slates near the Barr-Andlau granite pluton (Rosenbusch, 1877). One of the earliest examples of contact metamorphism to be recognized was the pyroxene granulite facies metamorphism of basaltic rocks by Tertiary gabbros of Scotland (Geikie, 1889).

In Turkey, various contact metamorphic occurrences with various mineral assemblages have also been reported; e.g., the assemblage of wollastonite + garnet + An73 plagioclase + orthoclase + corundum + hercynite + hedenbergite-diopside ± scapolite in calcareous next to granitoids (Ortakoy-Aksaray; Kocak, 1993; Kocak and Leake, 1994), that of muscovite + biotite + garnet and forsterite+calcite around the Ahiçay-Elmalıçay granitoid in the Kastamonu granitoid belt (Boztuğ and Yılmaz, 1995), andalusite + corundum + K-feldspar assemblage around granodiorite in Eastern Pontides (Topuz, 2006), dio+gar±ep±qtz around Karadoru granitoid (Çanakkale, Aysal *et al.*, 2006), and Spurrite + rustumite + hillebrandite + tilleyite + cuspidine + vesuvianite + monticellite + gehlenite one around tonalite Eastern Black Sea (Taner *et al.*, 2013).

The study area is located in Afyon-Bolkardağı Zone (Okay, 1986) or Konya complex (Robertson and Ustaomer, 2009; Lowen *et al.*, 2019) in the NNW part of Konya. The oldest formation in the region is Silurian-Early Carboniferous (Figure 1; Eren and Kurt, 2000) mostly massive shelf carbonate, with grey to bluish grey in colours (Bozdağ formation). The carbonate contains low-grade metamorphosed limestone, dolomitic limestone, and dolomite, with metachert band and lenses (Hekimbaşı, 1996; Kurt, 1997). It is aged as Late Silurian–Early Devonian (Göncüoğlu *et al.*, 2000), Middle-Late Devonian and Early Carboniferous age (Eren, 1993; Kurt, 1994) based on fusulinids, crinoids, corals, and trilobites. It hosts various calcite and barite veins emplaced through their joints, with thickness ranging from 10 to 40 cm.

The carbonates rocks were cut by various metaigneous rocks (Kadınhani metamagmatics) with sharp contacts around Bagrikurt and Sızma villages, which have various compositions ranging from basaltic to rhyolitic ones (Kurt, 1996, Özcan *et al.*, 1990; Kurt and Asan, 1999). The age of metaigneous rock is constrained to be Silurian-Lower Permian (Eren, 1993) and Early Triassic (Akal *et al.*, 2012) on the basis of stratigraphical characteristics and zircon geochronology, respectively.

The carbonates rocks intruded by metamafic dykes, are found out first time that has skarn zone development. This study aims to deal with geological and mineralogical characteristics of the skarn zone developed within the metacarbonates by metamafic dyke, around Ladik and Esirağıl area (Konya, Turkey).

2. METHODS

Thirty-two samples were collected from the skarn zone, metamafic and metacarbonates during field studies. Some samples are cut to see mineral structure. From fresh and representative samples, their thin sections were made to study under the polarizing microscope at the Department of Geological Eng., Konya Technical University.

2.1. Contact Metamorphism

Metamafic rocks occur as parallel dyke swarm around Ladik (Figure 1), with light-dark green colour. In the field, it is generally covered by its alteration products with dark colour and plants. Dyke assemblages of different thicknesses are observed, which generally strike in two directions; the dykes have trending in **(I)** ~E-W (older) and **(ii)** ~N-S (younger) directions, with a maximum length of 3078 m (i), and thickness of 73.11m (Koçak, 2020). The metamafic dyke also occurs as isolated dykes with a length of ~800 m around SSW of Bahçecik village (Figure 1, 2), which is cut by strike-slip faults.

Two skarn zones have ever been found out during field studies (Figure 1, 2); (a) In a road cutting around Ladik town, a typical skarn zone developed in metacarbonates in relation with the intrusion of dyke swarms. A chilly zone with thickness up to 25 cm, developed at the border of dyke and FeO mineralizations as pockets within the carbonates (Figure 3, 4) by contact metamorphism. (b) In the south of Bahçecik village, the skarn zone has been found out metacarbonates next to the isolated metamafic dykes, but mostly within metacarbonates as exoskarn (Figure 5, 6.) There is a linear dyke development with a length of ~790 m (Figure 5), where fresh specimens can be obtained especially on the hill in the south of Bahçecik village. The dykes are located perpendicular to the direction of the metacarbonates and were cut by some strike-slip faults. The location is characterized by existence of carbonate/calcsilicate xenoliths as blocks with FeO enrichment. Crystal size of the calcite in the metacarbonates next to the intrusion may increases towards to the dyke, which may have slight foliations parallel to the margins of intrusion. The carbonates may have been dissolved and consequently formed irregular space/pockets by hydrothermal solutions and were undergone brecciation producing a boudinage structure.

