RETROSPECTIVE RADIATION DOSIMETRY USING OPTICALLY STIMULATED LUMINESCENCE ON NATURAL AND SYNTHETIC MATERIALS.

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INTRODUCTION.

Optically stimulated luminescence (OSL) techniques especially aimed at using natural materials for retrospective reconstruction of accidental radiation doses in populated areas were developed and studied at Risø as part of an EU research project. Quartz and feldspars separated from building materials, such as bricks and tiles, in addition to porcelain items had their OSL signals measured using different light sources for stimulation to assess radiation doses received by the material. Radiation doses were also evaluated from OSL measured directly on unseparated samples i.e. directly from the surface of brick and tile materials.

APPARATUS AND TECHNIQUES.

The apparatus used for the experimental work were mainly OSL units developed as attachments to the existing automated Risø TL reader and include monochromators for obtaining wavelength resolved luminescence measurements. An automatic OSL scanning instrument was also developed with the aim of being able to perform continuous OSL scanning measurements of brick cross-sections, allowing radiation depth dose profiles to be measured directly.

The basic OSL unit developed contains light sources for both green light and infrared stimulation, enabling measurements of OSL signals from both quartz and feldspar samples. (Bøtter-Jensen and Duller , 1992).

A compact module was developed that allows for the monochromatic illumination of samples in the wavelength range 380 to 1020 nm, enabling the measurement of energy resolved OSL (Bøtter-Jensen et al. 1994 a, Bøtter-Jensen et al. 1994 b). A schematic diagram of the combined OSL attachment is shown in Fig. 1A.

A continuous OSL core scanner system was developed that allows the optical sensors to be moved across either sediment or brick cores. The core is scanned using an excitation slit beam of 1.0 mm x 1 mm which determines the resolution of the system. OSL dose normalization is made either by using short wave UV light or exposing the brick cores to a Cs-137 gamma field and afterwards scanning the OSL sensitivity across the brick profile. A schematic diagram of the OSL scanner system is shown in Fig. 1B.

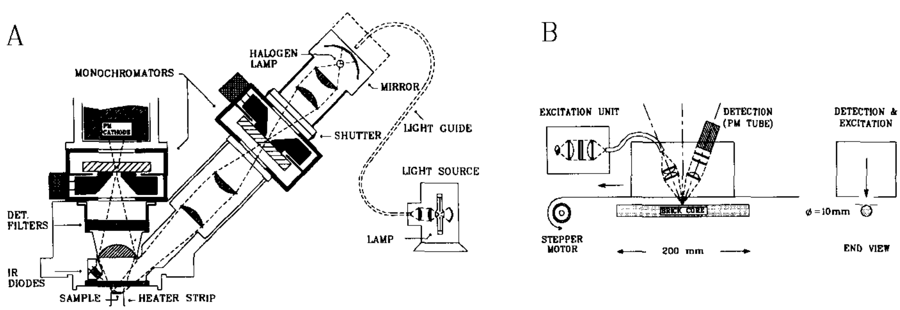

Fig.1.
(A) Schematic diagram of the OSL attachment showing the excitation lamp system with monochromators mounted on both the excitation side and the detection side.
(B) Schematic diagram of the automatic OSL brick core scanning system: the excitation beam is 1 mm wide.

OSL DOSIMETRY CHARACTERISTICS OF QUARTZ.

An attempt to determine the lower detection limit for OSL stimulated with green light on fired quartz was made by obtaining the dose response curves for a variety of quartz samples extracted from different specimens such as bricks, burnt stones and clay. An example of OSL versus dose for a sensitive quartz extracted from burnt clay obtained using the multiple aliquot method is shown in Fig. 2A. As seen, the lowest detectable dose for this material is well below 1 mGy. (Bluszcz and Bøtter-Jensen, 1995).

Quartz grains were extracted from a 40 years old brick and the absorbed dose was determined by GLSL using the additive dose technique. As seen from the dose response curve in Fig. 2B the dose was estimated to be about 200 mGy which is in very good agreement with the expected value based on an annual dose rate of about 5 mGy/y from the environmental radiation and the natural radioactivity in a typical brick. For this particular brick the lower detection limit for an additional accidental dose would be of the order of 20 mGy (10% above the background).

