Radon Precursory Anomalies for Some Earthquakes in N-W Himalaya, India

Vivek Walia[1], Hardev Singh Virk[2], Tsanyao Frank Yang[3], Monika Walia[3], Bikramjit Singh Bajwa[2]

[1]National Center for Research on Earthquake Engineering, Taipei, Taiwan

[2]Department of Physics, Guru Nanak Dev University, Amritsar, India

[3]Department of Geosciences, National Taiwan University, Taipei, Taiwan

LIST OF SOME SIGNIFICANT EARTHQUAKES IN INDIA AND ITS NEIGHBOURHOOD

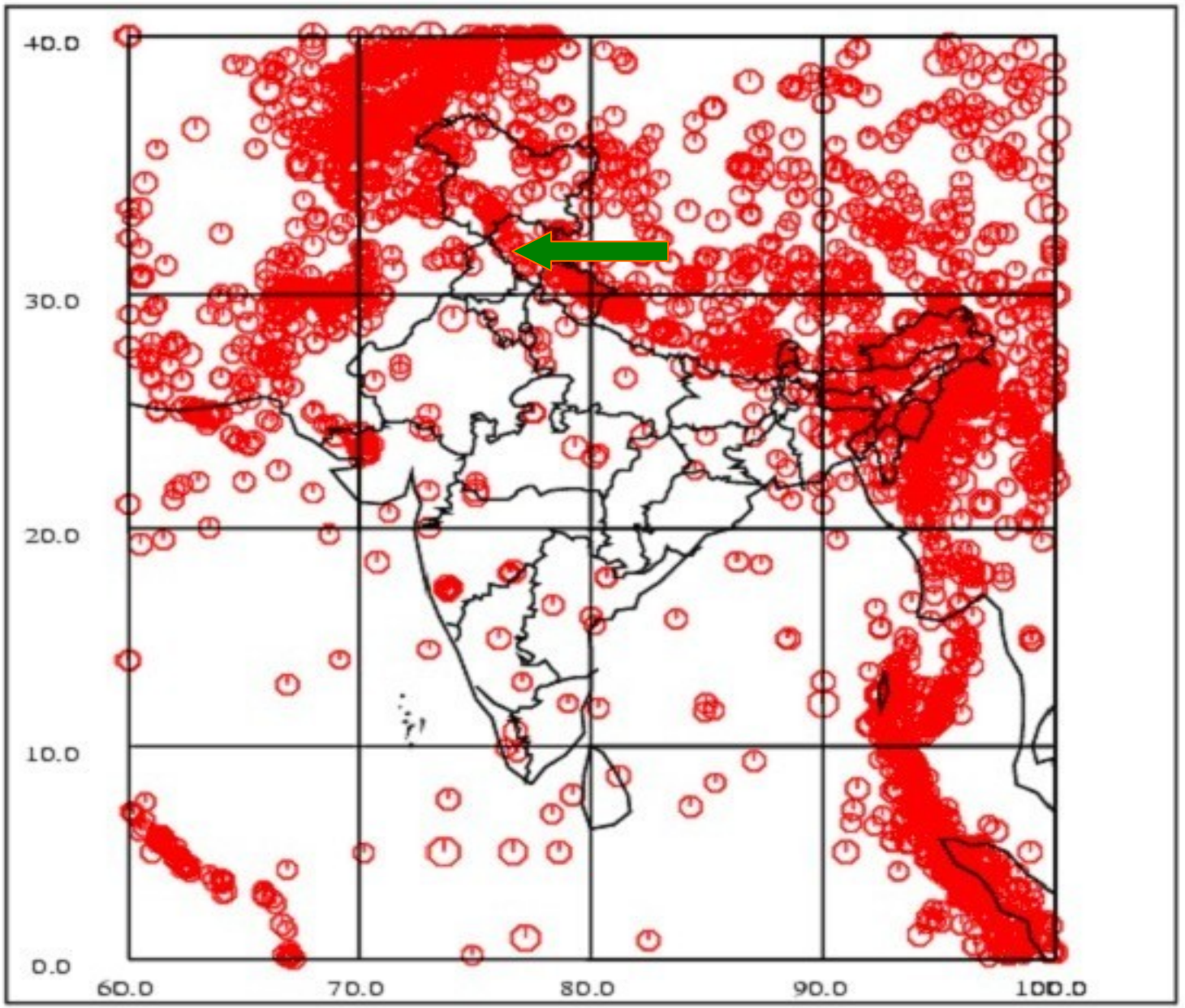
DATE	EPICENTRE		LOCATION	MAGNITUDE
	Lat(Deg N)	Long(Deg E)		
1819 JUN 16	23.6	68.6	KUTCH,GUJARAT	8.0
1869 JAN 10	25	93	NEAR CACHAR, ASSAM	7.5
1885 MAY 30	34.1	74.6	SOPOR, J&K	7.0
1897 JUN 12	26	91	SHILLONGPLATEAU	8.7
1905 APR 04	32.3	76.3	KANGRA, H.P	8.0
1918 JUL 08	24.5	91.0	SRIMANGAL, ASSAM	7.6
1930 JUL 02	25.8	90.2	DHUBRI, ASSAM	7.1
1934JAN 15	26.6	86.8	BIHAR-NEPALBORDER	8.3
1941 JUN 26	12.4	92.5	ANDAMAN ISLANDS	8.1
1943 OCT 23	26.8	94.0	ASSAM	7.2
1950 AUG 15	28.5	96.7	ARUNACHAL PRADESH-CHINA BORDER	8.5
1956 JUL 21	23.3	70.0	ANJAR, GUJARAT	7.0
1967 DEC 10	17.37	73.75	KOYNA, MAHARASHTRA	6.5
1975 JAN 19	32.38	78.49	KINNAUR, HP	6.2
1988 AUG 06	25.13	95.15	MANIPUR-MYANMAR BORDER	6.6
1988 AUG 21	26.72	86.63	BIHAR-NEPAL BORDER	6.4
1991 OCT 20	30.75	78.86	UTTARKASHI, UP HILLS	6.6
1993 SEP 30	18.07	76.62	LATUR-OSMANABAD, MAHARASHTRA	6.3
1997 MAY 22	23.08	80.06	JABALPUR,MP	6.0
1999 MAR 29	30.41	79.42	CHAMOLI DIST, UP	6.8
2001 JAN 26	23.40	70.28	BHUJ , GUJARAT	6.9

