SUMMARY OF ACHIEVEMENTS

Grzegorz Adamiec

Gliwice, 2015

1. First name and surname

Grzegorz Adamiec

2. Diplomas and degrees – their name, place and year of issue and the title of the PhD thesis.

- 1994 – Title of Masters of Science and engineer, technical physics, Silesian University of Technology, Gliwice, Poland
- 2000 – Doctor of Philosophy, Oxford University, „Aspects Of Pre-Dose And Other Luminescence Phenomena In Quartz Absorbed Dose Estimation."

  2005 – Officially recognised as a degree of philosophy doctor in physical sciences by the Faculty Board of the Faculty of Mathematics, Physics and Chemistry at the University of Silesia in Katowice

3. Information about employment in research establishments

- from October 2005 continuing – **faculty adjunct (equiv. assistant professor)**

  Institute of Physics – Centre for Science and Education, Department of Applied Radioisotopes, Silesian University of Technology, Gliwice
- February – September 2005 – **research assistant,**

  Institute of Physics, Department of Applied Radioisotopes, Silesian University of Technology, Gliwice, Poland
- May 2003-November 2004

  Marie-Curie fellowship "Dosimetry of neutrons and other aspects of dosimetry", Depto. Fisica Teorica, Atomica, Molecular y Nuclear, University of Valladolid, Spain
- December 1999-March 2003

  Post-doc fellowhsip. Project title "Design of a database based laboratory management system", AMS ^{14}C laboratory, Max-Planck-Institute for Biogeochemistry, Jena, Germany.
- 1996-2000

  Doctoral study, Research Laboratory for Archaeology and the History of Art, University of Oxford, UK.
- 1995-1996

  Research assistant, Research Laboratory for Archaeology and the History of Art, University of Oxford, UK.
- 1994-1995

  Research Assistant, Institute of Physics, Department of Applied Radioisotopes, Silesian University of Technology, Gliwice, Poland

4. Indication of achievement[1] *required by the paragraph 16 point 2 of the Act about scientific degrees and scientific title from 14 march 2003 r. (Journal of Acts no 65, pos. 595 with changes):*

a) *title of scientific/artistic achievement,*

Luminescence Phenomena in Natural Dosimetric Materials – Interpretation of Selected Experimental Observations

b) (author/authors, title/titles of publication, year of publication, name of publisher),

Label	Bibliographic data and description of contribution	No of cit.	IF	Contribution %
H1	Adamiec G., Bluszcz A., Bailey R., Garcia-Talavera M., 2006, Finding model parameters: Genetic algorithms and the numerical modelling of quartz luminescence. RADIATION MEASUREMENTS, 41, 897-902	15	0,92	80
H2	Bluszcz A. and Adamiec G., 2006, Application of differential evolution to fitting OSL decay curves. RADIATION MEASUREMENTS, **41,** 886-891	9	0,92	50
H3	Adamiec, G., Bailey, R. M., Wang, X.L and, Wintle, A.G., 2008. The mechanism of thermally transferred optically stimulated luminescence in quartz. JOURNAL OF PHYSICS D: APPLIED PHYSICS, 41, 135503 (14pp)	30	1,27	70
H4	Adamiec G., Duller G.A.T., Roberts, H.M., Wintle A.G., 2010. Improving the TT-OSL SAR protocol through source trap characterisation. RADIATION MEASUREMENTS, 45(7), 768-777	31	1,02	80
H5	Adamiec G., Heer A.J., Bluszcz A., 2012. Statistics of count numbers from a photomultiplier tube and its implications for error estimation. RADIATION MEASUREMENTS, 47(9), 746-751	3	0,86	40
H6	Wang, X. L.; Wintle, A. G.; Adamiec, G., 2012. Improving the reliability of single-aliquot regenerative dose dating using a new method of data analysis. QUATERNARY GEOCHRONOLOGY, 9, 65-74	3	4,015	60
H7	Stevens T., Adamiec G., Bird A.F., Luc H., 2013. An abrupt shift in dust source on the Chinese Loess Plateau revealed through high sampling resolution OSL dating. QUATERNARY SCIENCE REVIEWS, 82, 121-132	3	5,571	40
H8	Wang X.L., Wintle A.G., Adamiec G., 2014. Post-IR IRSL production in perthitic feldspar. RADIATION MEASUREMENTS, 64, 1-8	-	1,14[1]	40
H9	Wang X.L., Du J.H., Adamiec G., Wintle A.G., 2015. The origin of the medium OSL component in West Australian quartz. Journal of Luminescence, 159, 147-157	-	2,367[1]	40
H10	Bluszcz A., Adamiec G., Heer A., 2015. Estimation of equivalent dose and its uncertainty in the OSL SAR protocol when count numbers do not follow a Poisson distribution. Radiation Measurements. In Press. http://dx.doi.org/10.1016/j.radmeas.2015.01.004	-	1,14[1]	40

[1] Assumed IF for 2013

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[1] when the achievement is a multi-author work/works, co-author statements from each co-author describing their contribution to the work must be presented.

c) description of the scientific aim of the above-mentioned works and obtained results with a description of their possible application.

The aim of the conducted research was the interpretation of selected experimental observations of thermally and optically stimulated luminescence in quartz and feldspars using the band gap model, as well as development of new experimental data analysis methods.

1. Introduction

The idea of using thermoluminescence (TL) in dating archaeological ceramics was first developed in 1950s (Tite and Waine, 1962, Aitken et al., 1964). From that time on, dating using TL, and later optically stimulated luminescence (OSL) has been continuously evolving and found many applications in archaeology and earth sciences (Wintle, 2008). The possibility of estimating the age of ceramics that has been excavated from an archaeological site, or determining the chronology of creation of geological sediments, evolution of shorelines, river terraces, determination of the time of climatic events etc. forms a valuable tool for applications in geology, geography, palaeoclimatology and related disciplines.

According to McKeever (1985, p. 8) observations of TL in a diamond were probably described for the first time by Boyle (1663) and the first theoretical explanation on the basis of the band model of solids was published by Randall and Wilkins (1945a and 1945b). When a given phosphorescent material is irradiated with ionising radiation and then heated, even a long time after irradiation, it emits TL of an intensity dependent on the magnitude of the absorbed dose. TL is usually recorded using a photomultiplier tube. Thermoluminescence is phosphorescence of a lifetime of the order of a few minutes in normal conditions.

The first application of TL in ionising radiation dosimetry took place in 1953 when LiF was used to monitor the radiation emitted during a nuclear test.