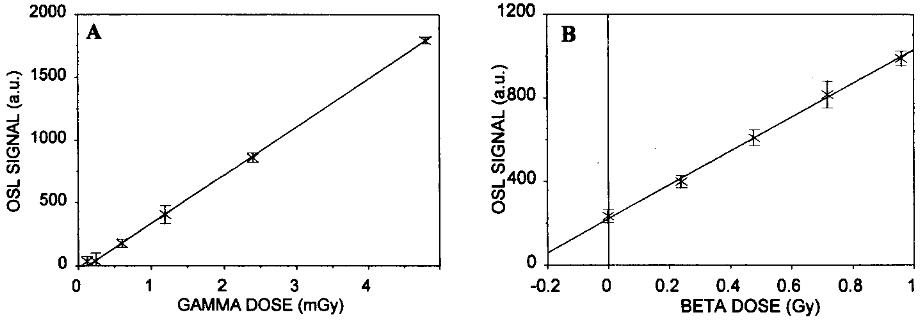

Fig.2.
(A) OSL versus ^{60}Co gamma dose (multiple sample technique) for quartz extracted from a burnt stone.
(B) OSL growth curve (multiple sample technique) for quartz extracted from a 40 years old brick.

OSL DOSIMETRY CHARACTERISTICS OF UNSEPARATED BRICK MATERIALS.

Depth-dose profiles in bricks were determined by measuring the OSL signals directly from the unseparated material across the brick using the automated OSL scanning system (Bøtter-Jensen et al., 1995). Examples of the normalized OSL as function of depth into brick material are shown for a ^{137}Cs irradiated bricks in Fig. 5A and 5 B. The fitted exponential curve also shown, correspond well with the expected attenuation in the brick material.

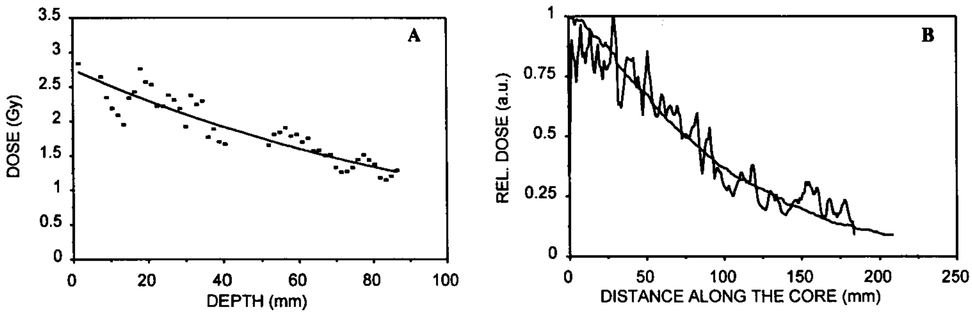

Fig.5.
(A) Dose versus depth into a brick irradiated with ^{137}Cs gamma radiation from one side. Measurements were made using green light OSL on 8 mm x 1 mm slices cut from a core through the brick.
(B) Relative depth dose profile into the same brick from ^{137}Cs gamma radiation exposed from one side and subsequently measured with the automatic OSL core scanner. The attenuation curve calculated by the Monte Carlo code MCNP is shown for comparison.

OSL DOSIMETRY CHARACTERISTICS OF PORCELAIN.

In view of the relevance of using OSL on porcelain in the field of retrospective dosimetry, we studied materials from a collection of mass produced ceramics that we consider would be representative of materials commonly found in many households. (Bøtter-Jensen et al. 1996).

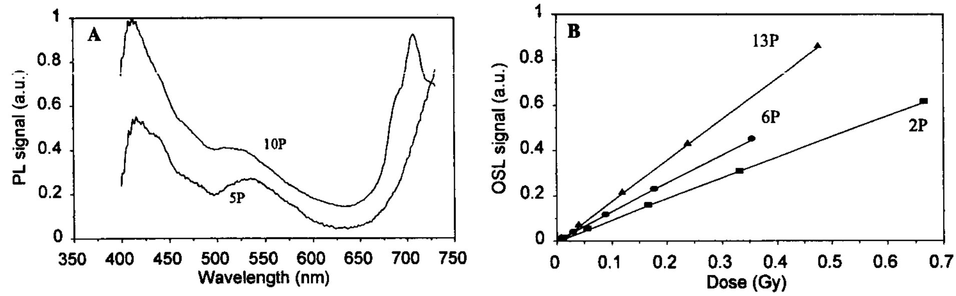

Fig.6.
(A) PL spectra (PL versus wavelength) for two bulk porcelain samples. The emission from Al_2O_3 is clearly demonstrated by the typical peaks at 410 and 700 nm.
(B) OSL versus ^{60}Co gamma dose for three different porcelain samples.

The time stable photoluminescence (PL) emission spectra were recorded with UV stimulation produced by a halogen lamp, filtered with U-340 filters (peak transmission at 340 nm). Fig. 6A shows PL spectra obtained from 2 different porcelain samples. The PL spectra compared with that obtained from Al_2O_3:C TL material, which has been shown to be an extremely sensitive OSL dosemeter material (Poolton et al.,1995).

Measured dose response curves, i.e. OSL versus ^{60}Co gamma dose, are shown for three porcelain samples in Fig 6B. For most porcelain samples the OSL signal increases linearly from 10 mGy up to 20 Gy and shows a further sublinear increase up to at least 200 Gy.

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