Quaternary International xxx (2016) 1–10

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Age determination for segments of the North Anatolian Fault (NAF) northern branch by $^{234}U/^{230}Th$ dating of Soğucak (Yalova) range-front travertines, south Marmara, Turkey

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ARTICLE INFO

Article history:
Received 7 March 2016
Received in revised form
2 August 2016
Accepted 7 August 2016
Available online xxx

Keywords:
Range-front type travertine
U/Th dating
North Anatolian fault
Active tectonics
Yalova

ABSTRACT

The Soğucak travertine occurrences developed along north segment of the North Anatolian Fault (NAF) in Yalova province, Marmara Region, Turkey. The range-front type travertines outcropping over an approximately 1 km^2 area with 20–40 m thickness are middle-thick bedded and back-tilted southward or horizontally. Lithology of the travertines includes physolite, stalactites-stalagmites, cave pearls, sharp pebble carbonate nodules, spherical-roller-intricate shapes and laminated banded travertines. Geochemical analysis was performed on six samples of the travertines. The samples showed high calcite composition (averagely 98%) and Mg carbonite content varying from 0.87 to 1.33%. The travertines were deposited by means of normal faults as indicated by structural and morphological relationship with active tectonics. $^{234}U/^{230}Th$ dating of the travertines provided an age range from 61.318 (±3.091) to 231.944 (±141.902) ka. Findings show that the travertine deposition and deployment of faults in the region occurred approximately at 231 ka, corresponding to Middle Pleistocene. Therefore, the age of both travertines and NAF was determined as Middle Pleistocene.

1. Introduction

Travertines have played an important role in recent years especially in relation to active tectonic studies in the West Anatolian graben systems of Turkey. Investigations on travertines in West Anatolia were initiated by Altunel and Hancock (1993a, b), Altunel (1994) and Çakır (1996, 1999) and were continued by Özkul et al. (2002), Dilsiz et al. (2004), Altunel and Karabacak (2005), Uysal et al. (2007), and Selim and Yanık (2009). Studies related to active tectonics in the western part of Turkey are listed as follows. Temiz (2012) conducted a study about determining the age of the active Manisa Fault (West Turkey) reactivation by using U/Th dating method of carbonate precipitates. Similarly, De Filipps et al. (2012) investigated the growth of fissure ridge travertines from geothermal springs of Denizli Basin, western Turkey. Also, the comparison of the Quaternary travertine sites in the Denizli extensional basin based on their depositional and geochemical data was carried out by Özkul et al. (2013). Additionally, Brogi et al. (2014) studied the evolution of a fault-controlled fissure-ridge type travertine deposit in the western Anatolia extensional province with an example of the Çukurbağ fissure-ridge in Pamukkale, Turkey.

The study area in this paper is located in the southeast Marmara Region, NW Turkey near the village of Soğucak, which is 7 km from Yalova city, regional capital of Yalova province. The morphology of the region has an uplift area (Armutlu Peninsula) to the northwest, a depression area (İznik Lake) in the southeast and a northern segment of the southern branch of the North Anatolian Fault (NAF) in the southward and northern branch of the NAF in the Sea of Marmara (Gazioğlu et al., 2002) (Fig. 1). The travertine occurrences (hereafter called Soğucak travertines) are located between two active fault branches of the NAF, almost in the mid-section of the Armutlu Peninsula. The first objective of this study was to find the occurrence mechanism of the travertines and their relationship with the NAF and its segments by means of field and laboratory data on a regional scale. The second objective was to determine the

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http://dx.doi.org/10.1016/j.quaint.2016.08.035
1040-6182/

Please cite this article in press as: Selim, H.H., et al., Age determination for segments of the North Anatolian Fault (NAF) northern branch by $^{234}U/^{230}Th$ dating of Soğucak (Yalova) range-front travertines, south Marmara, Turkey, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.08.035