The idea of using TL for dating ceramics relies on the fact that ceramics contains minerals displaying TL, which absorb ionising radiation emitted by radioactive isotopes present in the surroundings of a given object and inside the object itself. The knowledge of the total dose absorbed since the last zeroing event (firing in case of ceramics and exposure to sunlight in case of sediment) and the dose rate (named annual dose, expressed in Gy per year) allows calculating the time elapsed since the zeroing event.

The interest in quartz as a natural dosimetric material stems from its prevalence in the lithosphere and its properties allowing the most accurate estimation of the absorbed dose among all known natural dosimeters. Quartz is free from anomalous (athermal) fading of luminescence, observed e.g. in feldspars, for the first time described by Wintle (1973). Athermal fading of luminescence results in feldspars being much less suitable for dating, although in recent years new techniques for dating feldspars have been developed that give hope for future applications (Buylaert et al., 2009).

A systematic progress in research leads to an improvement dating techniques using luminescence – equally for determining the dose of absorbed ionising radiation and annual dose. One of the ground-breaking steps was the application of OSL to dating of geological sediments (Huntley et al., 1985). In the case of OSL, the zeroing of the "luminescence clock" is more likely to occur in geological sediments. From that time a dynamic development of dating methods using OSL took place. This technique has been applied to a wide variety of geological sediments. The range of the method may be 200-500 ka in favourable circumstances. The use of TT-OSL (thermally transferred OSL) gives hope that the range could be increased, however this is still debated.

After absorption of radiation dose, quartz emits light during heating. When stimulated with green, blue, and in increased temperatures also infrared light, light of a shorter wavelength than the stimulating light is emitted. The determination of the level of signal in the dated sample ("natural"), and calibration of the mineral response by measuring signal level in response to increasing laboratory doses allows to estimate the equivalent dose[2] absorbed by the investigated quartz – this principle allows using quartz for dosimetric properties. Additional determination of the annual dose at the location where the mineral was found, allows determining its age.

In this work, the question of determining the radiation dose is not considered – these problems constitute a separate research area. The author co-authored three publications that deal with calculating the annual dose on the basis of known concentration of natural radionuclides – U, Th and ^{40}K in a given sediment [P6, N5, N2].

In the research of TL and OSL of natural materials, such as quartz or feldspars, numerous difficulties are encountered, e.g. heterogeneity of the natural material (different properties of individual grains – see [P18] and [P15] and therein cited works) or low intensity of luminescence. These factors result in experimental work having to be carried out in a way minimising these factors.

For a long time the ages estimated using luminescence ages were characterised by large uncertainties (often in excess of 10%). With new observations, new dating techniques are being developed that provide better precision. With increasing precision the question of accuracy gains importance. The investigations of the physical basis of the method are important in order to determine the range of applicability, certainty of obtained results and to develop measurement protocols resulting in the most reliable results. Despite the fact that the idea of luminescence dating is simple, in practice many detailed problems are

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[2] Equivalent dose is a dose of gamma radiation resulting in the same level of luminescence signal than the dose of considered radiation. The difference between equivalent dose and the absorber dose depends on the type of radiation and the size of the grains. The largest difference is observed for alpha radiation.

encountered that require solution to obtain accurate and precise results. All research to achieve this aim are concentrating on estimating the equivalent dose through identification of a signal whose growth with increasing dose is the same in laboratory as in nature.

My research presented here concerns various aspects of analysis of phenomena exploited in dosimetric applications of natural minerals, mainly quartz, but in one case, also feldspar.

In particular, genetic algorithms were applied to finding the parameters of a numerical model of luminescence in quartz ([H1]). The ideas of the model were used in suggesting experiments aiming at explaining the mechanism of TT OSL ([H3, H4]) and providing a new interpretation of the creation of the medium component in quartz OSL decay curves ([H9]). In addition, using the approach developed in works [H3, H4] experimental work was carried out that allowed a new perspective on the production of post-IR IRSL in feldspar ([H8]).

At the same time, in the area of signal analysis, research on application of differential evolution to deconvoluted OSL decay curves into components was carried out ([H2]). Statistical analysis of luminescence measurement results was undertaken ([H5, H10]). Finally, a new method of data analysis in OSL Single Aliquot Regenerative Dose protocol was suggested ([H6]).

Analysis of the OSL decay curve shape in quartz extracted from Chinese loess allowed to suggest this method as a means of investigating varying provenance of quartz in loess profiles ([H7]).

Before giving a detailed description of my results, I will present some background information.

Thermoluminescence (TL) in quartz

TL glow curves are obtained in the process of recording the luminescence emitted during heating of a luminescent material while the temperature is being increased, most frequently linearly with a given heating rate. In the case of quartz, the glow curves consist of a few peaks. The shape of the glow curve depends on the electron and recombination centres present in the given material, as well as the luminescence detection band.

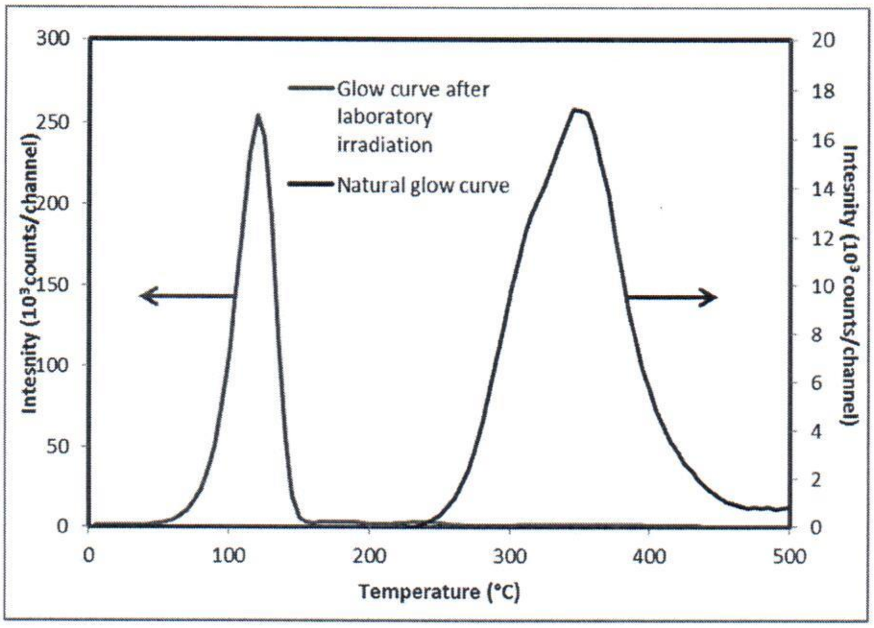

Fig. 1: Glow curves of natural quartz and quartz freshly irradiated in the laboratory. The small graph in upper left corner shows the freshly irradiated sample glow curve on a logarithmic scale.