PLOT OF EARTHQUAKES (M >= 5.0) FROM IMD CATALOGUE FOR THE PERIOD FROM 1800 TO SEPT. 2001

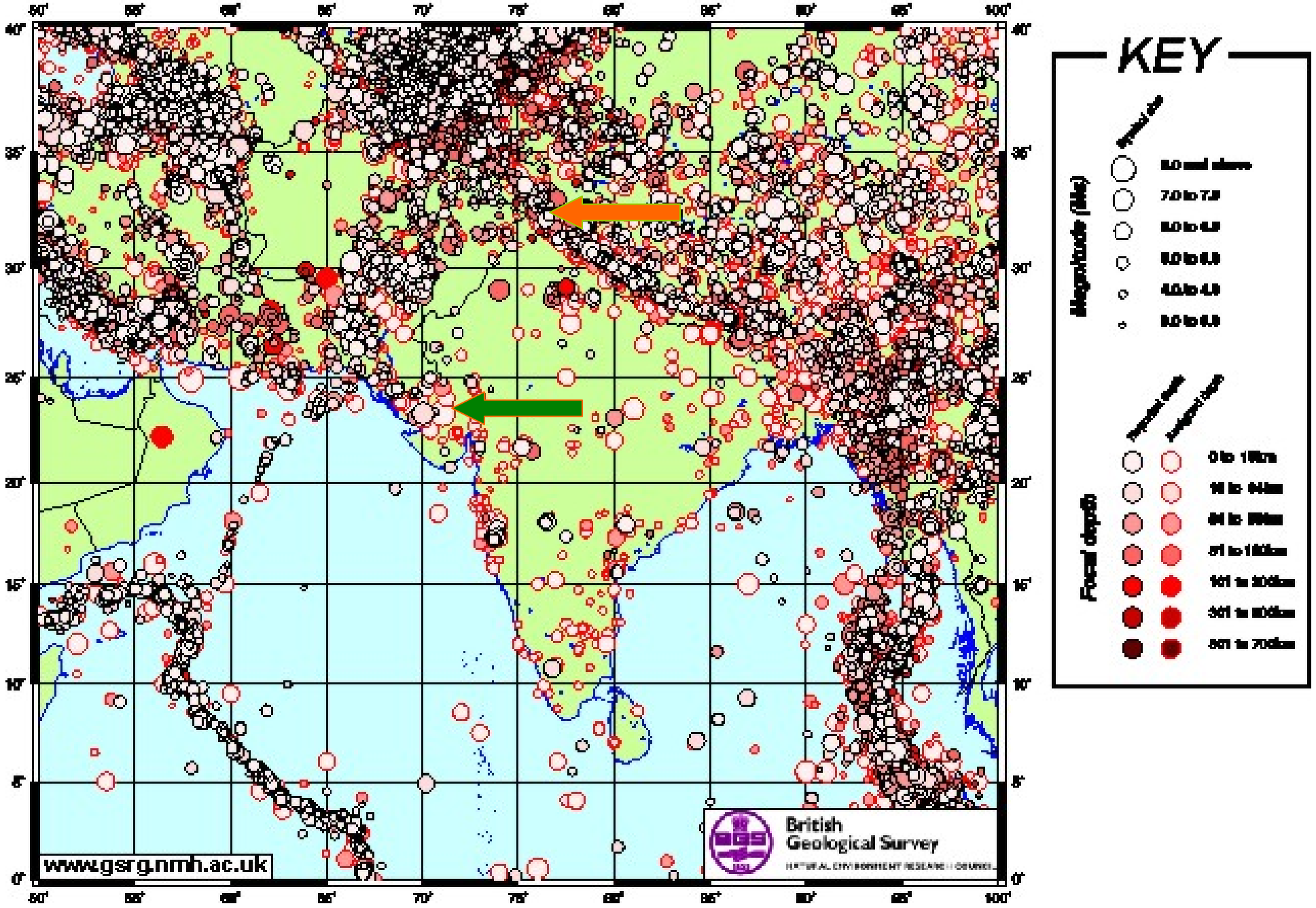
Total events: 3383
Selected events: 3383