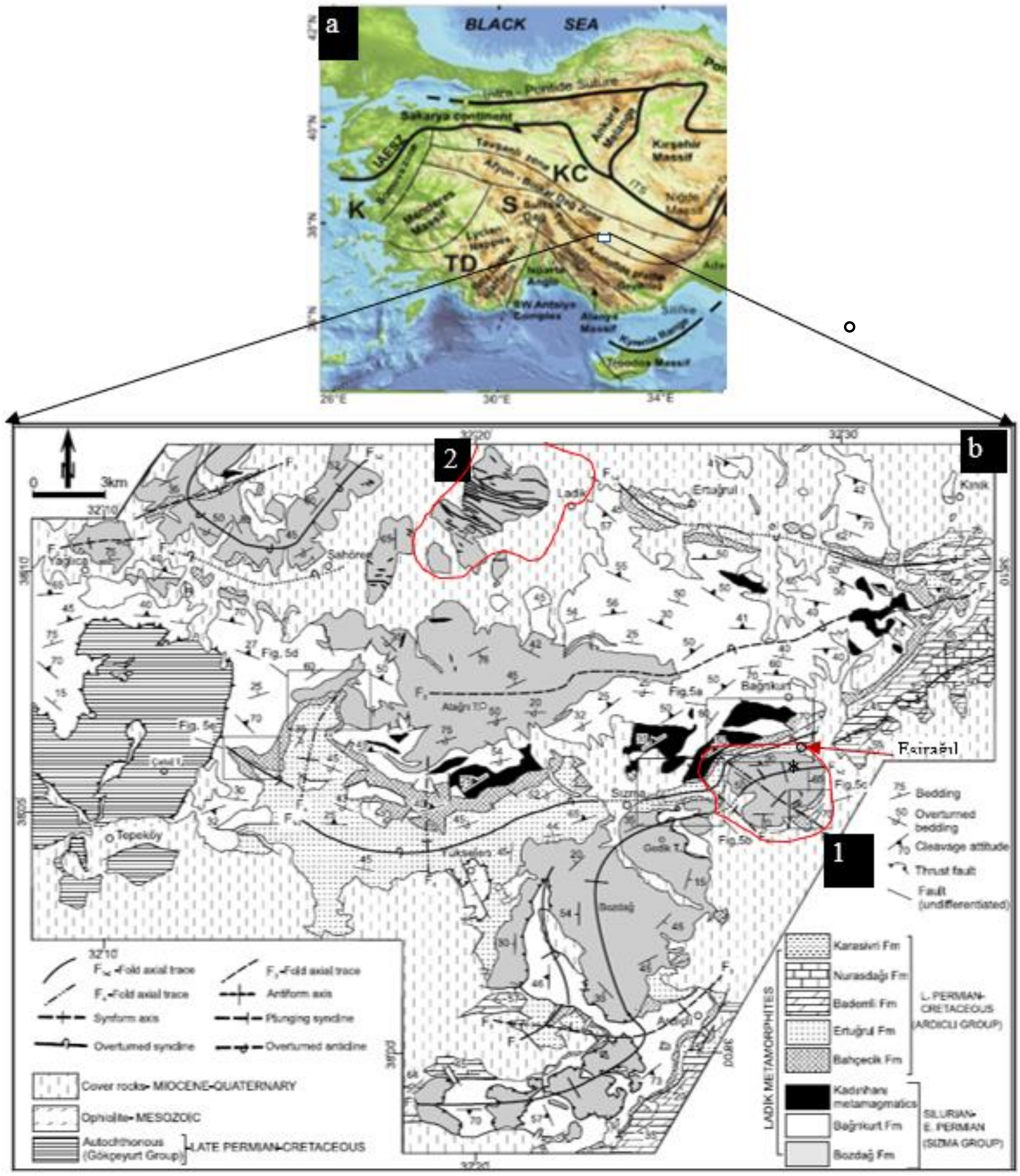

Figure 1: a) Outline tectonic map of Turkey (Robertson *et al.*, 2021). b) A geological map of the area (Eren, 1993) 1: Dyke swarms, 2: Isolated dykes. KC: Konya Complex, S: Sultandağı volcanics&tuffs (Tauride autochton), TD: Teke dere unit (Lycian nappes), K: Karaburun melange, Karaburun Peninsula

