"Thermal Evolution of Sedimentary Basin Using Fission Track Dating"& "Simulation of Earthquake Strong Ground Motions"

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Introduction

During the last decade much attention has been paid to the thermal evolution of sedimentary basins (Naeser and McCulloh, 1989). This growing interest has been fostered by the recognition that, among the various geological factors which control the maturation of oil and gas in sediments, temperature is the most important one.

In order to generate liquid hydrocarbons under natural conditions, the sediments must have experienced sufficient heating inside the "oil window" between 60 to 130°C, some time during their burial (Fig. 1). Apart from the maximum palaeotemperature, the thermal evolution of the sediments through geological time also influences the maturation process. In this article, I have described the applications of Fission Track Dating(FTD) for investigating the thermal history of sedimentary basins.

Principles of Fission Track Dating

FTD depends upon the natural spontaneous radioactive decay of the more abundant isotope of uranium, ^{238}U, by the explosive process of nuclear fission. In each fission event the two fission fragments fly apart at 180° to each other creating a single fission damage track in the enclosing atomic lattice. The fission tracks crossing the polished surface of material are magnified by chemical etching because of the preferential attack of their weakened, disordered structure.

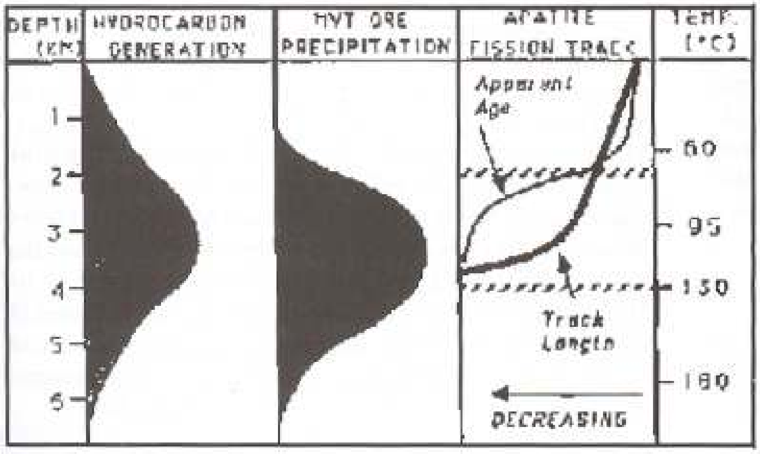

Fig. 1: Comparison of temperatures and depths for hydrocarbon generation. MVT ore precipitation and annealing of fission tracks in apatite (From Arne *et. al.*, 1983)

These enlarged tracks can be seen under an optical microscope. Their number thus provides a measure of the fraction of the total uranium atoms which have fissioned within a sample. Using the rate of spontaneous radio active fission decay of ^{238}U i.e. λ_F, the length of time during which fission tracks have been accumulating in the host material may be determined. (Fig. 2 shows the fission track in apatite).

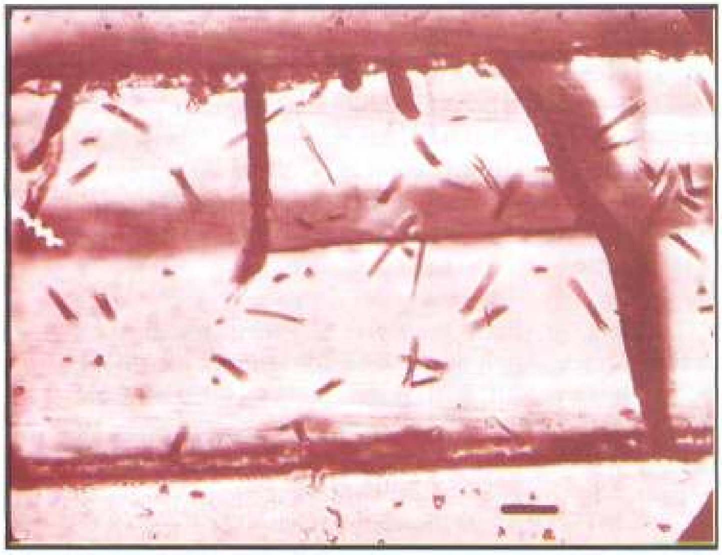

Fig.2 Fission tracks in an apatite crystal

The fission track age is calculated by using following formula

$$T=\frac{1}{\lambda_D}\ln\left[1+\frac{\lambda_D\phi\sigma I\rho_s}{\lambda_F\rho_i}\right]$$

where

λ_D = total decay constant for ^{238}U.
λ_F = spontaneous fission decay constant for ^{238}U.
I = ^{235}U/^{238}U isotope abundance ratio.
σ = thermal neutron fission cross-section ^{235}U.
ϕ = thermal neutron fluence.
ρ_s/ρ_i = spontaneous/induced fission track density ratio in the sample.