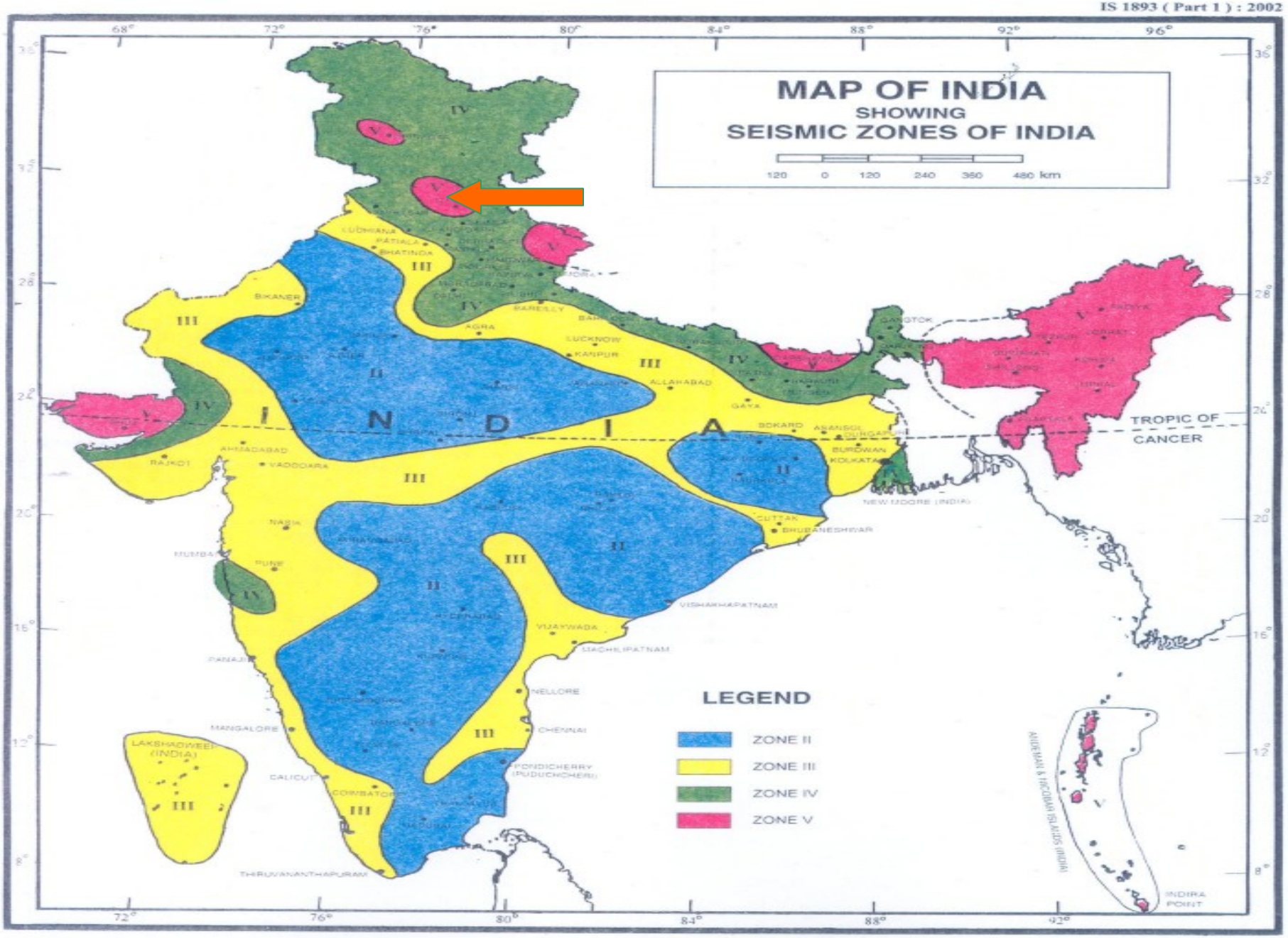
Magnitudes:

M = 5
M = 6
M = 7
M = 8



Seismicity of Southern Asia (above magnitude 3.0 Ms)