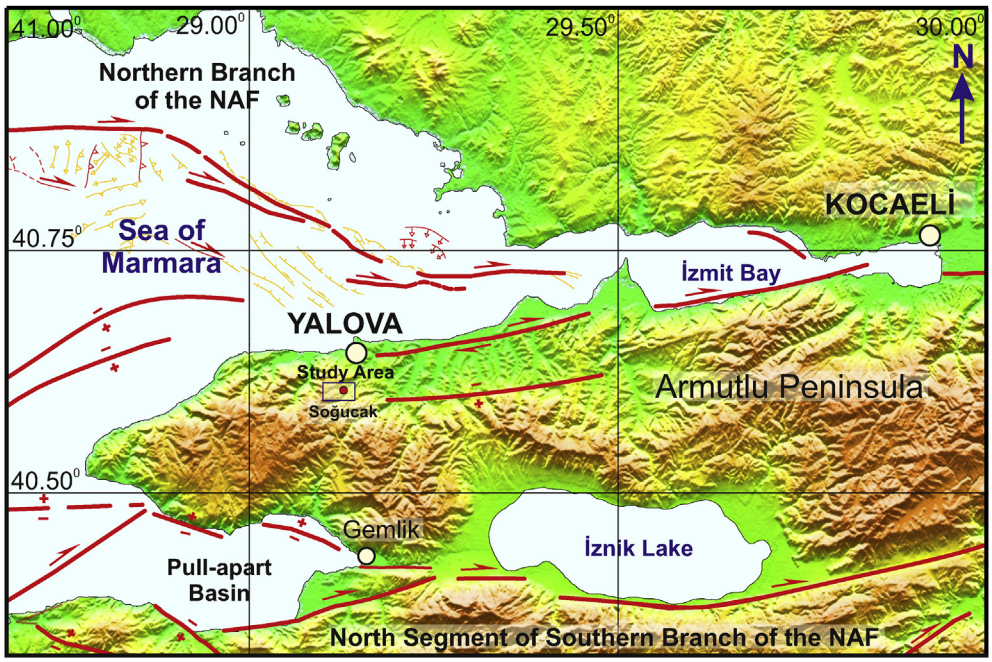

Fig. 1. Location map of study area showing north segment of southern branch and northern branch of the North Anatolian Fault (NAF) (İmren et al., 2001; Beyhan et al., 2009).

age of the NAF in the region using the U/Th dating method. There are several studies related to U/Th dating of geological deposits in different locations of the world. Muhs et al. (1989) applied the uranium-trend dating method for the southern California marine terrace deposits. Sturchio et al. (1994) performed uranium-series age determinations by mass spectrometric methods for travertines and associated carbonate veins to date the last glaciation in the Northern Yellowstone Area, Wyoming-Montana. Díaz and Hernández-Enrile (2001) employed U/Th dating method for the terrace-mound, fissure-ridge, eroded sheets and range-front travertine deposits to characterize paleoseismic activity along an active oblique-slip Alhama de Murcia fault in Betic Cordillera, Spain. Temiz et al. (2009) applied U/Th dating of fissure ridge travertines from the Kırşehir region in Central Anatolia, Turkey and evaluated their structural relations and implications for the Neotectonic development of the Anatolian block. Sierralta et al. (2010) investigated uranium-series dating of travertine from Sütto and evaluated implications for reconstruction of environmental change in Hungary. Nuriel et al. (2012) presented results from a microstructural, geochemical, and geochronological study of calcite precipitates associated with striated fault planes from the Dead Sea fault zone in northern Israel by using U-Th dating of samples from three adjacent fault planes. Gao et al. (2013) studied the travertine deposits near the Rongma hot springs in northern Tibet, China by U-series dating.

The Soğucak travertines are range-front type travertine occurrences. Travertines located on the hanging walls of normal faults were named as “range-front travertines” by Chafetz and Folk (1984). Additionally, many banded travertine occurrences developed within the parent rock extending parallel to the strike of normal faults in the study area. Altunel and Hancock (1993a, b) interpreted these banded travertine occurrences as hot water springs depositing the range-front type travertine occurrences. In addition, there are also cold water springs at different points along the normal faults.

The NAF and its segments constantly deform the morphologic and geologic features in the southern Marmara sub-region (Gürbüz and Gürer, 2008; Gazioğlu et al., 2010; Selim and Tüysüz, 2013; Selim et al., 2013). The Soğucak travertine occurrences in segments of the NAF to the south of Yalova are evidence of active faulting in the Neo-tectonic period. İmren et al. (2001), Le Pichon et al. (2001) and Şengör et al. (2005) indicate that the age of the NAF in the Marmara Region is 200 ka, based on geological and stratigraphic data. For the first time, this study utilized U/Th dating to determine a specific age for the Yalova Fault of the NAF and at the same time reveals the occurrence mechanism of travertines in the region.

2. Geological setting

The structure, geology and morphology of the southeast Marmara Region present a mosaic of morphotectonic elements bordered by active faults. The region includes lithologically different rocks of the Palaeotectonic and Neotectonic periods (Yiğitbaş et al., 1999, 2004). The study area also contains various rocks from Mesozoic to Quaternary (Fig. 2). To the south of Yalova, the Neogene and Quaternary deposits overlay the Mesozoic basement unconformably (Fig. 3).

The basement rocks consist of metamorphic rocks with Mesozoic green schist facies and volcano-clastics (lava-tuff-agglomerate). The first cover unit (Yalova formation) on the basement rocks, with clear angular unconformity, is Upper Miocene-Pliocene pebble stone, sandstone, mudstone, marl and coal intercalation deposited in a lake-stream environment. The unit presents red, yellow and greenish colors with clear cross-bedding (Rückert-Ülkümen and Yigitbaş, 2007). The upper part of the unit mainly consists of sandstone, mudstone and marl sequence. This cover unit was deposited before the NAF and the age of the unit correlates with Late Miocene-Pliocene basins located in the west Anatolia Region (Gürer et al., 2003, 2006; Gürbüz and Gürer, 2009). The Aktoprak formation, consisting of white beige mid-thin bedded limestone and marl, overlies the Yalova formation conformably.

The Quaternary units consist of travertines, talus, alluvial fans and alluvium. The travertines cover an area of approximately 1 km^2. The Soğucak travertine is of white-beige color, mid-thick bedded of 20–40 m thickness, cavernous, and level or tilted to

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