Chapter 7

Conclusions and Future Outlook

7.1 Conclusions

This thesis examined the basic physics underlying the dating of seismic events using fault gouges, sand dikes, fault scarps, sediments of truncated river channels using luminescence dating. The general conclusions from this thesis are,

A. Luminescence dating of sand dikes

1. Calculation from first principles, suggest that during the formation of sand dike, under favourable conditions grain friction between the sediment grains injected as dikes can result in flash heating that is sufficient to erase the pre-existing luminescence at the time of injection and at the same time, the transient nature of flash heating enables a preservation of the pristine mineral composition without any thermally induced alteration. Some of the suitable conditions for such a flash
heating to occur are of kinematic viscosity of order m²s⁻¹, minimum velocity of 30 ms⁻¹ for narrow dike (~5 cm wide)

2. Luminescence studies on samples of dikes from Assam along Mora Krishna river and from Kakoti site indicated evidence of such a heating. Further experiments such as estimation of heating using predose sensitization of quartz, suggested the temperature rise at least up to 400 °C during the injection of dikes. These studies also enable dating of past earthquake during 111 years, 300 years, 500 years and 1 ka, and we anticipate a magnitude of M > 6 for Beltagat and nearby sites and M> 7 for Kakoti and Namgaon sites.

B. Luminescence Studies on Fault Gouges

1. In this case also, calculation from first principles enabled us to compute the heat generation during faulting and grain friction heating. Computation of heat conduction shows that under reasonable condition a slip of ~10 cm can result in finite heating of gouge material up to 350 °C and more, and this heat then conducts to the gouge matrix and in the process resets the luminescence of the grains constituting the gouge.

2. Studies on fault gouges from Gish fault led to evidence of heating in gouge material of about 300-350 °C. The luminescence dating of fault gouge samples suggested at least two tectonic events at ~ 2 ka and 3.5 ka.

All these sequences were a direct consequence of the seismic/tectonic events and the basic effort in the case of fault gouge and sand dikes was to validate the basic premises of the application of luminescence methodology in respect of the zeroing of luminescence signals at the time of faulting/sand dike formation. The other application was the use of standard luminescence dating procedures to an important area in western India viz. Allah Bund to reconstruct the paleoseismic history of the area.

The resetting of the luminescence signal in both cases i.e. sand dikes and fault gouge was tested by theoretical calculations and experimental methods. Based on the present study following inferences can be drawn
1. The resetting of the luminescence signal in the formation of sand dikes is possible due to viscous heating. The calculations made by using viscous heating model for sand dikes suggested that a temperature rise > 400 °C is possible.

2. The resetting of luminescence is more at the center of the dike as compared towards the edge. The temperature increase in narrow dike is higher as compared to the dike of larger width. Therefore it is suggested that the dikes of narrow width are chosen for sampling and samples from the dikes should be collected from the center of the dike.

3. The extent of heating in sand dikes was estimated experimentally based on the sensitivity of the dike samples and host samples. This suggested that the rise in temperature during the injection of the dike was 350−400 °C.

4. The samples for dating of paleoseismic events using sand dikes from North East India suggested tectonic events at 111 years, 300 years, 500 year and 1 ka. The earthquake of magnitude M >6 caused the injection of dikes in Beltaghat and nearby site areas, and M > 7 caused the injection of dikes in Kakoti and Namgaon sites.

5. The simulations made for the estimation of rise in temperature during the rupture events due to friction heating (transient heating) suggested that the temperature rise can be > 400 °C for faulting at a depth of 1 km. This temperature rise will result in the resetting of luminescence signal in fault gouge material.

6. The extent of temperature rise for fault gouge material was made by using predose method and suggested that the gouge material experienced a temperature of ~500 °C. The laboratory stress experiments on the quartz samples suggested that the transient shock events which also result in the crushing of quartz grains will also contribute to the lowering of the luminescence and higher stress may result into the full resetting on the luminescence signal.

7. The luminescence studies of fault gouge samples collected from the Sikkim−Darjeeling Himalaya suggested two earthquakes in the areas at around 2 ka and 3.5 ka.
8. Luminescence dating of samples from fault scarp, truncated channels and historical site in the proximity of Allah bund area in Great Rann of Kuchchh suggest that the Allah bund scarp was created from at least two major earthquakes viz. the 1819 and between 2.5 and 1.4 ka respectively.

7.2 Future work

In present work while established the premises of dating of dikes and fault gouges, there is a need for further refinement, first by an extensive analysis of luminescence of fault gouges and sand dikes and their analysis in respect of the parameters such as host matrix and its physical characteristics, the slip in case of faulting, the depth of dike injection etc. Such a study will pave way or a more robust and routine application of luminescence methods for chronology. This is needed as in terms of sensitivity luminescence only provides a mean to date young historical events so that the methodology could be verified. Secondly luminescence parameters such as predose sensitization are also needed to provide additional constraints on heating and transient heating for fault gouge and sand dike respectively.

Theoretical calculations so far comprised several assumptions such as heat near the surface of the block, and away from the fault plane is zero, the velocity of the dike material during injection is less as compared to the center of the dike. For the estimation of temperature during the formation of sand dikes a linear flow of sand material is considered. However in nature the flow has to be decelerating and hence the heat generation should expectedly be nonlinear. Field observation suggests most of the sand dikes are of conical in shape (narrow at top and broad at bottom). Since the rise in temperature is affected by the width of the dike it is important to include this in the calculations. For this a detail mathematical model is needed, which takes into account the geometry of the dike and will help in considering the better position of samples for luminescence studies. In the present model we have considered the conservative value of kinematic viscosity; the model can be extended to include the effect of kinematic viscosity under confining pressure based on theoretical models for it.

Similarly for the estimation of rise in temperature we have not considered the second order effects which will also affect the temperature. For example as soon as the rupture on a fault plane takes place the dynamic frictional coefficient will change. This will have
significant effect and might cause lowering in the temperature as the recent measurement on the Great East Japan earthquake suggest a lower value of the frictional coefficient during the coseismic slip (Fulton et al., 2013; Ujiie et al., 2013). Also the effect of temperature due to the change in pore pressure as result of increase in temperature (coupling of the two as a feedback system) is not taken into account. The inclusion of this into the model will give better estimates of temperature rise during the rupture events.

The quartz can be used as a geothermometer based on the apparent age and temperature for different cooling rate (Li and Li, 2012). The detailed laboratory protocols need to be developed for this method which will be helpful in estimating the last cooling luminescence age for dikes and fault gouge samples.

In the present case dike samples from five different locations were studied to ascertain the resetting of luminescence signal. The North East area in India is seismically active and has experienced several earthquakes. However based on the sand dike studies we could identify four seismic events, and one of them was identified from the recent past (1905 earthquake). This indicated that the injection of dike was probably not there during other earthquakes, even these earthquakes were of higher magnitude M >7. This needs further investigations for the possible mechanism of the injection of the dikes in this area. Also the effect of multiple earthquakes on the resetting of luminescence in the dike material needs further experimental and theoretical work.
List of Publications

Papers in referred journal


Submitted


In preparation

1. Viscous heating as a possible Zeroing mechanism for OSL dating in sand dikes and results from North East India
2. Resetting of luminescence in fault gouges and luminescence dating of fault gouge from Sikkim Darjeeling Himalaya

Conference Abstracts


Other Publications


Conference Abstracts


2 Not related to thesis work