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SEDIMENTATION RATES IN THE LAKE QATTINAH USING ^{210}Pb AND ^{137}Cs AS GEOCHRONOMETER

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Abstract: The constant rate of supply (CRS) of excess ^{210}Pb model was successfully applied to assess ^{210}Pb data of two sediment cores from the lake Qattinah, Syria. Gamma spectrometry was used to determine ^{137}Cs and ^{210}Pb activity concentrations. The bottom of the cores was ^{210}Pb-dated to years 1907 and 1893. The accumulation rates were determined using ^{210}Pb method and found to vary similarly in both cores from 0.10 ± 0.01 to 3.78 ± 0.57 kg m^{-2} y^{-1} during the past century. ^{137}Cs was used as an independent chronometer. The two distinct peaks observed on the ^{137}Cs record of both cores, corresponding to 1965 and 1986, have allowed a successful validation of the CRS model.

Keywords: ^{210}Pb, ^{137}Cs, dating, Lake Qattinah, sediments.

1. INTRODUCTION

Age-dated lake sediments are commonly used to study historical changes in the atmospheric and surrounding environment. Lake sediments are known to provide reliable record since the majority of pollutant elements are retained in sediments (Mihelčić *et al.,* 1996; Gelen *et al.,* 2003; Mast *et al.*, 2010).

The ^{210}Pb method is widely used to characterize sediments on relatively short time scale (<150 years) (Evans and Rigler, 1980; Appleby, 2008; Kamman and Engstrom, 2002; Battarbee *et al.*, 1985; Turner and Delorme, 1996; Begy *et al.*, 2011; Gu *et al.*, 2011; Sabaris and Bonotto, 2011; Gharibreza *et al.*, 2013). ^{210}Pb, having a half life time of 22.3 years, is a member of the ^{238}U series that is distributed fairly uniformly across the Earth. The dating method is based on the release of ^{222}Rn gas (daughter of the ^{226}Ra) from the soil to the atmosphere. The short-lived ^{222}Rn (3.82 days) decays to ^{210}Pb, that returns to earth surface or water reservoir within weeks as a solid fallout. The ^{210}Pb activity is divided into two parts, the supported ^{210}Pb produced in-situ by the natural decay of ^{226}Ra, and the unsupported ^{210}Pb coming from the atmospheric fallout.

The age of the sediment layer can be determined by means of the unsupported part. When a sediment layer is buried under newer depositions, the unsupported activity declines following the natural decay law. Therefore, the present activity C_{excess} (measured) can be written as a function of the age and the initial activity at the moment of burial $C_{excess}(0)$ (**Eq. 1.1**; Appleby, 2008).

$$C_{excess}(t) = C_{excess}(0) \times e^{-\lambda t} \tag{1.1}$$

The key point is to have an estimation of the initial activity which allows determining the age of the sediment with a good accuracy. Two models are commonly used to resolve this issue. The constant rate of supply (CRS)

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model that assumes a constant unsupported ^{210}Pb flux to the sediment and allows a variable sediment rate (Appleby and Oldfield, 1978; Appleby, 2001). The second model is the CIC model (Shukla and Joshi, 1989; Godoy *et al.,* 1998), which assumes a constant initial concentration. In this model, the sediment occurs at a constant flux and then sedimentation rate is also constant.

^{210}Pb model can be validated by using independently determined dates from records of the artificial ^{137}Cs fallout radionuclides ($T_{1/2}$ of 30.2 years) (Appleby, 2008; Pennington *et al.*, 1973). ^{137}Cs appeared in the environment since the early 1950s following the first nuclear weapon testing. Two maxima can be identified, the first about 1965 caused by nuclear weapon testing, and the second corresponding to the Chernobyl accident in 1986 (Mihelčić *et al.,* 1996; Appleby, 2008).