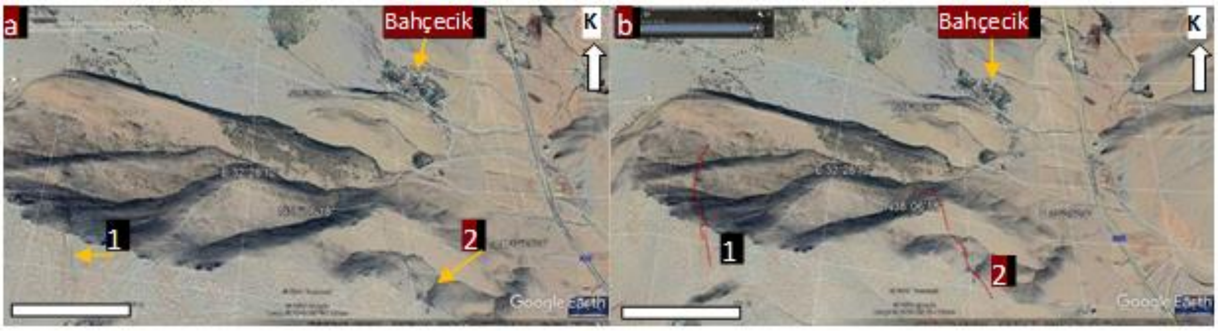

Figure 2: A Google Earth image of isolated dykes developing in SW(1) and SSW(2) of Bahçecik village. Scale bar 500 m.

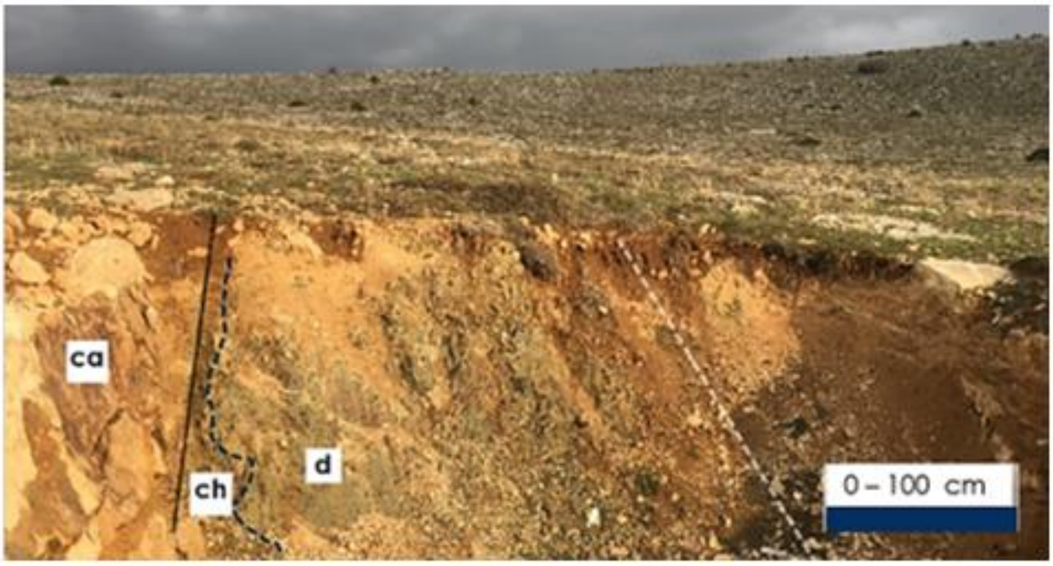

Figure 3: A subvertical mafic dyke(d) with the chilly zone (ch) cutting metacarbonates(ca) in a road cutting.