Fig. 1 shows examples of glow curves for grains of quartz separated from a geological sediment – a glow curve for the geological („natural") sample and of quartz freshly irradiated in the laboratory. The peaks which appeared in the low temperature region are thermally unstable and do not appear in the natural glow curves. After irradiation in the laboratory they decay at ambient temperature at a rate depending on their thermal stability. A few characteristic peaks are observed in natural quartzes originating from different sites. The absolute and relative intensity of the peaks is different in different samples. A review of the properties of various peaks in quartz can be found e.g. in Spooner and Questiaux (2000).

Optically stimulated luminescence (OSL)

Optically stimulated luminescence is emitted when a luminescent mineral irradiated with ionising radiation is exposed to stimulating light. The emitted luminescence has a shorter wavelength that the stimulating light. Because the stimulating light intensity is a few orders of magnitude larger than the recorded light, it is necessary to use appropriate filtering of the light reaching the light detector – most frequently, a photomultiplier, and recently occasionally a CCD camera when single grain luminescence is recorded. The standard detection band for quartz is 320-360 nm.

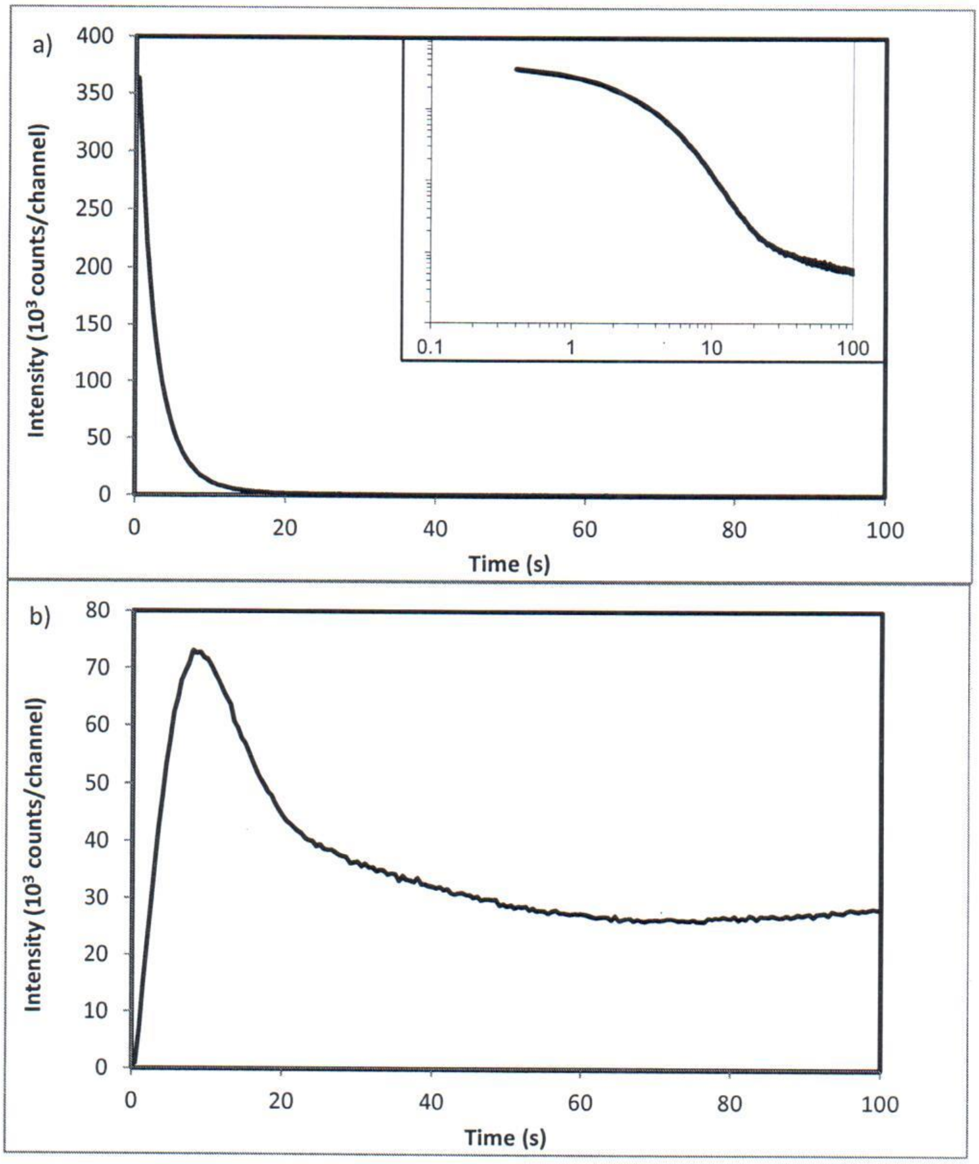

Fig. 2: a) An example of an OSL decay curve in quartz measured at 160°C. The graph in top, right corner is the same curve presented on a log-log scale, b) an example of an LM OSL curve of a quartz sample measured at 160°C.

Fig. 2a show san example of an OSL decay curve of quartz recorded during stimulation with blue light of an intensity of 30 mW cm^{-2} at a temperature of 160°C. Fig. 2b shown a linearly modulated OSL curve (LM OSL), i.e. luminescence intensity when the intensity of stimulating light is increased linearly – this allows a better visual distinction of fast decaying components under stimulation.

On the basis of the model band model of luminescence in quartz (see next subsection), assuming that retrapping of electrons excited into the conduction band is negligible, stimulation with light of constant intensity leads to a decay curve consisting of a sum of exponentially decaying components. When stimulating light intensity increases linearly, the components are described by the equation:

$$I_n(t) = Ab\frac{t}{P}e^{-bt^2/_{2P}} \quad (1)$$

where I_n – intensity of the *n*-th component, A – amplitude, b – a constant proportional to the cross section of interaction of a trapped electron with a photon and to the maximal flux of photons in a given measurement, P – total measurement time.

2. Model of luminescence in quartz

Quartz is a non-conducting crystal characterised by an indirect band gap. Due to this fact and because during measurements of optical absorption, excitons are created, it is difficult to determine exactly the width of the band gap. It is estimated that the band gap has an optical width of 7.4 eV (Huntley et al., 1996).