The aim of this work is to determine the age and the accumulation rates of the sediment layers in the lake Qattinah. The resulted ^{210}Pb chronology was successfully validated by reference to chronostratigraphic dates determined from records of fallout ^{137}Cs.

2. MATERIAL AND METHODS

Core sampling

Lake Qattinah is a lake near Homs, Syria, fed by the Orontes River. The lake is located 15 km from the city of Homs and it extends over 60 km^2. Cored sediment samples have been collected from two sites (**Fig. 1**), Q1 (34°38'34.15"N, 36°34'39.76"E) and Q2 (34°39'16.15"N, 36°36'19.96"E), during the rainy season (January 2011) using a gravity corer with a diameter of 7.20 cm. The first core (Q1) was collected from the deep part of the bay (30 m) for a length of 58.50 cm. The second one (Q2) was collected from shallow water (10 m) for a length of 51.00 cm. The cores were sectioned into 1.50 cm increment in the laboratory using a core extruder.

Analytical methods

All samples were crushed and sieved in a 90 µm sieve, dried for 72 hours in a controlled environment at 105°C in order to eliminate the humidity, and homogenized prior to analysis. Wet and dry massed were measured before and after drying and the density was calculated. Forty grams of each sample were filled in PVC cylindrical radon-tight containers (volume 27 cm^3) and stored for two weeks. The samples were then measured by gamma spectrometry (Eurysis systems, Lenglshiem, France) using high resolution (FWHM equals to 2 keV at 1.33 MeV), high relative efficiency (80%) and low background HpGe detectors to determine ^{226}Ra and ^{137}Cs. ^{226}Ra activity was determined by measuring its gamma emitting daughters, ^{214}Pb (295 keV) with an intensity 18.2% and ^{214}Bi (1764 keV) with an intensity 4.98%. Efficiency calibration was performed using CRM QCY48.

^{210}Pb activity was determined using gamma spectrometer (Bruker Baltic Ltd.) consisting of an HpGe N-type detector with a relative efficiency of 60% and FWHM of 1.2 and 2.3 at 122 and 1332 keV, respectively, connected to analytical software InterWiner-07 (Eurisys Measures). Samples were prepared as cylindrical shape ($r = 2.5$ cm, and $h = 1.1$ cm). A diluted CRM QCYB40 portion was used for calibration. The ^{210}Pb is measured directly through its gamma 46.5 keV line with an intensity of 4.2%. For self-absorption correction of the ^{210}Pb gamma-ray line, three factors were considered, namely composition, density and sample thickness. The details of the measurement of the activity and the combined uncertainty can be found elsewhere (Al-Masri *et al*., 2010), here we just remind the basic formulas. The activity concentration of ^{210}Pb is usually calculated using the following equation:

$$A = \frac{N}{E \times m \times t \times I_\gamma} \tag{2.1}$$

where N indicates the net counts under the peak, E is the photoelectric effect peak efficiency, m is the sample mass, t measurement time. I_γ is the gamma-ray emission probability. Self-absorption can be included in **Eq. 2.1** as follows:

$$A = \frac{N}{E \times m \times t \times I_\gamma \times F_1 \times F_2} \tag{2.2}$$

where F_1 is the thickness correction factor; F_2 is the density correction factor.

The combined uncertainty in ^{210}Pb determination can be given by the following equation:

$$\left(\frac{\sigma_A}{A}\right)^2 = \left(\frac{\sigma_N}{N}\right)^2 + \left(\frac{\sigma_E}{E}\right)^2 + \left(\frac{\sigma_t}{t}\right)^2 + \left(\frac{\sigma_m}{m}\right)^2 + \left(\frac{\sigma_{I_\gamma}}{I_\gamma}\right)^2 + \left(\frac{\sigma_{F_1}}{F_1}\right)^2 + \left(\frac{\sigma_{F_2}}{F_2}\right)^2 \tag{2.3}$$