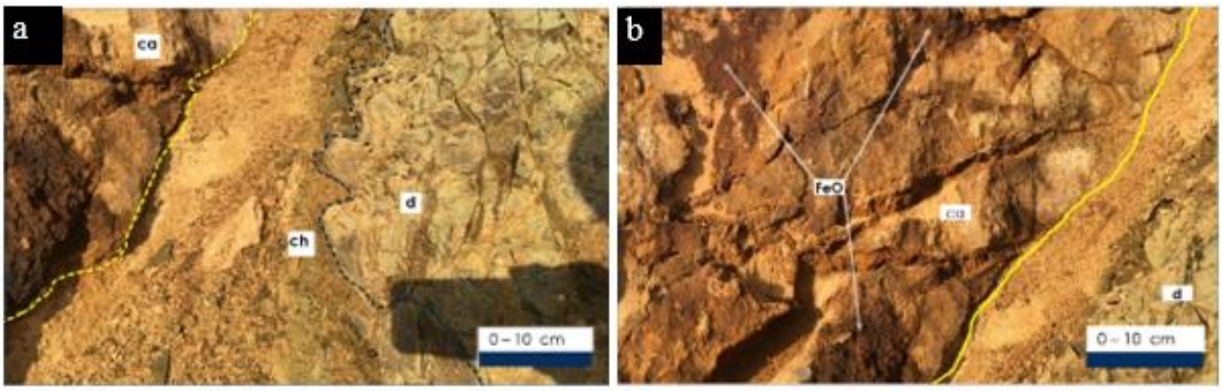

Figure 4: a) A close view of the chilly zone(ch) between the dyke and carbonates b)FeO mineralizations developed in the carbonates (ca) intruded by dyke (d).

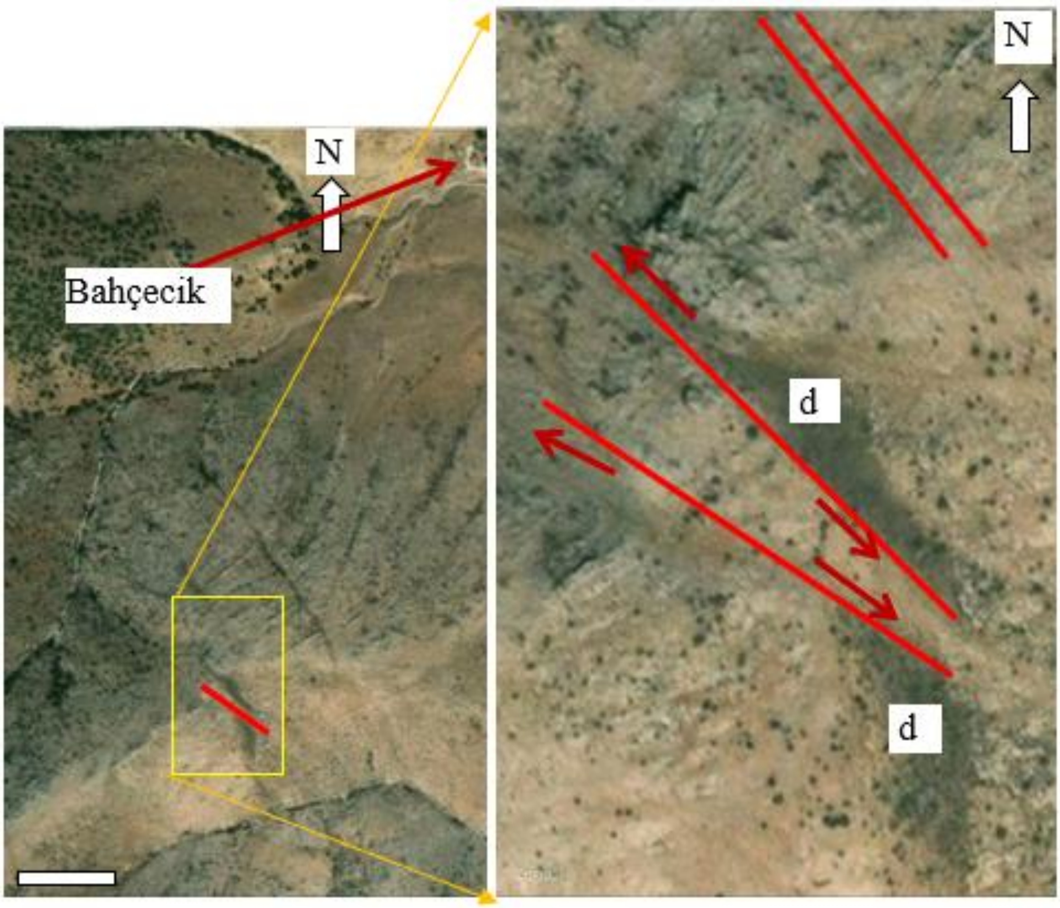

Figure 5: Google-Earth image of the dykes in the SSW of Bahçecik village. Scale bar is 250m.

