Different Luminescence dating for different environments

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Main research interests concern Quaternary paleoclimate evolution and sea level fluctuations, sedimentology (facies analysis) of shallow-marine (sand and gravely beach), coastal (aeolian) and alluvial (debris-flow and water-flow dominated fan systems) deposits, Luminescence dating. Another branch of his research is the comparison between the modern, very shallow water seagrass meadows-dominated coasts and the Oligocene-Miocene temperate-type carbonate ramps of Mediterranean basin. Quaternary climatic changes studies are nowadays the main goal. Several projects have been carried out on late Pleistocene-Holocene successions of the Mediterranean Sea. Recently these studies have been addressed in better understands the climate and sea-level fluctuations over the last 200 ka to predict the future scenarios of coastal evolution in the West Mediterranean basin.

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Introduction

Over the past twenty years, 'luminescence dating' has developed rapidly expanding its meaning and application, such that today it encompasses a range of protocols, materials and different sedimentary deposits up to becoming one of the most important method for studying Earth surface processes.
The luminescence dating technique depends on the ability of mineral grains (quartz and K-feldspar) to store energy within the crystalline structure and release it upon a stimulation (light or heat). Exposure to sunlight resets (or bleaches) luminescence signal before burial, which is than restored by exposition to natural radiation from the surrounding environment. The amount of energy absorbed per year by the grains during burial is termed the equivalent dose (De, Gy) whereas the dose rate (Dr, Gy/ka) can be derived by direct measurement of the radioactive decay. Final age (moment of sediment deposition) of deposits is the results of simple ratio of these two factors.
Standard Optically Stimulated Luminescence (OSL) performed on quartz mineral; has proved to be a powerful technique to establish absolute ages of sedimentary strata deposited during the past in a wide range of depositional environments (marine, fluvial, aeolian, colluvial etc.). However, fast saturation of quartz OSL signal limits dating to no more than 200 ka. In contrast, K-feldspar have shown low saturation rate of the infra-red stimulated luminescence (IRSL) signal and thus it has shown the potential to extend the luminescence dating range far beyond limits of Radiocarbon, U-series and OSL.
Despite this potential in dating, luminescence dating of K-feldspar was limited by anomalous fading of luminescence signal through time, which ultimately causes age underestimation. The recent discovered of post-IR IRSL protocol at low (150-180°C) and high (225-290°C) temperatures has shown to be stable at geological time, minimizing and/or overcoming the fading issue and age correction. Moreover, the free-fading post-IR IRSL protocol (pIRIR) has demonstrated to be reliable in several sedimentary context giving ages in agreement with OSL and independent ages. Nowadays, it is considered the most promising luminescence dating protocol with prospective ability to cover the entire Quaternary period from present to several hundred thousand years back in the past.

Material and Methods

The different environments presented are from Sardinia, a quasi stable island in the Middle of Mediterranean Sea (Fig. 1).

Fig. 1. Sardinia Island (Italy) in the centre of the Mediterranean Sea

The west and northwest coasts of Sardinia are quasi continuously draped by Quaternary strata overlapping the older substrate. Strata belong to beach ridge and alluvial systems and both terrestrial and intertidal marine carbonates. Based on the adopted absolute dating methodology (Luminescence, Murray and Wintle, 2000; Buylaert et al., 2011) they span in time from MIS8 (270 ka) to Present.

Results and Discussion

Beach Ridge Systems. They are composed of coastal dunes and shallow marine (beach and shoreface) deposits. As expected for the aeolian environment both quartz and k-feldspar grains have excellent luminescence characteristics. Therefore, no main problems have been encountered in dating these deposits. We have however documented that post IRIRSL$_{290}$ is not reliable for dating Holocene deposits. The shallow marine deposits show satisfactory luminescence characteristics for both quartz and k-feldspar grains. Some limitations has been encountered occasionally in dating the coarse gravel beaches. Moreover, marine deposits outcropping close to volcanic bodies have experienced very fast saturation of quartz grains and k-feldspar do not show good luminescence characteristics.
Alluvial systems. They are composed of alluvial fan and colluvial deposits. In general, quartz coarse grains saturate very fast, even though they normally show good luminescence characteristics possibly due to the relatively high environmental dose rate (>2Gy/ka). On the other hands, k-feldspar grains always show very good luminescence characteristics and therefore reliable ages.
Intertidal marine carbonate, known also as trottoirs, are algal bindstones able to trap clastic grains brought by longshore current or windblown. These deposits are characterized by very low environmental dose rate and by a wide dose rate inhomogeneity (hot and cold spots). Because of this, quartz grains in general underestimate the true ages. On the other hands, given the internal dose due to ^{40}K, the k-feldspar grains suffer less of these dose rate problems giving reliable ages.
Terrestrial carbonate. Holocene impure travertines have been dated with luminescence. Quartz has experienced good luminescence characteristics and reliable ages, whereas k-feldspar did not. Only the IR$_{50}$ signal has shown no evidences of partial bleaching giving reliable ages.

Conclusions

Given the ubiquity of quartz and k-feldspar minerals, flexibility of luminescence signal and grainsize and the scales of analysis available for dating, luminescence method is potentially applicable to all type of sedimentary deposits and similar, where other method fails or are not suitable.
Thus, it is now possible to optimise the materials and the appropriate protocol to date any particular deposits in response to any precise scientific question.

References

Buylaert J.P., Huot S., Murray A.S., Van den Haute P. (2011) - Infrared stimulated luminescence dating of an Eemian (MIS 5e) site in Denmark using K-feldspar. Boreas 40, 46-56.
Murray A.S., Wintle A.G. (2000) - Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. Radiat. Meas., 32, 57-73.