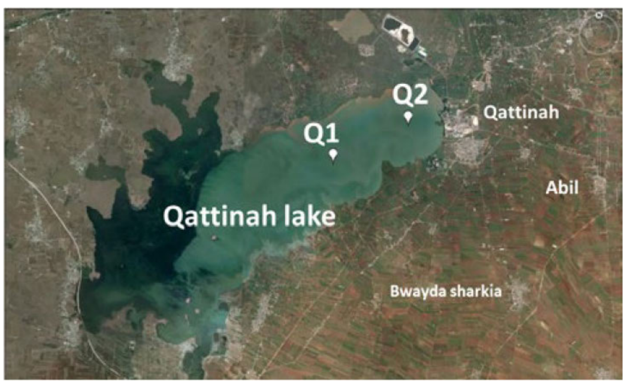

Fig. 1. *Map of the Lake Qattinah showing the sampling sites.*

3. RESULTS AND DISCUSSION

^{210}Pb dating

Fig. 2 shows the distribution of the excess ^{210}Pb along the depth for Q1 and Q2. Both distributions do not follow an exponential decrease, which indicates a variable sedimentation rate. Therefore, the CIC model could not be applied since it assumes a constant sedimentation rate with a monotonously decreasing excess of ^{210}Pb. Consequently, the CRS model was used for determining the sedimentation rate and the age of the sediment layers.

The calculations of the CRS model for cores Q1 and Q2 are detailed in Tables 1 and 2, respectively. The oldest layer of Q1 (58.50 cm) and Q2 (51.00) have been dated to years 1907 and 1893, respectively. The accumulation rate of the top layers corresponding to the surface sediments showed remarkably increased values. This could be attributed to the disturbance from waves or currents, or to certain activity of invertebrates (Hancock and Hunter, 1999).

The age of sediment layers, obtained from the CRS model, is shown in Fig. 3 as a function of the depth. A good agreement can be seen between the ages of sediments layers having the same depth in both cores.

Fig. 4 shows that the variation of the accumulation rates with the date of the sediment layers are very similar in Q1 and Q2. In both cores, the accumulation rates have increased with time. For the oldest layers (<1977) the average accumulation rate was 0.13 ± 0.02 (0.16 ± 0.02) kg m^{-2} y^{-1}, while it has increased to about 0.46 ± 0.07 (0.41 ± 0.06) kg m^{-2} y^{-1} during the period between 1977 to 2000 for Q1 (Q2). Recent layers have monitored a rapid increase in the accumulation rate to reach a value of 3.43 ± 0.55 (3.78 ± 0.57) kg m^{-2} y^{-1} with an average of 1.71 ± 0.27 (1.59 ± 0.26) kg m^{-2} y^{-1} for Q1 (Q2). These values of accumulation rates can be compared with recent studies (Begy *et al.*, 2011; Gu *et al.*, 2011; Sabaris and Bonotto, 2011; Gharibreza *et al.*, 2013). Also the increase of the accumulation rate in the newer layers has been observed. For example, in the work of Gharibreza *et al.* (2013) pre-1950 sediment accumulation rate was found to be about 0.6 ± 0.2 kg m^{-2} y^{-1}, and it increased to 2.0 ± 1.0 kg m^{-2} y^{-1} in recent layers.

This change could be related to the increasing of population, human and industrial activities in this area. Actually, at the beginning of the 1970's the region witnessed the construction of cement and fertilizer factories, upgrade of the oil refinery and recently the operation of industrial zone.