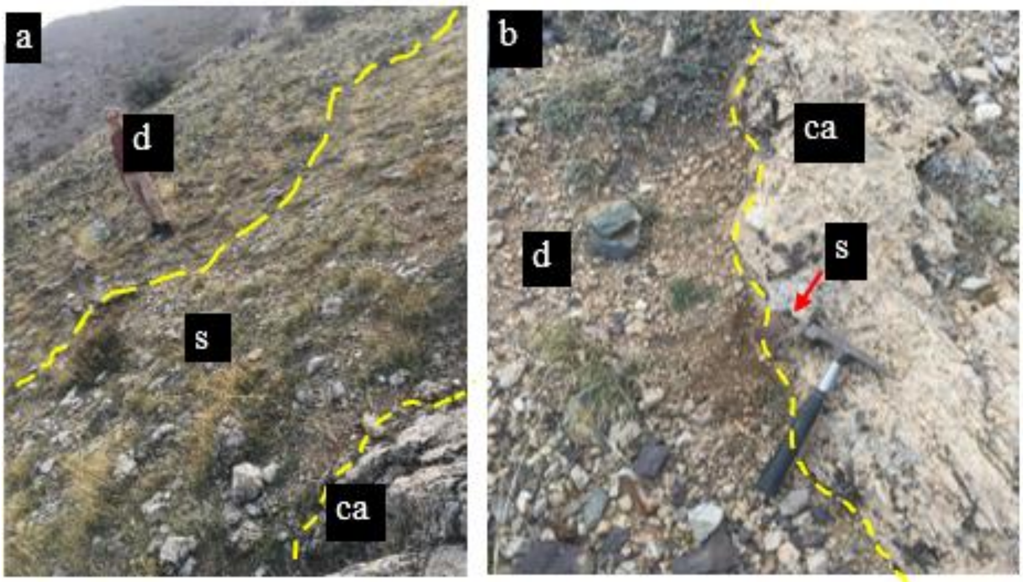

Figure 6: Skarn(s) ve metamafic(d) and wavy contact of metacarbonate (ca)

2.2. Mineralogy

The metamafic rocks can be classified as metadiabase/metagabbro. Mineralogical studies show that the primary components in the samples are quartz (5-20%), plagioclase (15-55%), orthoclase (0-5%), hornblende (5-40%), and pyroxene (0-18%). With alteration and metamorphism, glaucophane (0-8%), actinolite (0-36%), chlorite (20-60%), epidote (2-5%) and calcite (0-30%) have developed. The opaque minerals (magnetite/hematite, 0.1-0.3 mm, 4-30%) in the samples are mostly anhedral but sometimes prismatic and their amount varies between 10-30%.

Most of the iron mineralizations form as black euhedral crystals with three to six edges depending on section direction. The size ranges from less than 1 mm to 8 mm (Figure 7) in dispersed to laminated crystals, with occasional inclusions. The alteration process results in the development of red-brown coloured FeO coating from the euhedral opaque crystals(Figure 7).

The magnetite/hematite crystals may be rimmed by goethite (Figure 8a), or partially replaced by limonite/chlorite which is found as pseudomorph crystals with euhedral shape (Figure 8b). The opaque mineral is also rimmed and replaced by chlorite and quartz crystals (Figure 10a). The euhedral garnet may occur as large crystals, up to ~1.5 mm in size (Figure 9), and may contain some quartz inclusions, which exhibit parallel alignment to its edge and thus may form during its growth (Figure 10b).

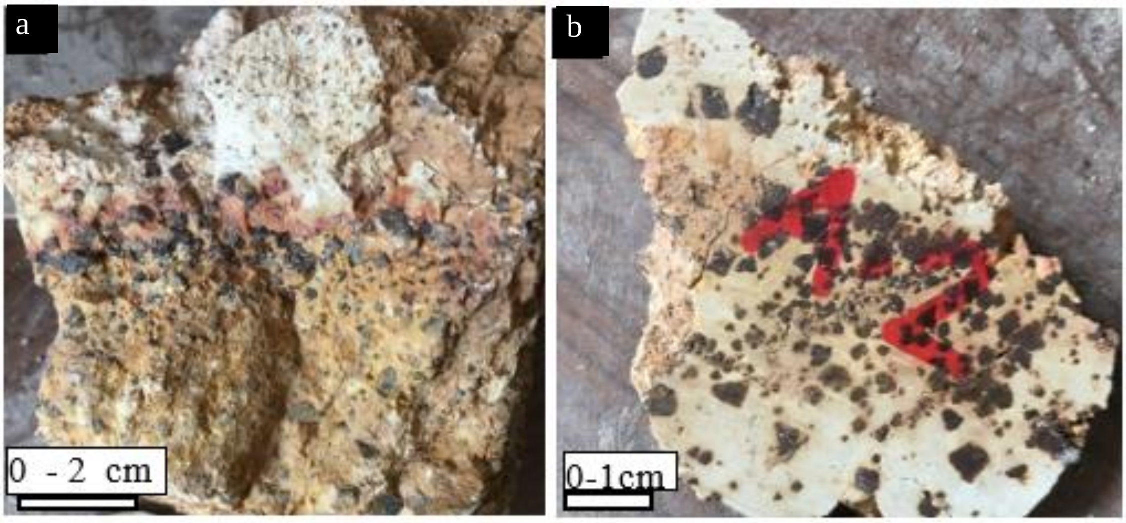

Figure 7: a) Skarn sample with Fe mineralization b) Close view of the skarn sample