The earliest and most simple model of this phenomenon involves electron and hole trapping sites in the energy gap (Randall and Wilkins, 1945a and 1945b). Ionising radiation results in the excitation of electrons into the conduction band. The electrons in the conduction band can recombine with holes trapped at hole trapping sites, or they can get trapped at metastable traps which are sufficiently deep to prevent a thermal stimulation of electrons into the conduction band in normal conditions. Only heating of the luminescent material or optical stimulation enables freeing the electrons and their transition to the conduction band. From the conduction band, electrons can recombine with holes trapped in recombination centres or they can be retrapped at electron trapping sites. In the case of recombination with holes trapped at luminescence centres light is emitted.

With time, this model was amended and extended. To explain the phenomenon of luminescence sensitivity[3] of quartz due to heating and irradiation it was necessary to introduce several hole trapping centres into the model (Zimmerman, 1971). A mathematical implementation of this model requires the selection of the values of a number of parameters characterising each trapping centre. A thermal transfer of holes between recombination centres explains the observed sensitivity change.

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[3] Luminescence sensitivity is the magnitude of the chosen luminescence signal – e.g. summed area of a TL peak or the magnitude of the OSL signal – emitted in response to a specific absorbed ionising radiation dose

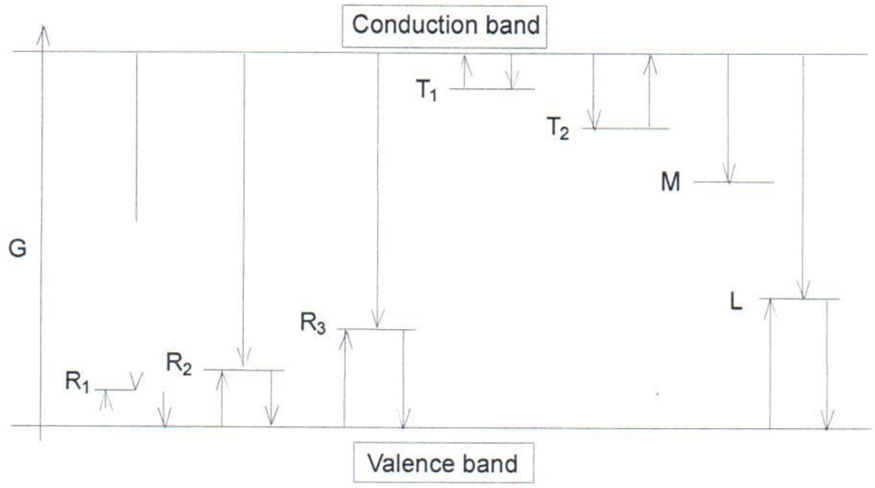

Fig. 3: Model of luminescence in quartz after [P13]. In the energy-gap there are electron traps T_1, T_2 and M (M represents all electron traps deeper than T_1 and T_2) and hole traps R_1, R_2, R_3 and L, where L indicates the recombination centre emitting the detected light.

Application of a numerical model to simulations of luminescence sensitivity changes

Bailey (2001) presented a complex numerical model of OSL, which was able to reflect sensitivity changes observed in quartz after cycles of irradiation, optical stimulation and heating. In my DPhil thesis (results also published in [P13]) I showed that a similar model can qualitatively describe the so-called pre-dose sensitisation observed for the 110°C peak in quartz heated to increasingly higher temperatures. The parameters in this model as well as the one presented by Bailey were determined by trial and error to match experimental observations.

It was interesting to see whether the ability of the model to mimic the observed sensitivity changes was the result of the fact that the proposed numerical model was described by a large number of parameters or whether it is possible to exactly reproduce sensitivity changes observed in quartz. In 2003, thanks to Dr Talavera I first encountered genetic algorithms which allow finding a global extremum of a function in the defined multi-dimensional search space. I decided to check whether the application of genetic algorithms would allow reconstructing the shapes of the thermal activation characteristics (TAC) in various types of quartz. I used genetic algorithms to minimise the sum of squared differences between the experimental and numerically simulated TAC. Despite the need to fit tens of parameters the application of the genetic algorithm described in [**H1**] turned out to be very fruitful reproducing sensitivity change patterns in four distinctly different quartz samples. This in turn increased the probability that the proposed numerical model correctly describes luminescence processes in quartz.

3. Thermally transferred optically stimulated luminescence (TT-OSL) and the origin of the medium OSL component in quartz

As mentioned above, TL dating was developed in the 1950s. While its application to fired materials, e.g. bricks or archaeological ceramics, turned out to frequently give correct age determinations in samples of known age, in geological sediments, TL often gives results significantly different from expectations. A solution was provided by OSL where sunlight zeroes the accumulated signal.

At the beginning, dating was performed with the use of many aliquots of quartz grains irradiated with different doses added on top of the natural. Such a procedure can be seen as calibration of a dosimetric material which is the given natural quartz. In this approach, it is assumed that grains placed on individual discs have the same properties.

In 1998, Murray and Roberts proposed the Single Aliquot Regenerative Dose (SAR) protocol which allows obtaining a calibration curve for each aliquot. Further improvements of this procedure were presented by Murray and Wintle (2000). The value of the equivalent dose for each aliquot is obtained by the measurement of the natural signal, construction of a growth curve of the luminescence signal and interpolation of the natural signal (Fig. 4 presents this process). Such an approach reduced errors associated e.g. with the heterogeneity of grain properties.

The maximal equivalent dose possible to be determined using OSL depends on the dose at which luminescence signal is saturated. Usually the limit is 200-400 Gy which limits the age of the sediment possible to be determined. An annual dose of 4 Gy/ka yields a limit of 100 thousand years; however, when the circumstances are favourable a range of 500 thousand years may be attainable.

In disciplines which use different dating methods often there is a need for increasing the range of dating. In 2006, a new dating method based on TT-OSL was proposed (Wang et al., 2006a, 2006b). This method allowed to determine the age of 780 thousand years old Chinese loess (from the Brunhes-Matuyama reversal) with 20 thousand years uncertainty. This led to a large interest with this method.

In the TT-OSL method the „traditional" OSL signal is optically erased and subsequently the sample is heated over a determined time (usually 10-40 s) to a particular temperature (most frequently 260°C) followed by a second OSL measurement (the details of the measurement protocol are given by Wang et al., 2006). This OSL signal is induced by heating. The procedure described by Wang et al. (2006) shows that TT-OSL increases up to very high doses, much higher than "traditional" OSL. The saturation of the signal is reached for doses exceeding 1 kGy.

