Çankaya Üniversitesi Fen-Edebiyat Fakültesi,
Journal of Arts and Sciences Sayı: 11 / Mayıs 2009

Dating of Active Main Fault Sample by use of Infrared Stimulated Luminescence

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Abstract

The optical dating technique is increasingly using to provide for the age assessment of detrital sedimentary deposits. This technique has been demonstrated to obtain accurate deposition chronologies for up to 800 ka although 150 ka is more typical. In this study it is aimed to determine the dating of Marmara fault sample using infrared stimulated luminescence (IRSL) technique and to test the luminescence signals bleaching during the fault movement. The sample was taken from Marmara Sea at the north of Turkey. The multiple-aliquots and single-aliquot procedures were used to obtain the equivalent dose (ED). The age found as 5800±390 year refers to the last deposition of the sediment. This work indicates the importance of environmental changes for the dating of geomorphologic processes and it is one of the novel applications of IRSL dating technique.

Keywords: IRSL, Optical dating, Fault sample, Equivalent dose, Dose rate, Marmara Sea.

Infrared Uyarmalı Lüminesans ile Aktif Ana Fay Örneklerinin Tarihlendirilmesi

Özet

Optik tarihlendirme tekniği birikinti sedimentlerin tarihlendirilmesi için gittikçe artan bir şekilde uygulanmaktadır. Bu teknikte, 150 ka'ya kadar ölçümler tipik olsa da 800 ka'ya kadar da doğru birikinti kronolojisi elde edilmektedir. Bu çalışmada Infrared Uyarmalı Luminesans tekniği kullanarak Marmara fay örneklerinin tarihlendirilmesi ve fay hareketi esnasında lüminesans sinyalinin sıfırlanmasının test edilmesi amaçlanmıştır. Kullanılan örnek Türkiye'nin kuzeyindeki Marmara denizinden alınmıştır. Eşdeğer dozun elde edilmesinde çok tablet ve tek tablet yöntemleri kullanılmıştır. Alınan sedimentlerin son birikinti süresi 5800±390 yıl olarak bulunmuştur. Bu çalışma jeomorfolojik süreçlerin tarihlendirilmesinde çevresel değişikliklerin önemini göstermektedir ve IRSL tarihlendirme tekniğinin yeni uygulamalarından biridir.

Anahtar Kelimeler: IRSL, Optik tarihlendirme, Fay örneği, Eşdeğer doz, Doz hızı, Marmara denizi.

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Introduction

Huntley et al. (1985) were the first to use the Optically Stimulated Luminescence (OSL) technique for the dating of sediments. Hütt et al. (1988) first showed that it was possible to stimulate a luminescence signal from feldspars using optical stimulation in the near infrared.

Recent advances in luminescence dating have led to increasing applications of the technique to sediments from the depositional environmental samples. Nowadays this technique is used in interdisciplinary works providing chronological data for deposit. In the applications of luminescence to the dating of geological materials, luminescence signals are used to estimate the amount of ionizing radiation to which the sample has been exposed since burial (e.g. Aitken 1998). This quantity is named as the equivalent dose (ED). There are two potential approaches to measure ED namely multiple-aliquots and single-aliquot. Recently much effort has been expended to determine this quantity using several procedures (e.g. Wintle 1997; Jain et al. 2003; Duller 1995; Stokes 1999; Tanır et al. 2000, 2005; Hütt & Jaek, 2001). The ED determination for the sample used in this study has been carried out using both multiple aliquots and single aliquot procedures.

Marmara sample used in this study was collected from the North Anatolian Fault (NAF) zone, one of the most active zones in the world. NAF is a natural laboratory for researchers on faulting and earthquake studies. Because of stream in Marmara Sea, the age of this zone is not very clearly known. It is noticed that the luminescence ages may be indicated that the last earthquake occurred. Knowledge on large earthquakes ($M \geq 7.0$), geology and fault kinematics is used to analyze conditions that favor isolated seismicity, clustered earthquakes or propagating sequences along the North Anatolian Fault (NAF) and the Sea of Marmara pull-apart. Earthquakes along the NAF tend to occur where previous events have increased the stress, but significant isolated events in the Sea of Marmara region (1894, 1912) have occurred, suggesting the secular loading has been the determining factor. Non-uniform stress relief during the 18th century sequence explains the occurrence of isolated events in Marmara in 1894 and 1912. As a consequence, the well known 20th century sequence along the NAF has not propagated as a sequence across the Sea of Marmara. The most linear part of the NAF across northern Turkey behaves as a single fault segment, accumulating stress during hundreds of years and rupturing entirely during very short periods. The Marmara pull-apart fault system behaves as a major geometric complexity, stopping or delaying the progression of earthquake clustering and propagating sequences. Fault zones interact with each other at a very large scale (Pondard et al., 2007).