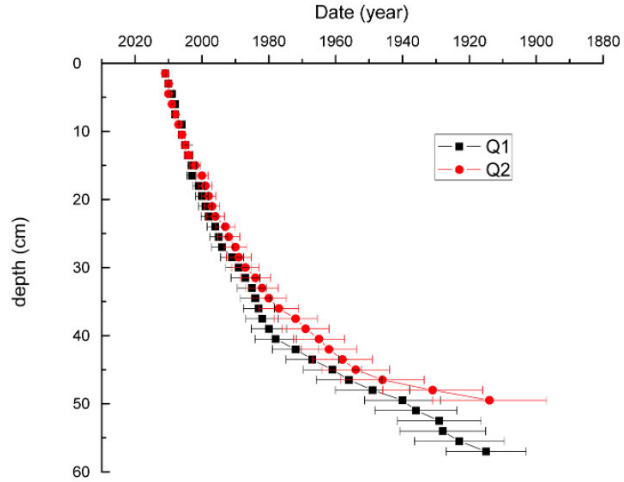

Fig. 3. *^{210}Pb-estimated age of sediment layers versus the depth. Error bars represent uncertainties based on the propagation of the combined uncertainty in ^{210}Pb.*

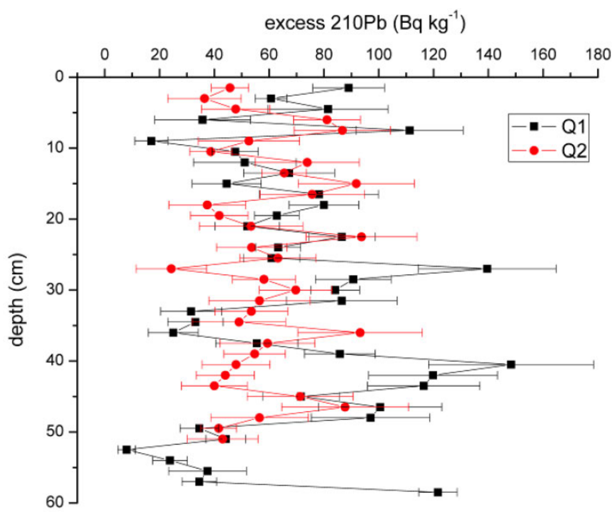

Fig. 2. *The profile of excess ^{210}Pb.*

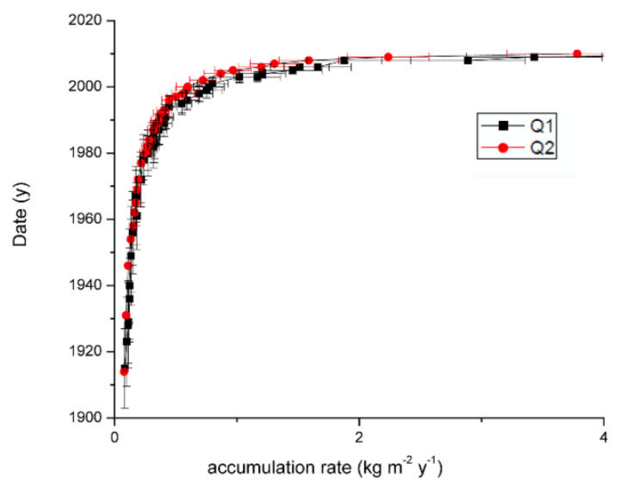

Fig. 4. *The variation of accumulation rate with the date of sediments layers. Error bars represent uncertainties based on the propagation of the combined uncertainty in ^{210}Pb.*

Table 1. *CRS analysis data for the calculation of the age and accumulation rates of sediment in each layer of core Q1.*