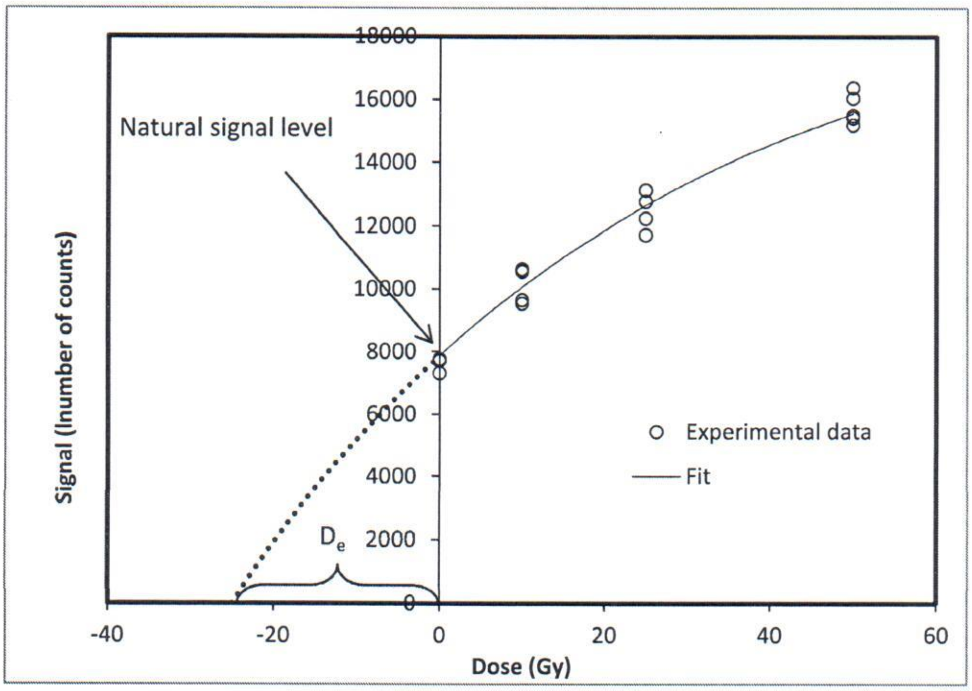

Fig. 4: Determination of the value of equivalent dose using SAR. On the vertical axis normalised level of OSL is shown. The growth curve is fitted by a saturating exponential function and the dose corresponding to the natural level of luminescence obtained by interpolation is called equivalent dose (D_e).

In 2006, during a two-month stay at the Department of Geography w Royal Holloway, University of London in the framework of the Centre of Excellence GADAM project realised at the Silesian University of Technology, and a two-month Royal Society incoming visits fellowship I participated in research initiated by Prof. Wintle to explain the physical basis of TT-OSL. The result was the paper [**H3**] in which we showed that initially proposed mechanism of TT-OSL production was likely incorrect and the actual source of the signal are deeper electron traps, not very sensitive to light (however sufficiently sensitive to allow the signal be erased by sunlight in well bleached sediments, like Chinese loess).

The research on my initiative and according to my idea was continued in 2009 when within the Marie-Curie Transfer of Knowledge Project realised at the Silesian University of Technology I completed a 3-month stay at the Department of Geography at the University of Wales in Aberystwyth. In collaboration with Prof. Duller, Dr Roberts and Prof. Wintle I undertook research aiming at a more detailed determination of the source traps responsible for TT-OSL. The results were published in the paper [**H4**]. The used technique employed TL and OSL measurements. The experiments that were carried out were designed assuming the correctness of the previously described model of luminescence in quartz. The proposed approach turned out to be appropriate and allowed to define source traps of the TT-OSL signal and determination of the kinetic parameters of the traps. This in turn allowed, for the first time, to estimate the lifetime of electrons in these traps and thus estimate the age range of the new dating tool. The papers [**H3**] and [**H4**] are currently cited by the majority of work concentrating on the principles of the TT-OSL dating method.

The approach developed in [**H4**] is based on measurements of the glow curve and the calculation of differential glow curves turned out to very helpful in determining the source of the medium component of the OSL in quartz (see next section). The research was initiated by Dr. Wang from the Institute of Earth Environment at the Chinese Academy of Sciences in Xi'an in China and the results published in [**H9**]. In the course of carrying out research work I suggested new experiments which would make more likely the hypothesis concerning the origin of the medium component in quartz OSL decay curve. This hypothesis could not be negated by any of the performed experiments and all the evidence suggests that the production of the medium component is mediated by the 170°C TL peak.

4. Development of data analysis methods

Components of OSL decay curves

Taking into account the existence of several TL peaks and the band model of luminescence (see section 2) it seems justified that OSL decay curves are composed of a few exponentially decaying components characterised by different decay rates. For the first time, this was experimentally shown by Bailey et al. (1997). In particular, they described the slowly decaying component. Based on this they suggested that in natural conditions the slowly decaying component is not always completely bleached, especially when the exposure to sunlight is very short. Not taking this fact into account may lead to obtaining an incorrect value of the equivalent dose, and in consequence, age. For this reason, decomposition of the OSL decay curve into components may be very important. Traditionally used signal is the integrated initial 1-2 s of the decay with the background level determined by further parts of the decay curve. Fig. 5a shows on a logarithmic scale an example of an OSL decay curve fitted by a sum of exponentially decaying components. It can be seen that when the initial 1-2 s are integrated and the background estimated on the basis of the last few seconds of the decay is subtracted, the obtained value will be dominated by the fastest component, but the contribution from other components will be non-negligible. The decomposition into components allows to determine the number of counts originating exclusively form the fastest component (i.e. the one that has been most likely bleached in natural conditions during deposition of the sediment).

When decomposing OSL decay curves into exponential components caution must be exercised and conclusions can be drawn after ensuring that the separated components are real, because the problem of fitting of OSL decay curves by a sum of exponential components is ill-posed (e.g. Istratov and Vyvenko, 1999), i.e. the statistics of counts obtained in measurements may not allow to distinguish such components and allow a correct fitting. In addition, as shown in [P15], OSL decay curves obtained for aliquots of heterogeneous samples can be decomposed into components whose existence is solely a result of this heterogeneity and summing of contributions of varying decay constants for individual grains, and not from the fact of existence of various electron centres.