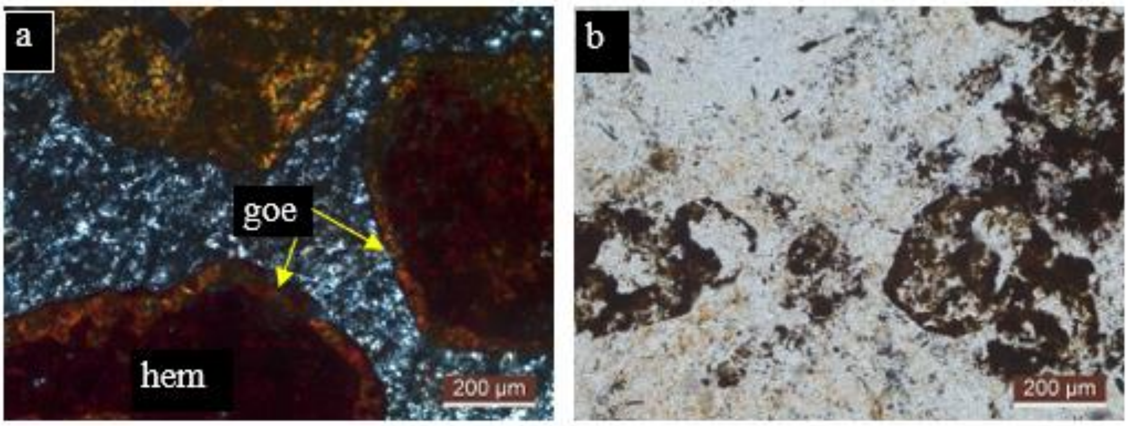

Figure 8: Microphotographs showing (a) central hematite, margins goethite(goe), and b)highly altered euhedral opaque minerals.

Figure 9: Large euhedral garnet crystals (gar) in the skarn zone.

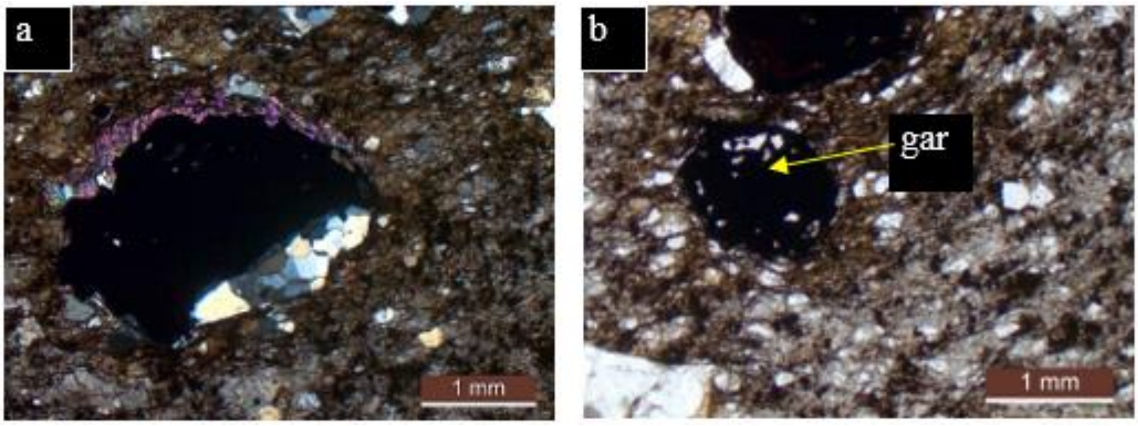

Figure 10: a) Felsic mineral and chlorite development from the edge of the opaque mineral (b) quartz inclusion in the euhedral garnet(gar).

3. DISCUSSION&RESULTS

Mafic dyke swarms are vertical dyke swarms in the similar orientation, representing the system of pre-formed stretched crustal fracture swarms in which the mafic magma is located (Ernst *et al.*, 1995; Hou *et al.*, 2006). A series of normal faults display small offsets of 1 m. or less, may indicate synemplacement extension, and can be formed in relation with emplacement of mafic magma. Existence of weak foliations parallel to the margins of intrusions suggest that the mafic magma was emplaced completely by magmatic flow (Paterson *et al.*, 2018).