Depth (cm)	Total ^{210}Pb (Bq kg^{-1})	Supported ^{210}Pb (Bq kg^{-1})	Excess ^{210}Pb (Bq kg^{-1})	Mass flux (kg m^{-2})	Inventory Excess ^{210}Pb (Bq m^{-2})	Cumulative Inventory Excess ^{210}Pb (Bq m^{-2})	Estimated year (y)	Date (y)	Accumulation rate (kg m^{-2} y^{-1})
1.5	96 ± 12	7.2 ± 1.5	89 ± 13	8.8	779.8	24792.7	1.03 ± 0.21	2011	8.5 ± 1.4
3.0	84.0 ± 5.0	23.3 ± 0.8	60.7 ± 5.8	9.1	550.4	24012.9	1.77 ± 0.32	2010	5.11 ± 0.82
4.5	104 ± 20	22.4 ± 1.9	82 ± 22	10.0	812.9	23462.5	2.91 ± 0.51	2009	3.43 ± 0.55
6.0	58 ± 15	22.3 ± 2.2	36 ± 18	9.9	351.3	22649.6	3.41 ± 0.53	2008	2.89 ± 0.47
7.5	122 ± 19	10.3 ± 0.9	111 ± 20	9.3	1032.8	22298.3	4.94 ± 0.85	2008	1.88 ± 0.30
9.0	30.0 ± 5.0	13.0 ± 1.0	17.0 ± 6.0	8.6	145.6	21265.4	5.16 ± 0.83	2006	1.66 ± 0.27
10.5	69.6 ± 6.9	22.0 ± 1.5	47.6 ± 8.4	8.8	417.2	21119.9	5.80 ± 0.88	2006	1.51 ± 0.24
12.0	77 ± 17	26.2 ± 1.8	51 ± 19	9.6	488.9	20702.7	6.6 ± 1.1	2005	1.46 ± 0.24
13.5	94 ± 15	27.0 ± 1.5	67 ± 17	9.1	614.1	20213.8	7.6 ± 1.2	2004	1.21 ± 0.19
15.0	70 ± 10	25.0 ± 2.0	45 ± 13	9.7	429.7	19599.7	8.3 ± 1.3	2003	1.17 ± 0.19
16.5	97 ± 20	18.6 ± 1.7	78 ± 22	9.8	764.8	19170.0	9.6 ± 1.5	2003	1.02 ± 0.16
18.0	89 ± 11	9.3 ± 1.4	80 ± 13	8.7	693.6	18405.2	10.8 ± 1.7	2001	0.80 ± 0.12
19.5	67.3 ± 7.2	4.5 ± 0.9	62.8 ± 8.1	9.2	575.3	17711.5	11.9 ± 1.9	2000	0.77 ± 0.12
21.0	62 ± 10	9.9 ± 1.3	52 ± 12	9.7	502.0	17136.3	12.8 ± 2	1999	0.75 ± 0.13
22.5	93 ± 10	6.7 ± 1.3	87 ± 12	10.1	872.9	16634.3	14.6 ± 2.3	1998	0.69 ± 0.11
24.0	75.7 ± 7.3	12.5 ± 0.9	63.3 ± 8.2	9.4	592.3	15761.4	15.8 ± 2.5	1996	0.59 ± 0.09
25.5	72.9 ± 9.1	12.0 ± 1.2	61 ± 10	9.4	570.2	15169.1	17 ± 2.7	1995	0.55 ± 0.08
27.0	150 ± 24	10.4 ± 1.3	140 ± 25	8.9	1236.8	14598.9	19.9 ± 3.2	1994	0.45 ± 0.06