Recent advances in luminescence dating have led to increasing application of the technique to sediments from a wide range of depositional scenarios. To determine the accurate age for these sediment samples is an important effort for palaeoenvironmental reconstruction that can be undertaken based on the age chronology. Because of this, the accuracy of ED determination has to be proven in different depositional environments.

For this reason in the work, the sample that was collected from the Sea of Marmara was investigated to obtain the ED using both the multiple-aliquots and the single-aliquot procedures. This work may help to relatively interpret the fault event in Marmara, and to understand the deposition chronologies of sediments in the floor of Marmara Sea.

Experimental Procedures

Apparatus

The apparatus used (OSL dating system 9010 reader) has been developed by Spooner et al. (1990). All data were collected using an IRSL add-on unit for the 9010 automated readers, which uses TEMT 484 IR diodes run at 40 mA giving a power of about 30 mW/cm^2 at the sample. Luminescence was detected using a Thorn EMI 9235 QA coupled to filters Schoot BG 39 (transmission band 340-620nm) photomultiplier (PM) tube. The α-contribution was measured using an Elsec 7286 low-level alpha counting system using an EMI 6097 B, photomultiplier. The background was typically 40cps as compared to the sample signal of a few thousand cps.

Geological Zone

The sample has been taken from Marmara Sea at the north of Turkey (Figure 1). The north Anatolian fault (NAF) in the sea of Marmara originated some 2×10^5 year ago (Pichon et al. 2001), by cutting across the older basin fabric generated by a dominant NNE-SSW extension before it began taking up major mention in the Pliocene (e.g. Pichon et al. 2001). Its tectonics was poorly known in its high potential for producing large earthquakes.

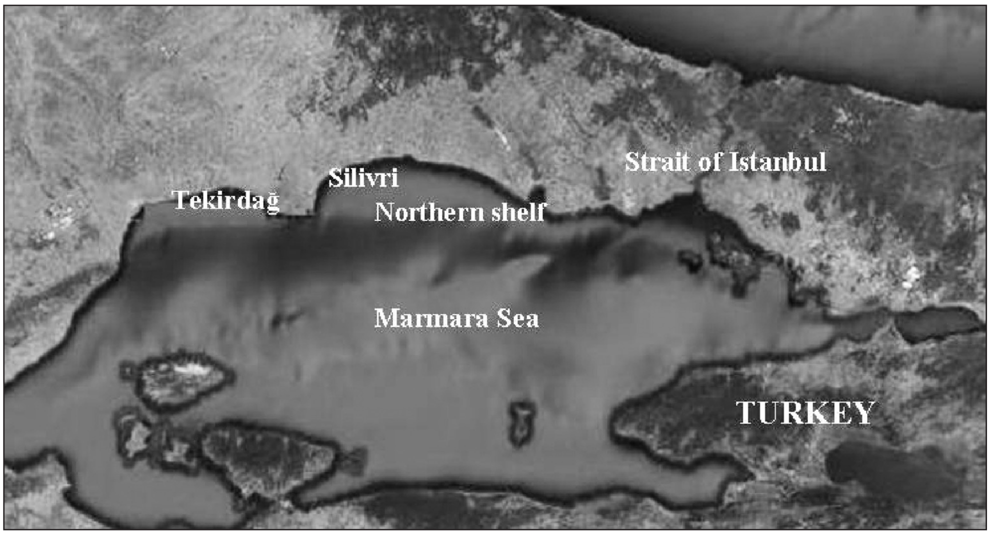

Figure 1. The northern shelf of the Marmara Sea at the north of Turkey.

Sample Preparation

All laboratory processes of sample preparation and luminescence measurement were carried out in subdued red light. The samples were gently crushed to suitable size with a agate mortar after removing 2cm outlayer and the core has been obtain. Thus, the core was extracted from sample for dating. All raw samples were treated with 10% HCl for 40 min and 40% H_2O_2 for 20 min at 22 ^oC to remove carbonate and organic matter, sequentially. The sample was dried and sieved and then sedimentation was used to select the size of fine grains (<20μm): The sample was washed in distilled water then in acetone and a suspension of grains was obtained. Then the grains were suspended in acetone and mounted with silicone oil on aluminum discs of 9.9mm diameter and 0.5mm thickness as aliquot for measurements. The alpha counting was performed by spreading a thin layer of dried, powdered sample on a 42mm diameter ZnS screen, positioned in a sealed Plexiglas holder. The potassium content of the sample is 2.287%.