The contact metamorphism can be observed only around the contacts of the dykes with carbonates, in where some normal faults developed. Crack networks may form in rocks to adjust strain, as microcracks are widespread in rocks that have undergone deformation at fairly low P and T (Bell and Wilson, 1981;

Denbrok and Spiers, 1991; Vernon, 1975).

The contact metamorphism in the region could be developed by a mixture of the coarsening, neocrystallization and metasomatism processes. The skarn formation can be classified as an oxidized Fe-rich calcic skarn, which contains the gar+mag/hem+chl+ser assemblage developed by metasomatic alterations in metacarbonates due to infiltration of fluids from the mafic magma, with iron, alumina and silica.

The size of the contact metamorphism zone is rather narrow, a few meters in thickness though maximum thicknesses in the dyke swarms and isolated dykes reach 70 m and ~200 m, respectively. The mafic magma has been partly or nearly completely solidified. Thus it may have a low temperature and a small amount (or even absence) of heat of crystallization, such as Alpine-type peridotite massifs (Turner and Verhoogen, 1960), Ayı-Dagı gabbro-diorite laccolith of Crimea (Anan'ev, 1999). The existence of chlorite and sericite, and the lack of hornblende, biotite and wollastonite may also indicate low pressure, relatively low temperatures (albite-epidote hornfels) (<500°C) and high PCO_2 conditions for the contact metamorphism.

4. REFERENCES

Akal, C., Candan, O., Koralay, O.E., Oberhansli, R., Chen, F.K.Prelevic, D., 2012, "Early Triassic potassic volcanism in the Afyon Zone of the Anatolides/Turkey: implications for the rifting of the Neo-Tethys", *International Journal of Earth Sciences*, 101, 1, 177-194.

Anan'ev, V.A., 1999. Kontaktoviy metamorfizm Ayu-Daga (Contact metamorphism on the Ayu-Dagh mountain). . Candidate of Science Dissertation Thesis, Novosibirsk.

Aysal, N., Öngen, S.Hanilçi, N., 2006, "Petrography Of The Contact Zone Rocks And Features Of The Skarn Formation Of Karadoru Granitoid Pluton, Yenice", *Çanakkale İstanbul Üniv. Müh. Fak. Yerbilimleri Dergisi*, 19, 183-194, .

Bell, I.A.Wilson, C.J.L., 1981, "Deformation of Biotite and Muscovite - Tem Microstructure and Deformation Model", *Tectonophysics*, 78, 1-4, 201-228.

Boztuğ, D.Yılmaz, O., 1995, "Daday-Devrekani masifi metamorfizması ve jeolojik evrimi, Kastamonu bölgesi, Batı Pontidler, Türkiye", *Türkiye Jeoloji Bülteni*, 38, 33-52.

Delesse, A., 1857, "Etudes sur le metamorphisme des roches.", *Annales des Mines*, 5a:12, 89–288.

Denbrok, S.W.J.Spiers, C.J., 1991, "Experimental-Evidence for Water Weakening of Quartzite by Microcracking Plus Solution Precipitation Creep", *Journal of the Geological Society*, 148, 541-548.

Eren, Y., 1993, "Konya kuzeybatısında Bozdağlar Masifinin otokton ve örtü birimlerinin stratigrafisi (in Turkish)", *Geol Bull Turk*, 36, 7-23.

Eren, Y., Kurt, H., 2000, "The stratigraphical, geochemical and geodynamical modelling of the northeast margin of Menderes-Tauris block", *J Fac Eng Arch Selcuk Univ*, 15, 25-41.

Ernst, R. E., Buchan, K. L., Palmer, H. C., 1995, "Giant dyke swarms: Characteristics, distribution and geotectonic applications", *Physics and Chemistry of Dykes*, 3-21.

Geikie, A., 1889, "II.—The History of Volcanic Action during the Tertiary Period in the British Isles", *Transactions of the Royal Society of Edinburgh*, 35, 1, 21-184.

Göncüoğlu, M.C., Kozur, H.W., Turhan, N.Göncüoğlu, Y., 2000, "Stratigraphy of the Silurian–Lower Carboniferous rock units in Konya area, VIII International Meeting of IGCP 421 in 1st Congresso Iberico de Paleontologia, Evora, 227–228.