Application of Fission Track Dating in oil maturation studies:

The fission tracks in apatite are sensitive to thermal variations. Their number as well as the dimensions (length) changes with temperature. The temperature window at which track annealing in apatite takes place is the same as required for oil maturation. This enables the reconstruction of the thermal history of sedimentary basins, by means of apatite fission track analysis. Let us provide the clastic sediment contain detrital apatite grains. Depending on their geological provenance, the individual apatite grains contain various amounts of fossil fission tracks at the time of sedimentation. As long as the temperature of a sedimentary rock stays low, new fission tracks are steadily added to the initial ones with time. With increasing subsidence and burial, the temperature increases and essentially above 60°C. causes partial track fading with characteristic track shortening. The degree of shortening is very sensitive to the maximum temperature reached and less to the duration of heating. The shortening affects only those tracks which are present at the time of heating, all tracks subsequently formed at lower temperatures are longer.

Each track, although starting with virtually the same length; has thus experienced a different thermal history which creates varying degree of shortening according to the temperature which that track has experienced. The present day overall length distribution(Fig. 3) therefore represents an integration of these temperatures histories experienced by each track and thus records the overall temperature history of the sample.

Fig. 3(i) (from Gleadow et. al. 1983) shows 3 apatite confined track length distribution for samples of varying thermal history, A, B, & C, representing samples buried at different levels in the track annealing zone, as may be envisaged with progressive burial in a sedimentary basins.

In Fig. 3(ii)- the distributions are given for:

(D): a past thermal event, perhaps a magmatic intrusion, where a bimodal distribution is found relating to the 2 generations of tracks formed before the thermal event (the shortened tracks) and after the thermal event (the longer tracks).

(E): a slow-cooling event, such as slow-uplift; here a greater propagation of longer, younger tracks are preserved, giving a right-skewed distribution.

(F): a recent heating event, such as sudden rapid burial or a recent magmatic event plunges a sample and its track length distribution (similar to A) into the annealing zone to give a similar if slightly broader distribution, but with each track shortened.

Some Case Histories

Fission track apatite analysis has been used for investigating many sedimentary basins in UK(Bray et. al., 1992), USA(Roger et. al., 1994), South Africa (Duane et. al., 1991), Canada(Grist et. al., 1995). But in India such type of work has been done for Cenozoic Forland basin of NW Himalaya in Fission Track Lab of Department of Earth Sciences at Kurukshetra Univer

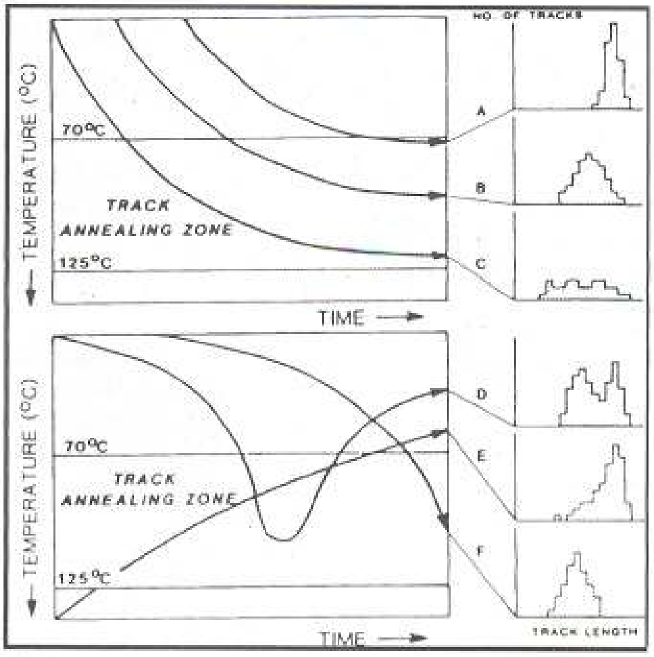

Fig. 3 Temperature-time paths and the resulting apatite track length distributions for rocks of varying thermal history.