Determination of Equivalent Dose

To see the sample's response to IR light, at first one aliquot of sample was illuminated, from which the bleach time of the sample was specified. The IRSL decay curve from the sample is shown in Figure 2. It is seen from Figure 2 that the traps were emptied in 200 s.

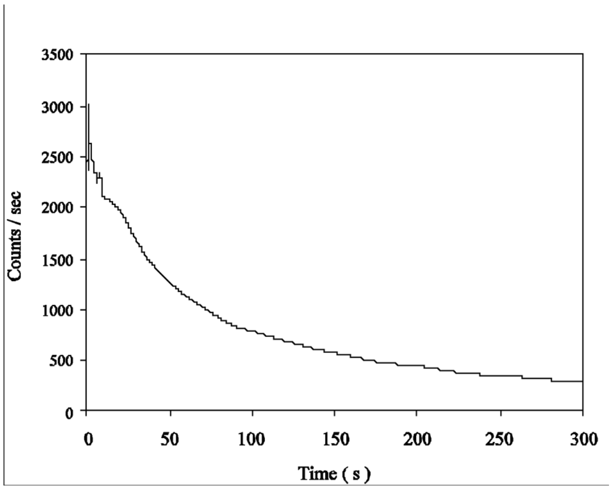

Figure 2. IRSL decay curve of Marmara fault sample. The bleach time of the sample was specified from this graph.

For OSL dating, it is important to select a preheating procedure which is necessary to eliminate the thermally unstable IRSL components. The preheat procedure of 5 min at

220 °C on the basis of a natural dose/(natural+additive) dose 'plateau' test has been used for the multiple-aliquot dating, as originally developed by Rhodes (1988). Also various preheat conditions have been proposed, e.g., 10 min at 220 °C (Tanır et al., 2000), 1 min at 220 °C (Williams et al., 2006) and 3 min at 205 °C (Atlıhan and Meriç, 2008). In this study, all the aliquots were preheated at 220 °C for 2 minutes after irradiated.

In order to determine the equivalent dose using multiple aliquots procedure the four sets of aliquots (there are four aliquots in each set) were prepared and exposed to 0, 4, 8 and 16 Gy beta doses. IRSL growth curve was plotted by taken the total IRSL count in 300s and then extrapolated to dose axis to determine ED (Figure 3).

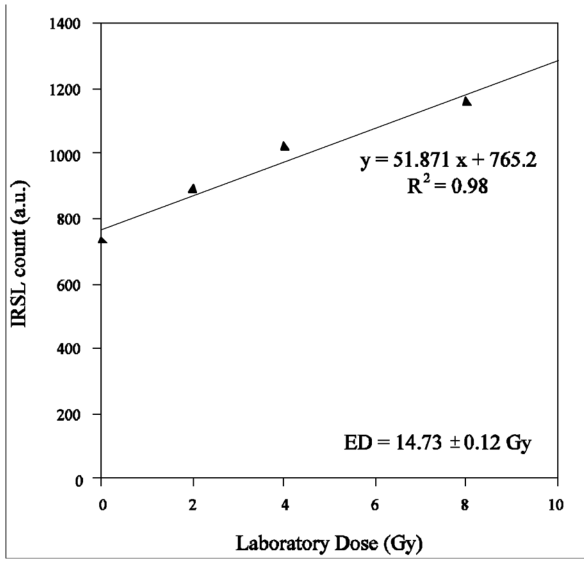

Figure 3. The ED determination using multiple aliquots procedure for only four aliquots. ED=14.73±0.12 Gy.

In the single aliquot procedure, the three aliquots were prepared. They were given 0, 4, 8 Gy beta-doses and the Single Aliquot Regeneration Additive Dose (SARA) procedure was applied by excepting the step for the calculation of D (Calculated Dose) in the original SARA (e.g. Duller 1991). The complete IRSL signal from each aliquot was measured to define regeneration signal level: $L(\beta_1)$, $L(\beta_2)$, $L(\beta_3)$. The ED was calculated by plotting the line against laboratory β-doses-calculated doses (Figure 3). The details of the steps for this procedure can be seen in the work carried out by Tanır et al. (2005). It can be seen from the Figure 3 & 4 that the ED values are 14.73±0.12Gy and 14.86± 0.14Gy respectively.