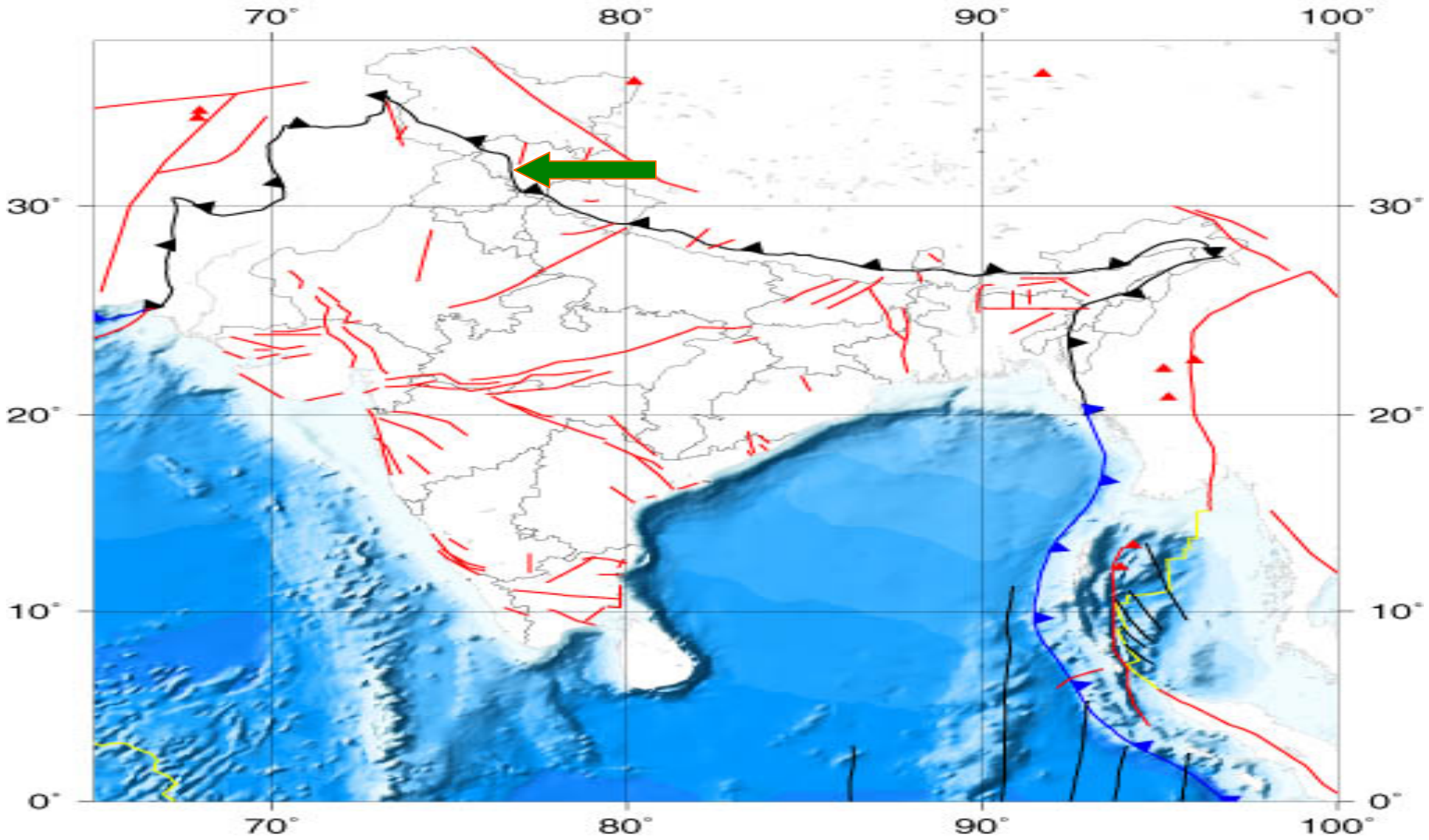




NOTE : Towns falling at the boundary of zones demarcation line between two zones shall be considered in High Zone.

TECTONIC MAP OF INDIA

Faults active since the Quaternary period (See References)



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Subduction Boundary

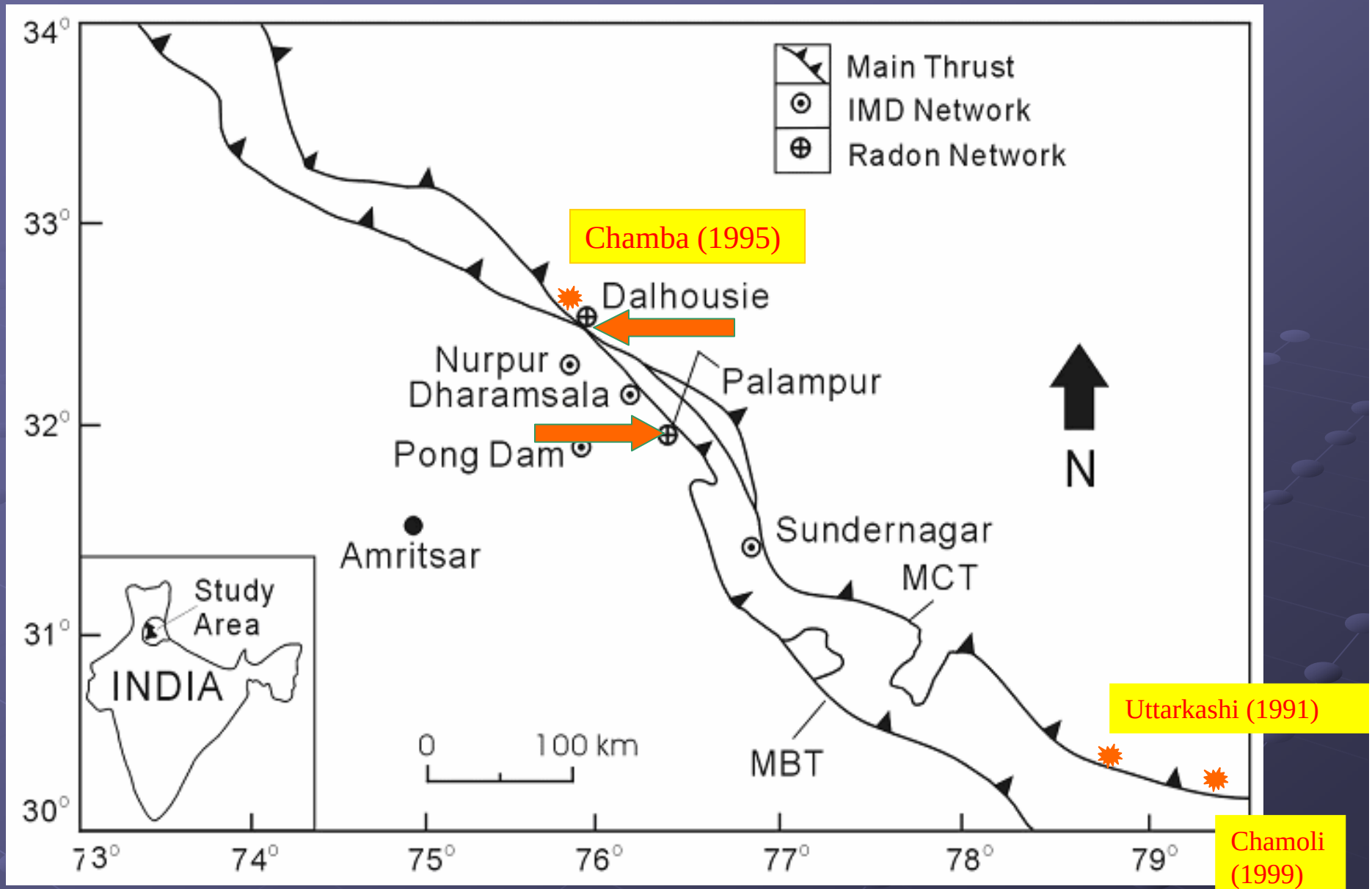
Thrust Boundary

Fault or Fault Zone

Spreading Centre

Fracture Zone

Active Volcano


Main Thrust
IMD Network
Radon Network
Chamba (1995)
Dalhousie
Nurpur
Dharamsala
Palampur
Pong Dam
N
Amritsar
Sundernagar
MCT
Study Area
INDIA
0
100 km
MBT
Uttarkashi (1991)
Chamoli (1999)
34°
33°
32°
31°
30°
73°
74°
75°
76°
77°
78°
79°

Subsurface Soil Gases

- Radon (^{222}Rn)
- Helium (^{4}He)
- Carbon-di-oxide (CO_2)
- Methane (CH_4)

What is Radon?