Simulations of Earthquake Strong Ground Motions

The realistic strong ground motion time histories are required for a more detailed evaluation of seismic hazard to the complex structure such as high rise buildings, dams, and power plants etc. The records of strong ground motions from the past earthquake can provide a wealth of information for this purpose. Such records from the past earthquakes are few or absent in many regions of the world. An alternative way is to simulate the strong ground motion time histories for future earthquakes using theoretical or/and empirical techniques. The simulated realistic accelerograms not only enhance the sparse data base of strong ground motion recordings but also provide the time histories for the specific seismic sources and propagation paths.

A number of techniques for simulating the strong ground motions for the future earthquakes have been proposed. These include Green's function techniques, Stochastic techniques and composite source technique. These techniques require detailed input that may not be available in many seismogenic regions. Based on the semi-empirical method of Irikura (1986) and Midoikawa (1993), Dinesh (2001) developed a fast method to simulate the earthquake strong ground motions. The method of Midorikawa (1993) consists of superposing the envelopes of strong motion waveforms, instead of actual time histories, of smaller magnitude earthquakes to estimate the peak ground accelerations due to a larger magnitude earthquake.

The elastodynamic radiation from an earthquake may be approximated by a band limited white noise (Boore, 1983). Hence in order to synthesize accelerogram the envelope function can be multiplied with a band limited normalized white noise (Khattri, 1998). Dinesh (2001) proposed to estimate the envelope function of the target earthquake by randomly distributing the subevents of varying sizes on the fault plane. In order to find the best locations of the subevents, Dinesh (2001) used the genetic algorithm. In order to implement this technique of simulation the parameters required are-fault area, orientation of the fault, hypocenter, size of the subevents, stress drop, rupture speed, observed peak ground accelerations, source-site distance and attenuation parameter.

Dinesh(2001) has demonstrated the suitability of the above method by modeling the empirical accelerograms of one small and two moderate magnitude Himalayan earthquakes. The main characteristics of the simulated accelerograms comprising of the duration of the strong ground shaking, peak ground acceleration, Fourier and response spectra are, in general, in good agreement with those of observed ones at most of the sites. Figure 4 shows the example of this comparison at few sites for 1991 Uttarkashi earthquake (Dinesh, 2001). The continuous lines in Fourier and response spectra correspond to simulated accelerograms. The long dash and small dash lines, respectively correspond to the transverse and longitudinal components of the recorded accelerograms.

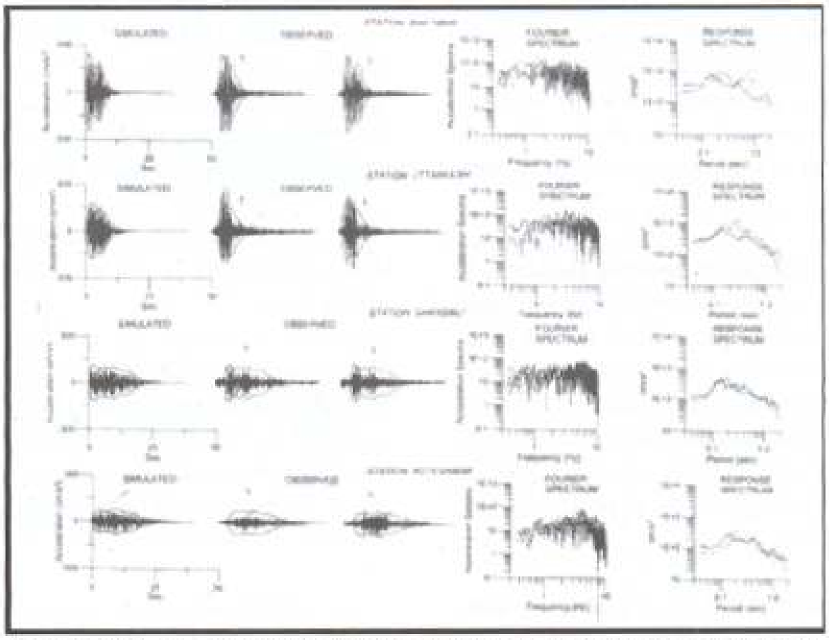

Fig. 4 Comparison of simulated & observed accelerogram of 4 sites for the 1991, Uttarkashi Earthquake. The comparison of corresponding fourier transform & response spectra are also shown.(After Dinesh, 2001)

The technique can be used to prepare the scenario hazard maps for different regions. It can also be used to obtain the appropriate rupture models as well as accelerograms for the historical events for which only intensity maps are available.

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