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Luminescence Dating at PRL: Progress Thus Far

A.K. Singhvi and **N. Juyal**

We live in unusual times. These are the times when the magnitude of Man induced changes in Earth Surface Processes and the Climate closely equal to those in the past 500ka of the Earth's history. For any sensible futuristic land use planning, it becomes imperative to understand the basic processes that affect the landscapes. This makes it imperative that the time scales and response times of landscapes (to climatic and tectonic perturbations) and geomorphic thresholds for land surface processes are understood in their entirety. This calls for appropriate radiometric dating framework for sediments that could provide a long time series of events so that variousl periodicities can be determined. These inputs then provide constraints on a range of processes ranging from desertification to neo-tectonics and paleo-seismology.

Thus, one of the key aspects of modern day Earth Sciences is to better quantify the rates of processes on land. A survey of the existing methods indicates that amongst the existing methods, ***the radiocarbon method*** is often beset with a limited dating range, problems of preservation, calibration and contamination. Besides that of the association of the samples with their strata always remains enigmatic. Other techniques such as ***cosmogenic radio-nuclides*** have difficulties in the estimation of shielding depths in the case of continuously accreting sediments and the inherited signal. This makes the application of the method, model dependent with time being itself a variable. The use of ***Uranium series dis-equilibrium*** is attractive due to its high precision, but its application is limited to pure carbonates –that are rare in terrestrial settings. In this context it is clear that a void in the techniques that could provide ages from a century scale to few hundred ka's existed.

Developments in luminescence dating over the past two decades has filled this gap with several advantages that include, its applicability to the constituent minerals such as quartz and feldspars, its ability to provide calender ages, its ability to date the most recent depositional event of sediments and its dating range of a century to a million years. Technological innovations now enable single grain measurements routinely and permit a rigorous analysis of a sample.Futher thse developments inform on the physics of basic luminescence processes such as the understanding of anomalous loss of trapped charges - termed anomalous or athermal fading, the understanding of dose distribution in soils at a single grain level to aspects of retrospective dosimetry.

In this talk I will discuss the basics of this radiation damage methods, outline its technical capabilities and complexities and then discuss some case studies involving fluvial sediments of south India, Aeolian sediments of Thar desert and paleoseismology /neotectonics.

The talk will focus on the work done by the luminescence dating laboratory at PRL With the initiatives of Prof. D. Lal, Prof. D. P. Agarwal and Prof. N. Bhandari, and with encouragement and support from Prof. M.J. Aitken of the Oxford Universit, since the late seventies. The initial objective was to supplement the dating of archeological sites devoid of material that could be dated by radiocarbon. The scope of this laboratory expanded with time to include geological applications and the some of the significant results are listed below:

1. First demonstration of dating of desert sands - a contribution now considered to be the third revolution in Desert Sciences after those of Bagnold on the Physics of blown sand and of Farouk El Baz on the Remote Sensing of Desert regions. This initial PRL work has so far inspired over 2000 publications and today luminescence dating is essential for any publication on Desert evolution.
2. Reconstruction of the Quaternary history of Thar Desert and the Deserts Arabia, Mexico, the US, the Western Sahara. Demonstration that the conventional paradigm of a simultaneous expansion and contraction of deserts in the world was not tenable. This implied that albedo changes used thus far in paleo-climate modeling have been overestimated.
3. Demonstration that Thar is in contracted stage, has regional gradients, has accentuated dune migration rates in areas of increased human activity.
4. Reconstruction of past surface wind patterns using remote sensing and luminescence dating of pristine and reworked dune forms.
5. Development of novel dating methodologies for the dating of pedogenic carbonates, gypsum, barites and volcanic ashes etc for climate specific event chronologies.
6. Demonstration of large hiatuses and phase lags in terrestrial records of dust (loess - paleosols) and deserts sand accretions, lake records and suggestion for a total reexamination of land sea and land -land correlation, inferred tele-connection and periodicities.
7. Development of Fulgurites as a Quantitative Paleo-ecological tool in Deserts.

8. Dating of Karst deposits of Tibet and reconstruction of past air temperatures.
9. Development of chronologies of glaciations, demonstration of inadequacies of radiocarbon dating for Himalayan paleo-lakes and paleoflood history of fluvial systems in Himalaya with important ramification on recurrence of major floods events like those in 1970 and 2013.
10. Use of Meteorite luminescence to deduce their thermal and radiation history, pre-atmospheric orbits of meteorites.
11. Study of dose and dose rate effects in minerals over a million fold range of dose-rates and elucidation of dose dependent dose rate effects.
12. Demonstration of heterogeneity of beta dose at single grain level in soils and sediments. This work has changed the way luminescence ages using single grains were computed.
13. Indigenous development of a system to date surfaces for the dating of glacial moraines and other complex samples.
14. Development of dating of fault gouges, sand dikes, tsunami sediments and thermo-chronology application of OSL using the heat generated by grain friction during fault generation or dike injection.
15. Help with the development of 12 laboratories for luminescence dating in India

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