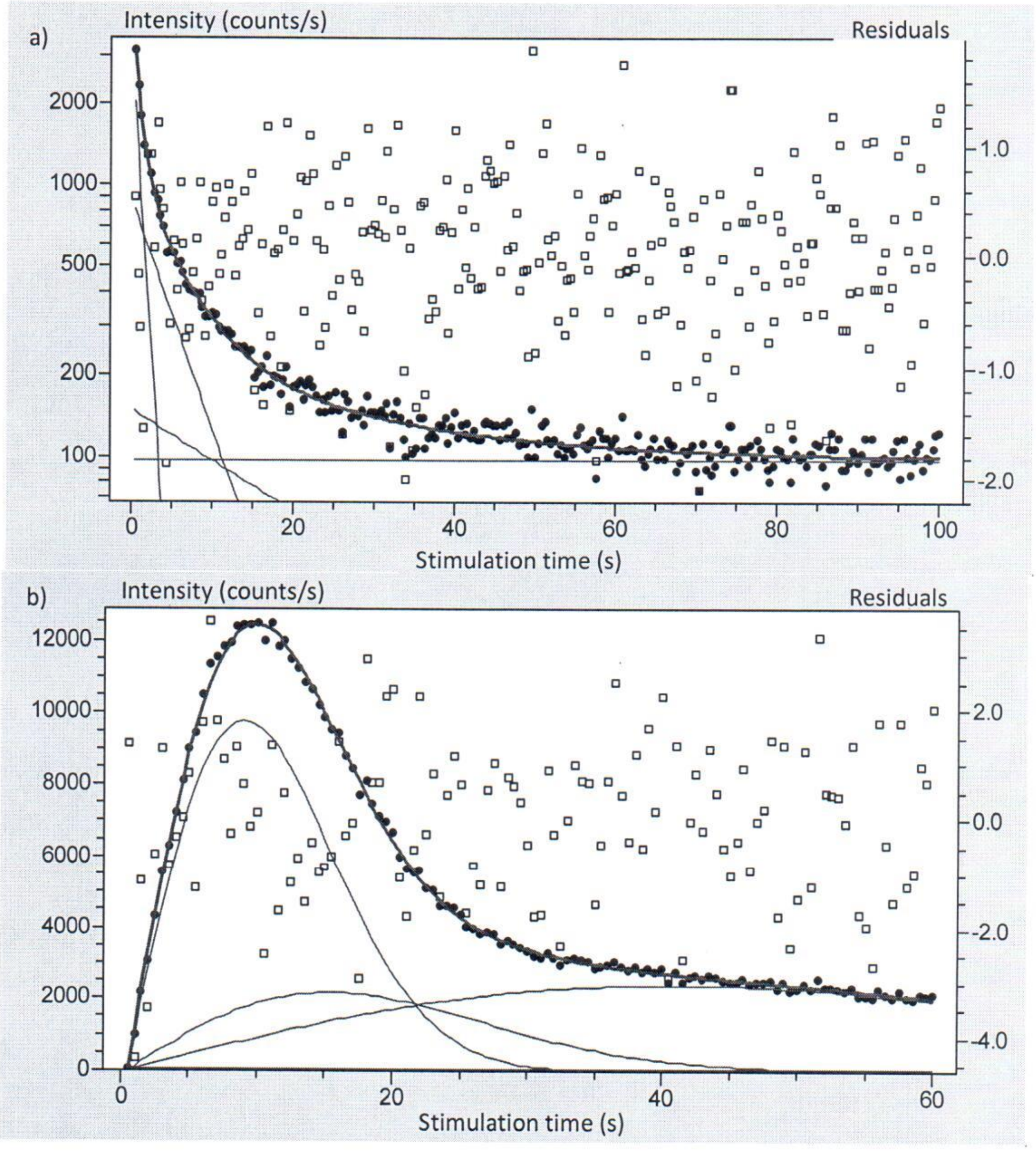

Fig. 5: An example of an OSL decay curve decomposition (a) and an LM OSL curve (b). On graph a) it can be seen that the summing of the counts from the first 1-2 s of the decays would lead to the inclusion of counts from the slower components.

An efficient decomposition of a decay curve into a sum of a few exponential components using the least squares method with the application of deterministic algorithms (e.g. Levenberg-Marquard) requires a specification of the initial values of parameters fairly close to the solution (global minimum) because experience shows that deterministic algorithms often find local minima. The same problem concerns fitting of a sum of components of the LM-OSL curve.

The application of the differential evolution algorithm and its significant modification allowed obtaining a very effective algorithm for fitting a sum of exponential components to a decay curve (or a sum of components described by Eq. (1) to an LM OSL curve). The obtained algorithm is presented in [**H2**]. The algorithm requires only specifying the range of change of decay constants. In addition, the *F* statistics was applied to determine the number of components that are statistically justified for a given dataset. This provided a good tool allowing for fully automated and effective decomposition of OSL decay curves into exponential components.

In the measurement data analysis area remain papers [**H5**] and [**H10**]. In these works a statistical model of luminescence count numbers using a photomultiplier tube is presented. Up to now, in algorithms of fitting experimental data it has been assumed that the number of photon counts follows a Poisson distribution. However, observations of the range of change of normalised residuals in the work [**H2**] led me to the conclusion that the standard deviation of the number of recorded counts is greater than the square root of the number of counts, which would be observed for Poisson distributed counts. Detailed experiments and the processing of data led to the work [**H5**]. In this work, together with co-authors we have shown that the variance of the number of counts is proportional to the number of counts whereas the proportionality factor is larger than 1. In addition, this factor is different for photon counts and dark current counts.

The count number statistics has been more deeply analysed in the paper [**H10**], where we show that count numbers of photos are described by negative binomial distributions, a different one for photon counts and dark current counts. This knowledge allowed us to formulate modified weights in the growth curve fitting (see Fig. 4) leading to obtaining unbiased estimators of the equivalent doe D_e and its uncertainty.

A new method of data analysis in SAR OSL

The paper [**H6**] proposes a new way of analysing OSL measurement data in the SAR protocol, where instead of building growth curves using the L/T ratios (the luminescence signal L divided by the normalising OSL signal T) L versus T plots are built. The obtained slopes are used to build the growth curve and determining D_e. In the investigated quartz, this procedure allowed obtaining a more accurate and precise value of the recovered dose, than the traditional approach.

5. Application of the characteristics of OSL signal to establishing the provenance of quartz

The earlier work on the shape of OSL decay curves [H2] led Thomas Stevens to invite me to look at certain anomalies in the age distribution of a part of the loess profile at Beiguoyuan. The idea relied on checking whether the shape of the OSL decay curves in the anomalous part of the profile somehow deviates from the shape in other parts of the profile. This seemed to be made more likely by the seeming presence of the ultra-fast component in the decay curve. This observation, in conjunction with using the analysis of the suggested by me analysis of heavy mineral content and taking into account other indicators in the profile allowed to draw the conclusion that the source of quartz in the anomalous part of the profile is probably different than in the rest of the profile. This in turn has implications in palaeoclimatic research in east Asia. The results of this work are published in [**H7**].