Hou, G. T., Li, J. H., Liu, Y. L., Qian, X. L., 2006, "The late paleoproterozoic extension event: aulacogens and dyke swarms in the North China craton", *Progress in Natural Science*, 16, 2, 201-208.

Kerrick, D. M., 1991, "Overview of Contact-Metamorphism", *Contact Metamorphism*, 26, 1-12.

Kocak, K., 1993. The Petrology and geochemistry of the Ortaköy area, Central Turkey. PhD thesis Thesis, Glasgow U., Glasgow, 280

Kocak, K., Leake, B. E., 1994, "The Petrology of the Ortakoy District and Its Ophiolite at the Western Edge of the Middle Anatolian Massif, Turkey", *Journal of African Earth Sciences*, 18, 2, 163-174.

Koçak, K., 2020, "Outlines Of The Mafic Dyke Swarm From Ladik Area, Nw Konya/Turkey, International

Scientific Conference GEOBALCANICA 2020, 79-83.

Kurt, H., 1994, Petrography and Geochemistry of Kadinhani (Konya) area, Central Turkey, Glasgow Uni., Glasgw, 191.

Kurt, H., 1996, "Geochemical characteristics of the meta-igneous rocks near Kadınhanı (Konya), Turkey", *Geosound* 28, 1-22.

Kurt, H., 1997, "Geochemistry of metasedimentary rocks of the Kadinhani (Konya) area, Turkey", *GEOSOUND*, 31, 1-21.

Kurt, H., Asan, K., 1999, "Geological Bulletin Of Turkey - Kadınhanı (Konya) K ' ca zengin metatrakiandezitinin jeokimyası ve petrojenezi", *TJB*, 42, 1, 57-67.

Lowen, K., Meinhold, G., Arslan, A., Gungor, T., Berndt, J., 2019, "Evolution of the Palaeotethys in the Eastern Mediterranean: a multi-method approach to unravel the age, provenance and tectonic setting of the Upper Palaeozoic Konya Complex and its Mesozoic cover sequence (south-central Turkey)", *International Geology Review*.

Okay, A. I., 1986, "High-pressure/low temperature metamorphic rocks of Turkey.", *Geol. Soc. Amer. Mem*, 164, 338-348.

Özcan, A., Göncüoğlu, M. C., Turhan, N., Şentürk, K., Uysal, Ş., Işık, A., 1990. Konya-Kadınhanı-Ilgın dolayının temel jeolojisi (in Turkish), MTA Genel Müdürlüğü Jeoloji Etütleri Dairesi.

Paterson, S. R., Vernon, R. H., Fowler, T. K., 2018, Aureole Tectonics. In: M.K. Derrill (Editor), Contact Metamorphism. De Gruyter, 673-722.

Reverdatto, V.V., Likhanov, I.I., Polyansky, O.P., Sheplev, V.S.Kolobov, V.Y., 2019, The Nature and Models of metamorphism. *Springer Nature Switzerland AG*, Switzerland, 330.

Robertson, A. H. F., Parlak, O., Ustaomer, T., 2021, "Late Palaeozoic extensional volcanism along the northern margin of Gondwana in southern Turkey: implications for Palaeotethyan development", *International Journal of Earth Sciences*, 110, 6, 1961-1994.

Robertson, A. H. F., Ustaomer, T., 2009, "Formation of the Late Palaeozoic Konya Complex and comparable units in southern Turkey by subduction-accretion processes: Implications for the tectonic development of Tethys in the Eastern Mediterranean region", *Tectonophysics*, 473, 1-2, 113-148.

Rosenbusch, H., 1877, Die Steiger Schiefer und ihre Contactzone an der Granititen von Barr-Andlau und Hohwald. . Abhandlungen zur Geol. Specialkarte von Elsass-Lothringen. *Band I, Druch und Verlag von R. Schultz and Co.*, Strassburg.

Taner, M. F., Martin, R. F., Gault, R. A., 2013, "The Mineralogy Of Skarns Of The Spurrite–Merwinite Subfacies, Sanidinite Facies, Güneyce–Ikizdere Area, Eastern Black Sea, Turkey", *The Canadian Mineralogist*, 51, 6, 893-911.

Topuz, G., 2006, "Contact metamorphism around the Eocene Saraycik Granodiorite, eastern Pontides, Turkey", *Turkish Journal of Earth Sciences*, 15, 1, 75-94.

Turner, F. J., Verhoogen, J., 1960, Igneous and metamorphic petrology. International series in the earth sciences. *McGraw-Hill*, New York.

Vernon, R. H., 1975, "Deformation and recrystallization of a plagioclase grain", *American Mineralogist*, 60, 9-10, 884-888.