- A radioactive & inert gas
- 7.5 times heavier than air
- 100 times heavier than hydrogen
- Three isotopes :

Radon (Rn^{222}) 3.83 days

Thoron (Rn^{220}) 54.5 sec

Actinon (Rn^{219}) 3.92 sec

What is Helium (He^4)?

- Generated during the radioactive decay of isotopes of uranium and thorium in rocks and soil
- Highly diffusive and inert gas
- Shows the value 5.24 ppm in air

$$U^{238} \longrightarrow Ra^{226} \longrightarrow Rn^{222} \longrightarrow Pb^{206} + 8\ He^{4}$$

$$Th^{232} \longrightarrow Ra^{224} \longrightarrow Rn^{220} \longrightarrow Pb^{208} + 7\ He^{4}$$

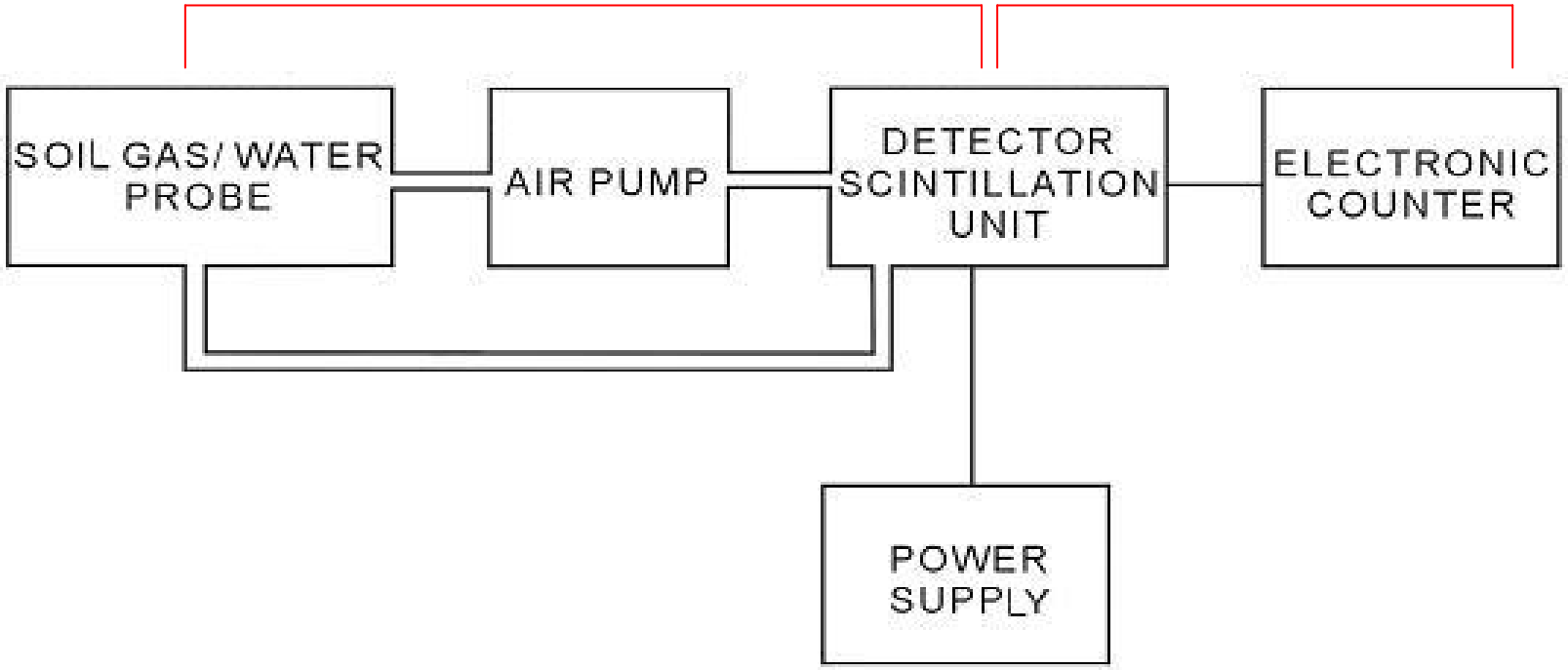
$$U^{235} \longrightarrow Ra^{223} \longrightarrow Rn^{219} \longrightarrow Pb^{207} + 7\ He^{4}$$

Factors controlling emanation

- Transmission Characteristics of Bedrock
- Mineralogical Effects
- Uranium/Thorium Concentration
- Carrier Fluids
- Weather and Soil Types

- Gases measured in soils can be strongly disturbed by environmental variables like atmospheric pressure, soil temperature, rainfall, soil moisture etc.