6. Origin of post-IR IRSL in potassium feldspar

The research method developed in [**H4**] and [**H9**], relying on using a conjunction of TL and OSL measurements turned out to be fruitful in research of feldspar undertaken with Dr. Wang and Prof. Wintle. The IRSL signal (Infrared Stimulated Luminescence), earlier used in dating using feldspar is characterised by anomalous (athermal) fading, like thermoluminescence emitted by feldspars. This in turn leads to obtaining age underestimates. The anomalous fading is the result of tunnelling of electrons from electron traps into recombination centres.

A few years ago (Buylaert et al., 2009) it has been suggested to use the post-IR IRSL signal. Here the "traditional" IRSL signal is bleached, subsequently the feldspar is heated to a relatively high temperature (e.g. 290°C). Next, IRSL signal is measured again (this signal is often labelled as post-IR IRSL_{290}). This thermally induced signal is characterised by a relatively high thermal stability and it seems the obtained ages are much closer to the expected results and are in better agreement with ages obtained using other dating methods when available. Time will show whether this is so, however from the moment this method has been suggested a question about the origin of the signal has been posed.

Among others, Jain and Ankjærgaard (2011) and Andersen et al. (2012) attempted to find an answer. Their research indicated that the source of the IRSL and post-IR IRSL signal is the same as opposed to other workers' opinions (e.g. Li and Li, 2011a, 2011b).

The effort undertaken in [**H8**] allowed reaching a similar conclusion through carrying out completely different type of experiments than the cited works. In addition, we have shown the post-IR IRSL signal is a by-product of the production of IRSL.

7. Description of the possibilities of application of obtained results

The obtained results may be exploited in the following way:

1. The methods developed in the determination of the origin of TT-OSL may be used in determining the life time of charge in various trapping sites, and as a consequence assessing the range of applicability of various measurement protocols using OSL and TL
2. The methods developed in feldspar research may be used in investigating the origin of various OSL and TL signals in various crystals
3. The results concerning the statistics of count numbers obtained from a photomultiplier may be used to better estimate measurement errors in luminescence measurements and develop methods of estimating the equivalent dose and its uncertainty
4. Adaptive algorithms, in particular genetic and differentia evolution constitute tools for searching global extrema characterised by a significantly decreased risk of getting stuck in a local one. Their implementation is simple while they allow solving complex optimisation problems.

5. Description of other scientific and research achievements.

MSc diploma – dating of neolithic ceramics from Kazimierza Wielka

My first encounter with luminescence dating took place at my university course. In my second year I started participating in the activity of the Department of Applied Isotopes at the Silesian University of Technology, where I got involved in scintillation gamma spectrometry.

In my fifth year I spent three months at the Research Laboratory for Archaeology and the History of Art at the University of Oxford where I applied thermoluminescence to dating polymineral fine grain fraction extracted from archaeological ceramics collected at a neolithic site Kazimierza Wielka in Poland. My MSc. thesis and paper [N6] were based on the obtained results.

Research assistant – work in the area of accident dosimetry

My first stay abroad after obtaining my MSc. took place a year after graduating from the university when I went to the Research Laboratory for Archaeology and the History of Art at the University of Oxford. I was employed in a research project financed by the European Commission. The project was devoted to accident dosimetry with the application of commonly used ceramic materials to estimate radiation doses, especially after radiation accidents. In particular, I worked on utilising bricks and porcelain from electric appliances in dosimetry. The investigated materials originated from sites in Ukraine and Belarus. The major results of the research were summarised in two papers [P21] and [P22]. They concerned estimating the absorbed dose using the TL peak observed at 230°C.

Doctoral study

Immediately after the completion of the employment as a research assistant I undertook a doctoral study at the Research Laboratory for Archaeology and the History of Art at the University of Oxford. The result was my DPhil thesis entitled „Aspects Of Pre-Dose And Other Luminescence Phenomena In Quartz Absorbed Dose Estimation". In my thesis I investigated thermoluminescence sensitivity in quartz, properties of porcelain for the purpose of accident dosimetry, heterogeneity of luminescence properties of quartz in the form of grains and crushed natural crystals and possible consequences thereof, numerical modelling of the pre-dose phenomenon in quartz. The results from the thesis were published in papers [P13, P14, P15, P18]. In this period I also co-authored the paper [P19] which was not connected with the main research of my thesis and devoted to using NaCl for dosimetric purposes.

Post-doc fellowship at the Max Planck Institute for Biogeochemistry in Jena

After finalising my doctoral study I took up a post-doc position at the newly established AMS Laboratory at the Max Planck Institute for Biogeochemistry in Jena, Germany. During my work there I participated in organising the work of the new laboratory, and in particular my task was to develop a Laboratory Information System (LIMS) – AMSIS. The creation of the system required an analysis of the measurement processes and data flow in the laboratory. One of the aims of the system was to help improving quality control of the obtained results. The gained experience was very helpful in a later period, when organising the work of the Gliwice Luminescence Dating Laboratory. The system AMSIS, described in [P17], was implemented in Visual Basic and utilised the IBM DB2 database.

Post-doc fellowship in the Marie-Curie programme at the University in Valladolid

After completion of the fellowship in Jena, I obtained a post-doctoral fellowship at the University of Valladolid within the Marie Curie programme. During the fellowship I was involved in neutron dosimetry using a PIN diode and using such a diode for the purposes of measuring radon concentration in air. In the first case a PIN diode is coupled with a ^{6}LiF or polyethylene converter recording emitted alpha particles or recoil protons. This creates a possibility of manufacturing economic neutron detectors. The results are published in the paper [P16].

In the case of applying a PIN diode for detecting radon in air a chamber was designed and constructed that utilised a radial electric field to direct radon decay products onto the face of the PIN diode increasing collection efficiency of the system as compared to a system without electric field. The decay products that get deposited on the surface, decay emitting alpha particles which are then detected by the PIN diode. Results are summarised in the work [P12].

Managing third party research projects in the Gliwice Luminescence Dating Laboratory

Since 2006 I have had the role of a manager of third-party research projects undertaken in the Gliwice Luminescence Dating Laboratory. Since assuming this position, together with the team, I undertook efforts to improve the organisation of the work in the laboratory and to implement experimental techniques used in similar laboratories worldwide. In the time the laboratory carried out analyses for a total sum exceeding 1 million PLN and some results have been published in papers [P1, P2, P3, P4].

One of very interesting research areas undertaken in the laboratory is determining the chronology of Polish loesses. The project is led by Dr. Piotr Moska, and it is the first effort on this scale to provide loess chronology undertaken in Poland. The results obtained so far have been published in [P7] and [P10].