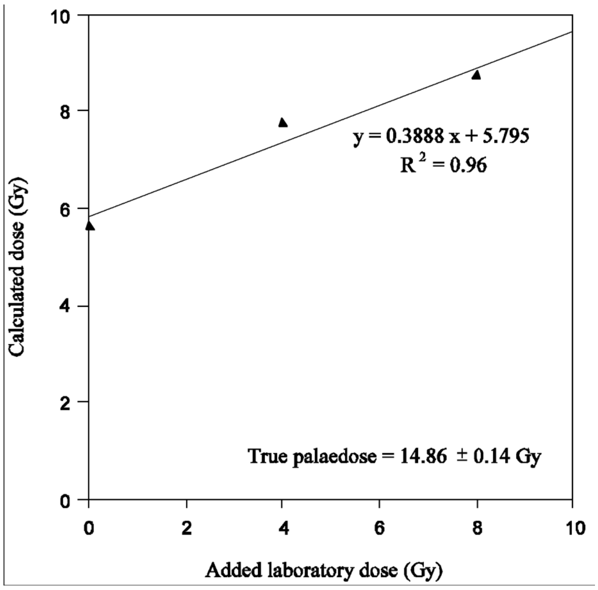

Figure 4. The obtained D-values were plotted as a function of the added doses given to the aliquots before measurements of the IRSL signal. The regression line is extrapolated to find the intercept with the x-axis, which is taken to be the true. ED= 14.86±0.14 Gy, namely true palaedose.

Determination of Annual Dose-Rate and Age

The annual dose was calculated from the concentrations of U, Th by using α-spectrometer and K by atomic absorption. An α-efficiency of 0.07 was used Ulusoy (2004). The contribution of cosmic rays was neglected and water attenuation was considered (moisture content: 100%). The calculation of the dose-rate of Marmara Sample was performed by AGE code which is included into the OSL-9010 dating system. The annual dose and age values were also given in Table 1.

Table 1. The estimate of age for Marmara sample. Th and U contents are 10.41 and 0.43 counts/1000 s respectively. K content is %2.287. Total random error is %3.7; total systematic error is %6.2 and total error %6.6.

Methods	ED (Gy)	Annual-dose (Gy/1000year)	Age(year)
IRSL multiple-aliquot	14.86±0.14	2.528	5880±390
IRSL single-aliquot	14.73±0.12	2.528	5830±390

In principle the age is obtained from the equation Age = ED / Annual dose-rate. The dose-rate represents the rate at which energy is absorbed from the flux of nuclear radiation. Dose-rate measurement is evaluated by assessment of the radioactivity (U, Th, and K) of the sediment sample and the age of the sample is found.

Results and Discussion

The multiple-aliquots growth curve coincides very well with that from single-aliquot procedure. This agreement gives us confidence in the reliability of the growth curves from both procedures. The age found in this work refers to the last deposition of the sediment and provides a time scale for recurrent surface ruptures on a fault. The luminescence signals bleaching during the fault movement can be tested by using IRSL. As seen from Table 1, according to this work the sediments from NAF sample in the 230 cm depth have started to accumulate approximately 5800±390 year ago or signals from them has been zeroed during the fault movement 5800±390 years ago. That is dating value is the burial time of the sample from NAF.

Assuming total zeroing, the level of IRSL measured in the sediment sample relates to charge accumulation only since the last depositional cycle. Luminescence age help to provide a time scale for recurrent surface reptures on a normal fault in the Marmara Sea.

In the IRSL dating technique for many sedimentary environmental, it can be safely assumed that the geological IRSL is completely zeroed during transport and depositional and the gross IRSL measured in the laboratory is related entirely to charge trapped during the burial period (e.g. Stokes 1999)**.**

Optical Stimulated luminescence dating method provides an accurate index of the period of time since the deposition in many sedimentary environments. It is powerful tool in geomorphologic research, providing age control for sediments in range 0-150.000 year. To determine the accurate age for sediment samples is an important effort for palaeoenvironmental reconstruction. Optical dating method allows direct assessment of depositional dynamism.

The IRSL signals present in sedimentary feldspars are being increasingly understood and new dating protocols are being developed. We believe that this study can contribute to the systematic of IRSL investigations on dating. It is necessary to increase the number of dating studies of geological samples.

Acknowledgements

This work was supported by the project of Gazi University numbered F.E.F. 05/2003-19 and we thank TUBİTAK for collecting the sample used in this study.

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