28.5	104 ± 12	12.9 ± 1.7	91 ± 14	9.2	830.0	13362.1	21.9 ± 3.5	1991	0.42 ± 0.06
30.0	92.0 ± 7.9	7.9 ± 1.1	84.1 ± 8.9	9.8	822.1	12532.1	24.1 ± 3.9	1989	0.41 ± 0.06
31.5	99 ± 18	12.1 ± 1.6	87 ± 20	9.6	830.7	11710.0	26.5 ± 4.3	1987	0.36 ± 0.07
33.0	51.5 ± 9.9	20.0 ± 1.3	32 ± 11	8.7	275.7	10879.3	27.3 ± 4.4	1985	0.32 ± 0.05
34.5	48.1 ± 8.6	15.0 ± 1.5	33 ± 10	8.6	283.6	10603.6	28.2 ± 4.5	1984	0.30 ± 0.05
36.0	37.0 ± 8.1	12.0 ± 1.0	25.0 ± 9.1	9.4	236.3	10320.0	28.9 ± 4.6	1983	0.33 ± 0.05
37.5	68 ± 13	13.0 ± 1.1	56 ± 15	9.8	542.4	10083.7	30.7 ± 4.9	1982	0.32 ± 0.05
39.0	104 ± 11	18.0 ± 1.5	86 ± 13	9.1	783.3	9541.3	33.5 ± 5.3	1980	0.27 ± 0.05
40.5	168 ± 28	19.8 ± 2.1	148 ± 30	9.2	1358.9	8758.1	38.9 ± 6.2	1978	0.24 ± 0.03
42.0	131 ± 22	11.0 ± 1.5	120 ± 24	9.4	1130.7	7399.1	44.2 ± 7	1972	0.21 ± 0.03
43.5	130 ± 20	13.3 ± 0.9	116 ± 21	8.7	1018.0	6268.4	49.9 ± 7.9	1967	0.18 ± 0.03
45.0	83 ± 12	11.7 ± 1.6	72 ± 14	9.8	701.8	5250.4	54.6 ± 8.7	1961	0.18 ± 0.03
46.5	119 ± 21	18.6 ± 1.7	101 ± 23	9.2	921.2	4548.6	61.8 ± 9.8	1956	0.15 ± 0.02
48.0	108 ± 20	10.6 ± 1.5	97 ± 22	9.6	933.7	3627.5	71 ± 11	1949	0.13 ± 0.02
49.5	39.7 ± 6.2	5.3 ± 0.8	34.5 ± 7.0	9.2	318.3	2693.8	76 ± 11	1940	0.12 ± 0.02
51.0	54.8 ± 6.6	10.5 ± 0.6	44.2 ± 7.3	10.0	442.3	2375.5	82 ± 12	1936	0.12 ± 0.01
52.5	20.0 ± 2.5	12.0 ± 0.7	8.0 ± 3.2	9.4	75.5	1933.2	83 ± 13	1929	0.11 ± 0.01
54.0	38.4 ± 5.5	14.5 ± 0.8	23.8 ± 6.3	9.8	232.7	1857.7	88 ± 13	1928	0.11 ± 0.01
55.5	59 ± 13	21.2 ± 1.3	38 ± 14	9.4	354.5	1625.0	96 ± 13	1923	0.10 ± 0.01
57.0	46.5 ± 4.8	12.0 ± 1.5	34.5 ± 6.3	8.5	294.9	1270.5	104 ± 12	1915	0.08 ± 0.01
58.5	141.6 ± 6.2	20.0 ± 0.8	121.6 ± 7.0	8.0	975.6	975.6		1907	