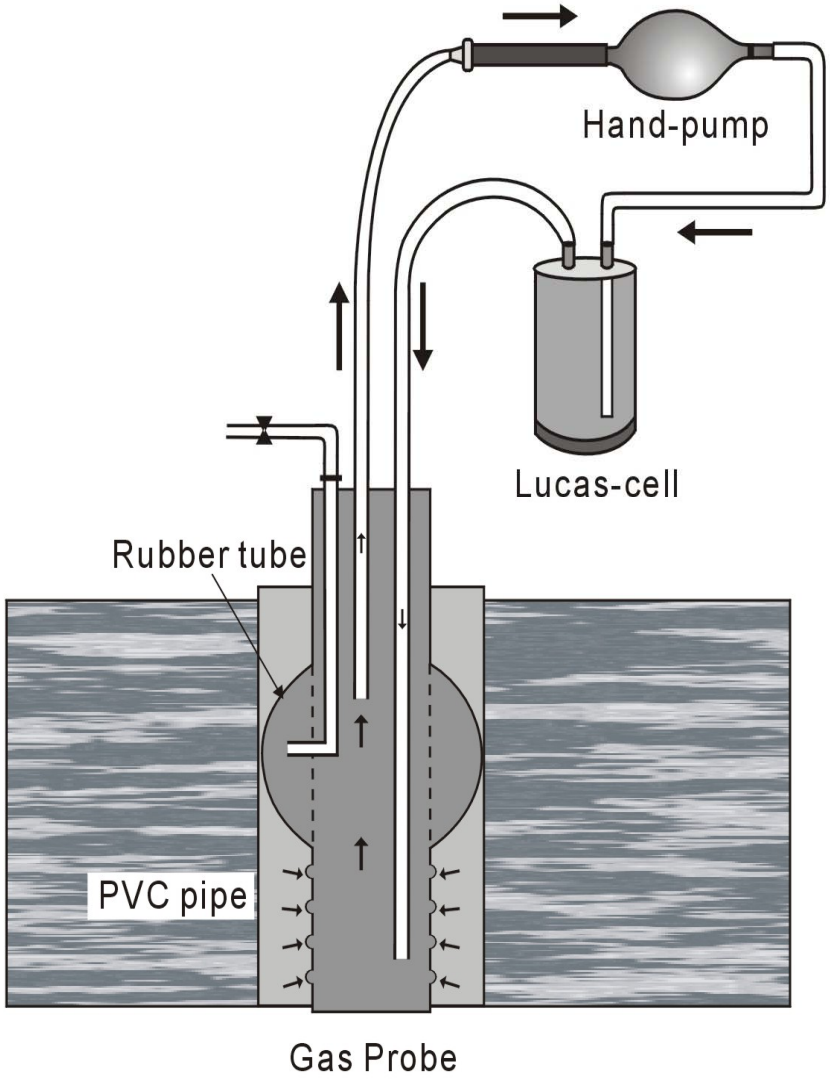
Emanometry Technique



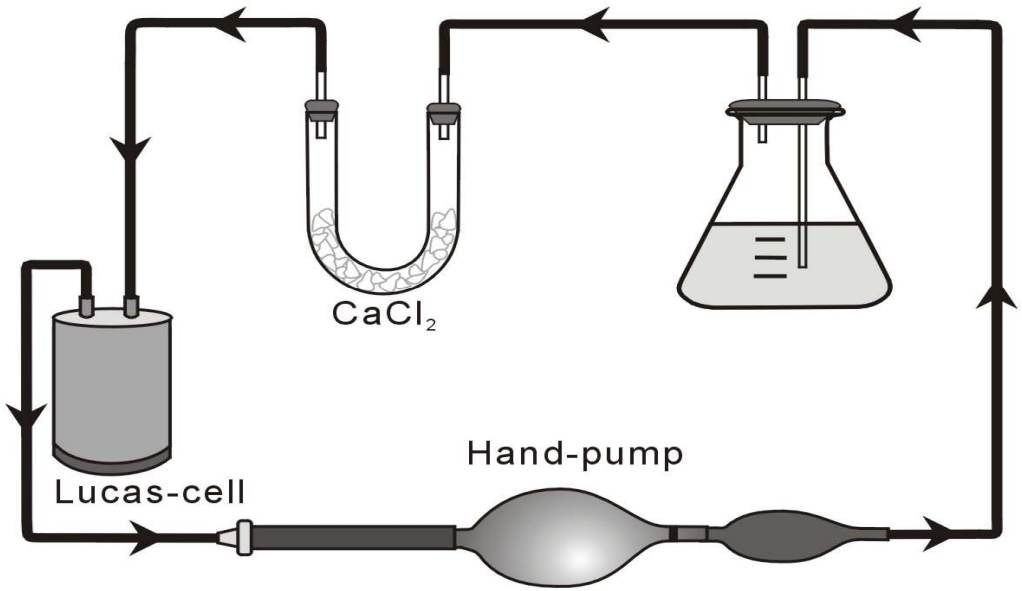
Soil-Gas Emanometry

Radon Emanometer used for radon sampling

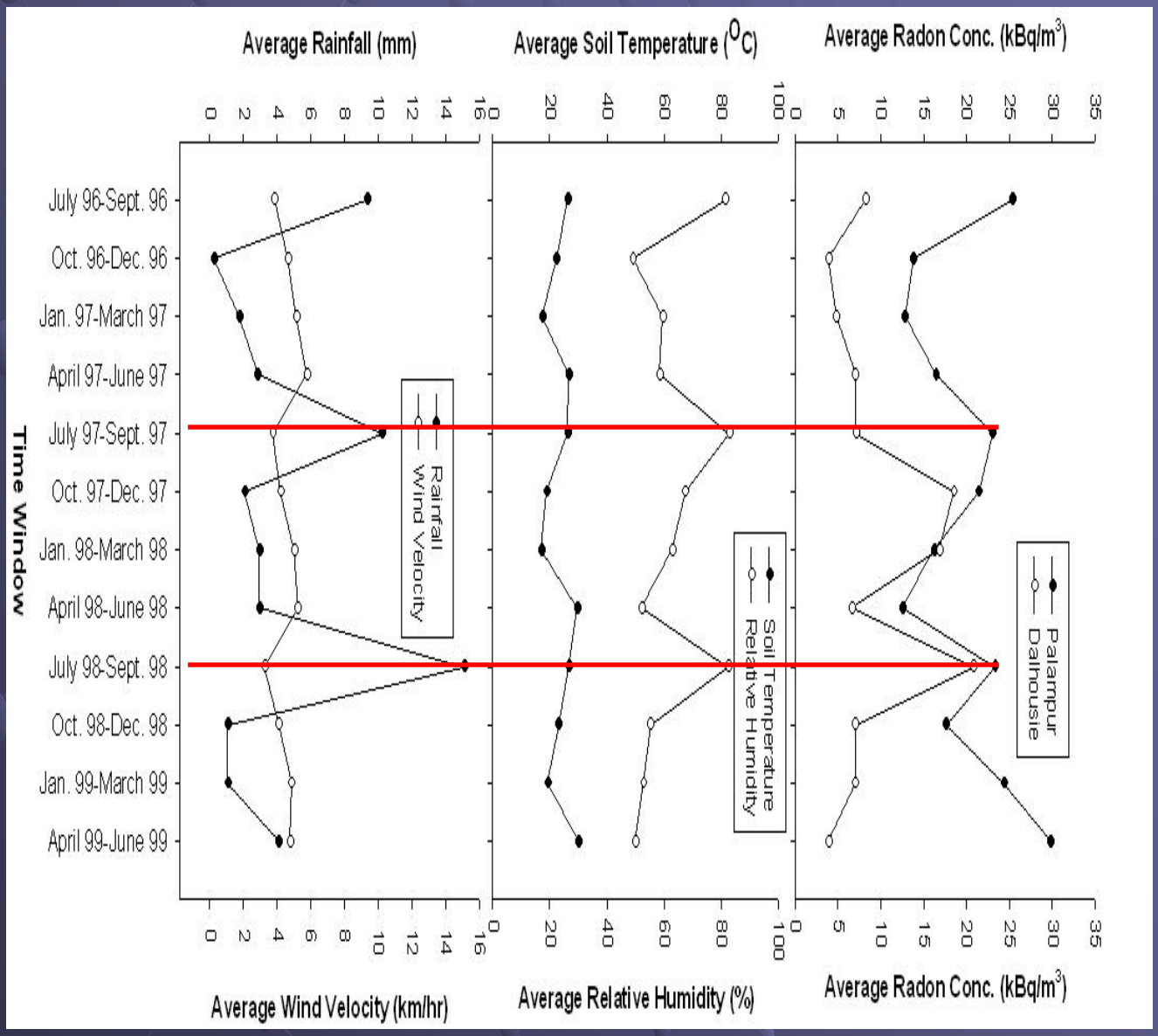
Soil-gas probe used for radon sampling



Groundwater Emanometry



Groundwater radon sampling methodolgy


Average Rainfall (mm)
Average Soil Temperature (°C)
Average Radon Conc. (kBq/m³)
Time Window
July 96-Sept. 96
Oct. 96-Dec. 96
Jan. 97-March 97
April 97-June 97
July 97-Sept. 97
Oct. 97-Dec. 97
Jan. 98-March 98
April 98-June 98
July 98-Sept. 98
Oct. 98-Dec. 98
Jan. 99-March 99
April 99-June 99
Rainfall
Wind Velocity
Soil Temperature
Relative Humidity
Palampur
Dalhousie
Average Wind Velocity (km/hr)
Average Relative Humidity (%)
Average Radon Conc. (kBq/m³)

Correlation coefficient of radon concentration in soil-gas with different meteorological parameters at Palampur

Parameter	Average (Avg)	Standard Deviation (Std)	% Variation Coefficient (Std/Avg)	Correlation Coefficient
Radon (Bq/L)	22	12.7	58	—
Temperature (^{O}C)	23.9	5.4	23	0.18
Relative Humidity (%)	64.3	18.1	28	0.31
Rainfall (mm)	5.5	14.8	267	0.19
Wind Velocity (km/hr)	4.5	1.4	32	-0.27