Applied research in the area of constructing a luminescence reader

Since November 2011 a consortium consisting of the Jan Długosz Academy in Częstochowa (leader), Jan Niewodniczański Institute of Nuclear Physics in Cracow, Nicolaus Copernicus University in Toruń and Silesian University of Technology work on a project „LUMDOZ - A modular luminescence system for radiation protection and retrospective dosimetry" financed by the Polish Centre for Research and Development. I am the PI of the part realised at the Silesian University of Technology. The work within the project concentrates on applied and basic research which will allow constructing a luminescence reader of high technical parameters competing with similar systems worldwide. To date, the results have been published in papers [H8, H9, H10].

Reviewing and editorial activity

Since 2005, I have been heavily involved in the publication of the international journal Geochronometria whose owner is the Silesian University of Technology. Initially I had the function of the Consulting Editor and from 2010 Managing Editor. In this period the journal published 285 papers. Thanks to the work of the whole editorial team the journal underwent significant development. The first impact factor was awarded in 2007 and currently (year 2014) it is equal 1.243. From the beginning of the year 2015, the journal is published in the Open Access model and it is distributed by de Gruyter Open.

Since 2006 I completed over 90 reviews for various journals and in 2010 I was a guest Editor to the issue 47(9) of Radiation Measurements published by Elsevier. Since February 2015, I assumed the role of a member of the Editorial Board of Radiation Measurements.

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P1.	Danuta Dzieduszyńska, Joanna Petera-Zganiacz, Juliusz Twardy, Piotr Kittel, Piotr Moska, Grzegorz Adamiec, 2014, Optical Dating And Sedimentary Record From The Terrace Depositional Profile Of The Warta River (Central Poland), GEOCHRONOMETRIA, 41:4, 361–368.	-	1,243[1]
P2.	Panin, A.V., Adamiec, G., Arslanov, K.A., Bronnikova, M.A., Filippov, V.V., Sheremetskaya, E.D., Zaretskaya, N.E., Zazovskaya, E.P., 2014. Absolute chronology of fluvial events in the Upper Dnieper River system and its palaeogeographic implications. GEOCHRONOMETRIA, 41:3, 278-293	-	1,243[1]
P3.	Fedorowicz S., Łanczont M., Bogucki A., Kusiak J., Mroczek P., Adamiec G., Bluszcz A., Moska P., Tracz M., 2013. Loess-paleosol sequence at Korshiv (Ukraine): Chronology based on complementary and parallel dating (TL, OSL), and litho-pedosedimentary analyses. QUATERNARY INTERNATIONAL, 296, 117-130	1	2,128
P4.	Wiśniewski A., Adamiec G., Badura J., Bluszcz A., Kowalska A., Kufel-Diakowska B., Mikołajczyk A., Murczkiewicz M., Musil R., Przybylski B., Skrzypek G., Stefaniak K., Zych J., 2013. Occupation dynamics north of the Carpathians and Sudetes during the Weichselian (MIS5d-3): The Lower Silesia (SW Poland) case study. QUATERNARY INTERNATIONAL, **294**, 20–40	3	2,128
P5.	Bailiff I.K. (Guest Editor), Adamiec G. (Guest Editor), Bluszcz A. (Guest Editor), Bos A.J.J. (Guest Editor), Chen R. (Guest Editor), Chruścińska A. (Guest Editor), Duller G.A.T. (Guest Editor), 2012. 13th International Conference on Luminescence and Electron Spin Resonance Dating, 10–14 July, 2011, Toruń, Poland. RADIATION MEASUREMENTS, **47(9)**, 649–651	-	0,86
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P9.	Pagonis V., Adamiec G., Athanassas C., Chen R., Baker A., Larsen M., Thompson Z., 2011. Simulations of thermally transferred OSL signals in quartz: Accuracy and precision of the protocols for equivalent dose evaluation. NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH SECTION B: BEAM INTERACTIONS WITH MATERIALS AND ATOMS, **269(12)**, 1431–1443	7	1,21
P10.	Moska P., Adamiec G., Jary Z., 2011. OSL dating and lithological characteristics of loess deposits from Bialy Kosciol. GEOCHRONOMETRIA, **38**(2), 162-171	6	0,425
P11.	Koul D.K., Adamiec G. and Chougaonkar M.P., 2009. Participation of the R-centres in the sensitization of the OSL signal, JOURNAL OF PHYSICS D:	1	2,083

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P13.	Adamiec G., 2005, Investigation of a numerical model of the pre-dose mechanism in quartz. RADIATION MEASUREMENTS, **39**, No. 2, 175-189	9	1,02
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P16.	Adamiec G., Iñiguez M.P., Lorente A., Voytchev M. and Gallego E., 2004, Response of a silicon PIN photodiode around an Am-Be neutron source. NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH A: ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT, **534**, 544-550	2	1,35
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P18.	Adamiec G., 2000, Variations in luminescence properties and pre-dose sensitisation of single quartz grains. RADIATION MEASUREMENTS, **32**, 427-432	27	0,97[2]
P19.	Bailey R.M., Adamiec G. and Rhodes E.J., 2000, Optically stimulated luminescence properties of NaCl related to dating. RADIATION MEASUREMENTS, **32**, 717-723	28	0,97[2]
P20.	Göksu H.Y., Stoneham D., Bailiff I.K. and Adamiec G., 1998, A new technique in retrospective TL dosimetry: Pre-dose effect in the 230°C TL glow peak of porcelain. APPLIED RADIATION AND ISOTOPES, **49**, 99-104	8	0,77[2]
P21.	Adamiec G., Stoneham D. and Göksu H.Y., 1997, Accident dose estimation using porcelain. A comparison between different thermoluminescence methods. RADIATION MEASUREMENTS, **27**, 389-39	5	0,97

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N1	Heer A.J., Adamiec G., Moska P., 2012, How many grains are there on a single aliquot? Ancient TL, **30(1)**, 9-16	1
N2	Guerin, G., Mercier, N., Adamiec, G., 2011. Dose-rate conversion factors: update. Ancient TL, **29(1)**, 5-8	48
N3	Pazdur A., Adamiec G., 2005, Physics and engineering education for isotopic environmental studies and environmental protection. PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON ENGINEERING EDUCATION. ICEE'2005. Global education interlink, Gliwice, Poland, July 25-29, 2005. Vol. 2. . Eds: Jerzy Mościński, Marcin Maciążek, 754-759	-
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	simulation of quartz luminescence. GEOCHRONOMETRIA, **23,** 9-14	
N5	Adamiec G. and Aitken M.J., 1998, Dose-rate conversion factors: update. ANCIENT TL, **16**, No. 2, 37-51	685
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