Table 2. *CRS analysis data for the calculation of the age and accumulation rates of sediment in each layer of core Q2.*

Depth (cm)	Total ^{210}Pb (Bq kg^{-1})	Supported ^{210}Pb (Bq kg^{-1})	Excess ^{210}Pb (Bq kg^{-1})	Mass flux (kg m^{-2})	Inventory Excess ^{210}Pb (Bq m^{-2})	Cumulative Inventory Excess ^{210}Pb (Bq m^{-2})	Estimated year (y)	Date (y)	Accumulation rate (kg m^{-2} y^{-1})
1.5	65.7 ± 6.2	20.0 ± 0.7	45.7 ± 6.8	6.8	308.8	15820.0	0.63 ± 0.09	2011	10.7 ± 1.6
3.0	48 ± 12	11.2 ± 1.2	36 ± 13	6.6	241.3	15511.2	1.14 ± 0.17	2010	5.83 ± 0.88
4.5	56 ± 11	8.4 ± 1.0	48 ± 13	7.0	334.9	15269.9	1.58 ± 0.29	2010	3.78 ± 0.57
6.0	90 ± 11	9.1 ± 1.3	81 ± 12	6.9	557.7	14935.1	3.08 ± 0.47	2009	2.24 ± 0.33
7.5	96 ± 16	9.0 ± 1.3	87 ± 18	7.1	617.7	14377.4	4.49 ± 0.68	2008	1.59 ± 0.24
9.0	69 ± 17	15.9 ± 1.8	53 ± 19	7.0	368.4	13759.7	5.36 ± 0.83	2007	1.31 ± 0.20
10.5	50.7 ± 6.9	12.0 ± 0.9	38.7 ± 7.7	7.2	280.4	13391.2	6.04 ± 0.91	2006	1.20 ± 0.18
12.0	98 ± 18	24.3 ± 1.5	74 ± 19	7.1	526.5	13110.8	7.4 ± 1.1	2005	0.97 ± 0.15
13.5	79.5 ± 7.3	14.0 ± 0.8	65.5 ± 8.1	7.5	491.2	12584.3	8.6 ± 1.3	2004	0.87 ± 0.14
15.0	107 ± 20	14.9 ± 1.7	92 ± 21	7.6	699.5	12093.1	10.6 ± 1.6	2002	0.72 ± 0.11
16.5	92 ± 18	16.2 ± 1.4	76 ± 19	7.2	548.5	11393.5	12.1 ± 1.8	2000	0.60 ± 0.09
18.0	57 ± 12	19.9 ± 1.8	37 ± 14	7.6	284.6	10845.0	13.0 ± 2.0	1999	0.59 ± 0.09
19.5	61.8 ± 9.0	20.0 ± 1.5	42 ± 11	7.9	328.9	10560.5	14.0 ± 2.1	1998	0.56 ± 0.09
21.0	74 ± 17	20.4 ± 1.8	53 ± 19	7.7	413.5	10231.6	15.3 ± 2.3	1997	0.50 ± 0.08
22.5	105 ± 19	11.5 ± 1.5	94 ± 20	8.0	748.0	9818.1	17.9 ± 2.7	1996	0.45 ± 0.06
24.0	63 ± 11	9.6 ± 1.5	54 ± 13	7.9	421.5	9070.1	19.4 ± 2.9	1993	0.40 ± 0.06
25.5	85 ± 13	21.2 ± 0.8	63 ± 14	8.1	512.7	8648.6	21.4 ± 3.3	1992	0.38 ± 0.06
27.0	38 ± 11	13.7 ± 1.6	24 ± 13	8.0	193.8	8135.9	22.2 ± 3.4	1990	0.36 ± 0.06
28.5	80 ± 10	22.0 ± 1.5	58 ± 12	8.2	477.9	7942.0	24.2 ± 3.7	1989	0.34 ± 0.05
30.0	84 ± 12	14.1 ± 1.6	70 ± 13	8.5	591.1	7464.2	26.8 ± 4.1	1987	0.32 ± 0.05
31.5	70 ± 17	13.5 ± 1.7	57 ± 19	8.2	464.9	6873.0	29.1 ± 4.5	1984	0.28 ± 0.05
33.0	67 ± 12	13.8 ± 1.0	53 ± 13	8.4	446.6	6408.1	31.4 ± 4.8	1982	0.27 ± 0.05
34.5	69 ± 15	20.0 ± 2.5	49 ± 17	8.5	415.4	5961.5	33.7 ± 5.2	1980	0.25 ± 0.05
36.0	118 ± 21	25.0 ± 1.5	93 ± 23	8.4	778.8	5546.1	38.6 ± 5.9	1977	0.22 ± 0.03
37.5	77 ± 16	17.2 ± 1.5	59 ± 17	8.1	481.7	4767.2	42.0 ± 6.5	1972	0.19 ± 0.03
39.0	70.2 ± 9.9	15.5 ± 1.3	55 ± 11	8.5	464.1	4285.5	45.7 ± 6.9	1969	0.19 ± 0.03
40.5	59.1 ± 9.8	11.2 ± 2.6	48 ± 12	8.5	406.5	3821.4	49.3 ± 7.6	1965	0.17 ± 0.03
42.0	59.7 ± 9.4	15.8 ± 1.2	44 ± 11	8.6	378.1	3415.0	53.1 ± 8.2	1962	0.16 ± 0.03
43.5	60 ± 10	20.0 ± 2.0	40 ± 12	8.7	348.9	3036.9	57.0 ± 8.9	1958	0.15 ± 0.03
45.0	87 ± 18	15.9 ± 1.6	71 ± 19	8.6	613.3	2687.9	65 ± 10	1954	0.13 ± 0.02
46.5	110 ± 22	22.0 ± 1.5	88 ± 23	8.8	775.8	2074.7	80 ± 12	1946	0.11 ± 0.02
48.0	78 ± 16	21.5 ± 1.6	57 ± 18	9.1	514.0	1298.8	97 ± 15	1931	0.09 ± 0.02
49.5	53.7 ± 5.7	12.1 ± 0.8	41.6 ± 6.5	9.2	383.4	784.9	118 ± 17	1914	0.08 ± 0.01
51.0	62 ± 12	18.5 ± 1.0	43 ± 13	9.3	401.5	401.5		1893	

^{137}Cs dating

The ^{137}Cs record of the core Q1 (and Q2) has two distinct peaks, at 30 cm and 43 cm (30 cm and 40 cm) (**Fig. 5**). The older peak is identified as a record of the 1965 fallout maximum from the atmospheric testing of nuclear weapons (Appleby *et al.*, 1991). The more recent ^{137}Cs peak can be identified as a record of the fallout from the 1986 Chernobyl reactor fire. A sediment layer at 30 cm has been ^{210}Pb-dated to the years 1989 and 1987 in the cores Q1 and Q2, respectively. Moreover, the sediment layers at 43 and 40 cm have been ^{210}Pb-dated to the years 1966 and 1965 in cores Q1 and Q2, respectively. The agreement of the ^{137}Cs and ^{210}Pb dating validates the CRS model, and consequently, the calculated sedimentation rate and the age of sediment layers.

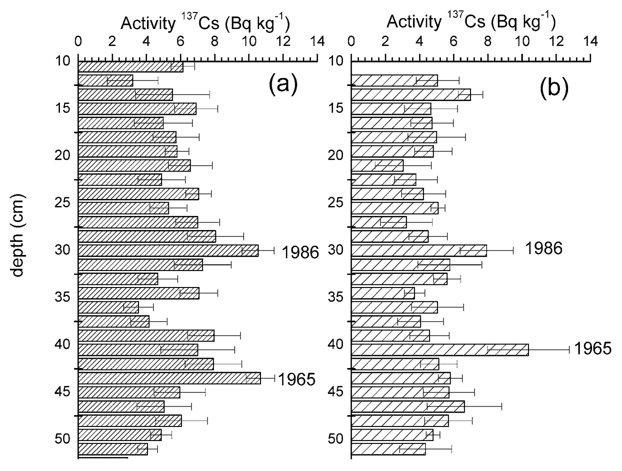

Fig. 5. *Activities of ^{137}Cs in the vertical sediment cores (a) Q1 and (b) Q2.*

4. CONCLUSION

The accumulation rates of two sediment cores sampled from the lake Qattinah, Homs, Syria, was determined using the ^{210}Pb method. The CRS model was chosen because of the non-monotonous decrease of the excess ^{210}Pb. The resulted CRS chronology was successfully validated by comparison with the ^{137}Cs dating method. The age of sediment layers has been determined and the bottom of the cores has been dated to years 1907 and 1893. In both cores, the ages of the sediment layers of the same depth have shown a good correlation. The accumulation rate was found to be similar at the studied sites. The accumulation rate exhibited a significant increase over time, especially in the last four decades. This increase can be related to the increase of the human and industrial activities in this area.

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