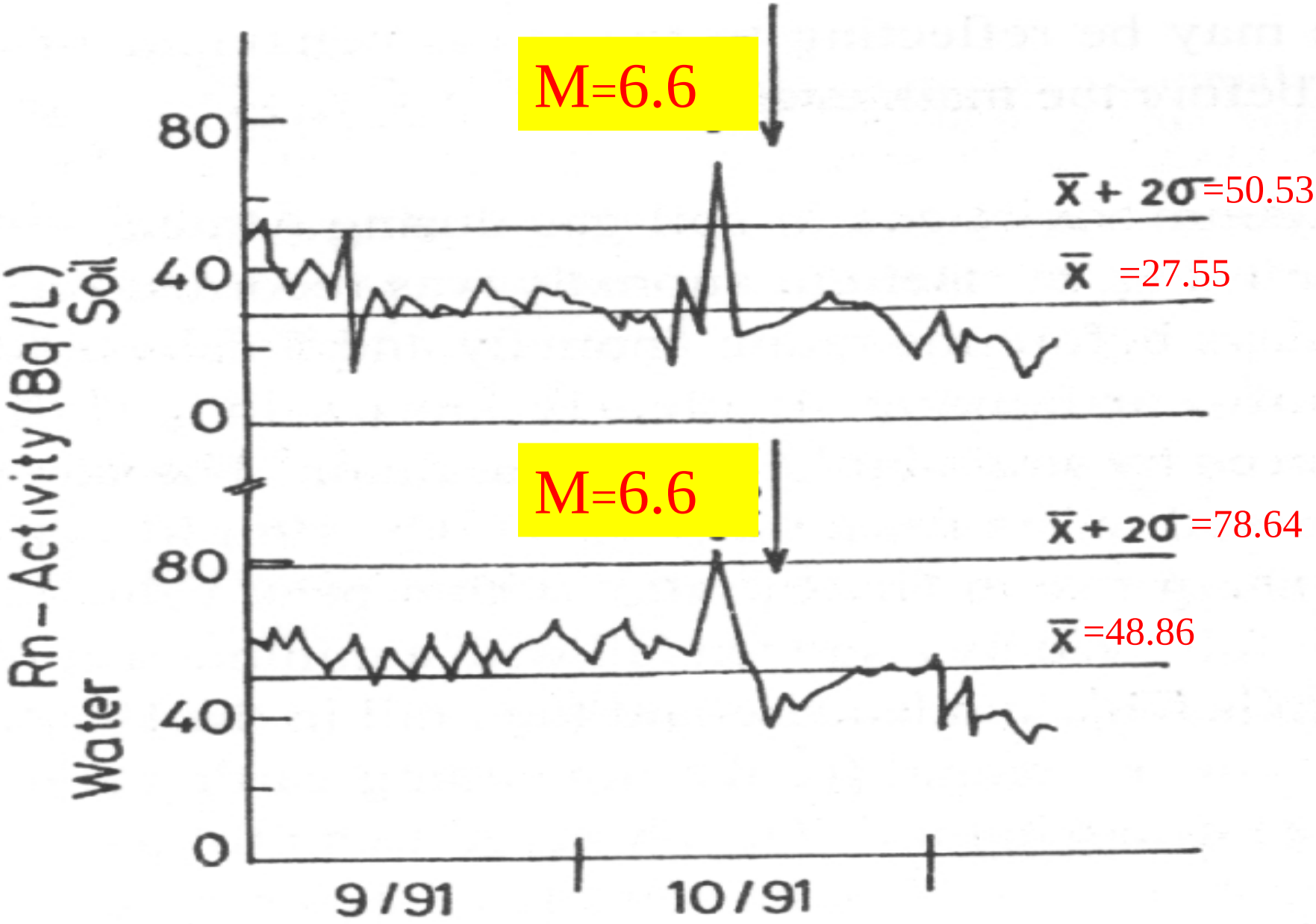
Radon Anomaly

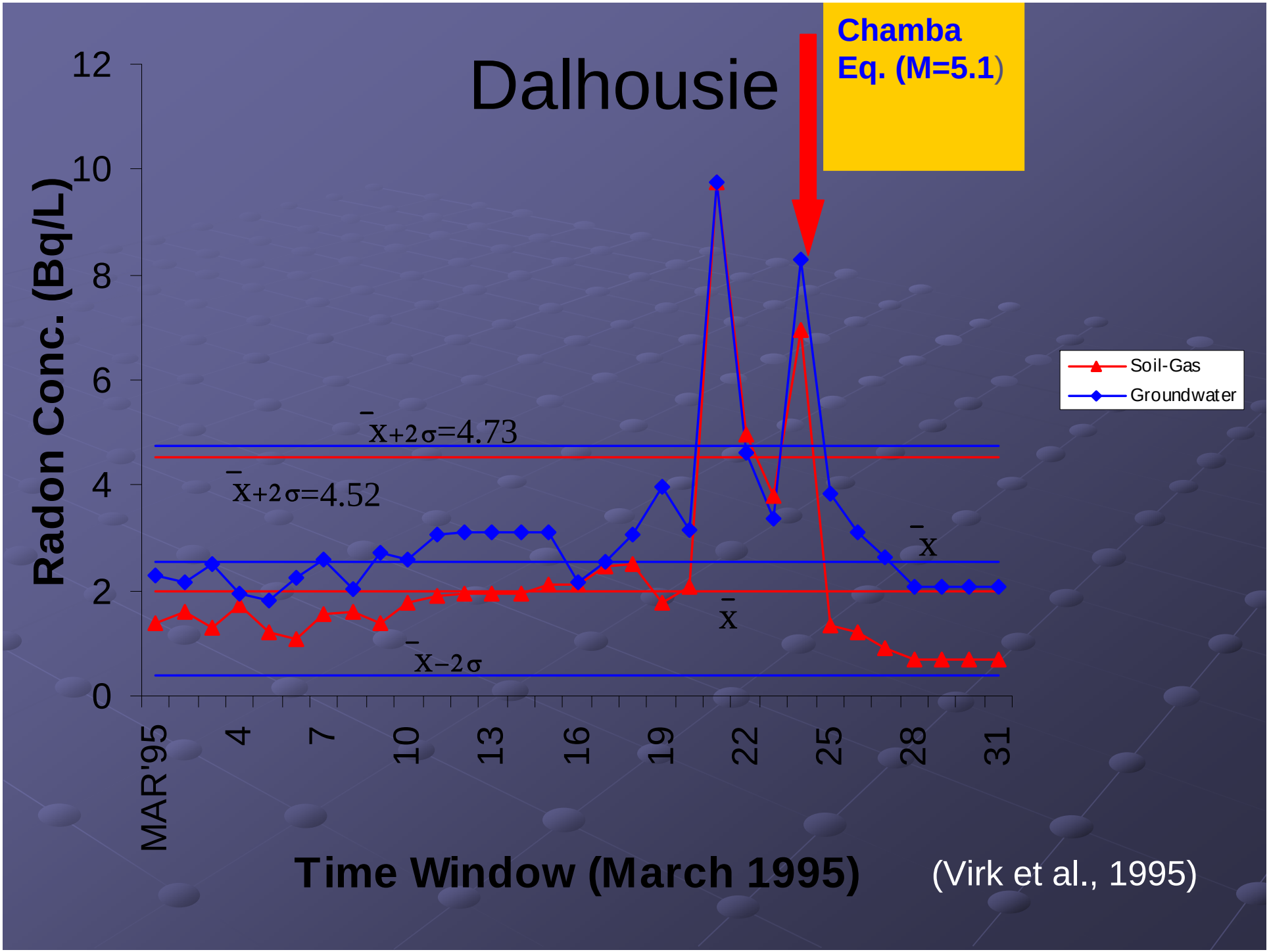
•Radon anomaly is defined as any sudden change in radon concentration crossing the average of that season by $\pm 2\sigma$.

•Radon anomalies followed by seismic event is Pre-seismic

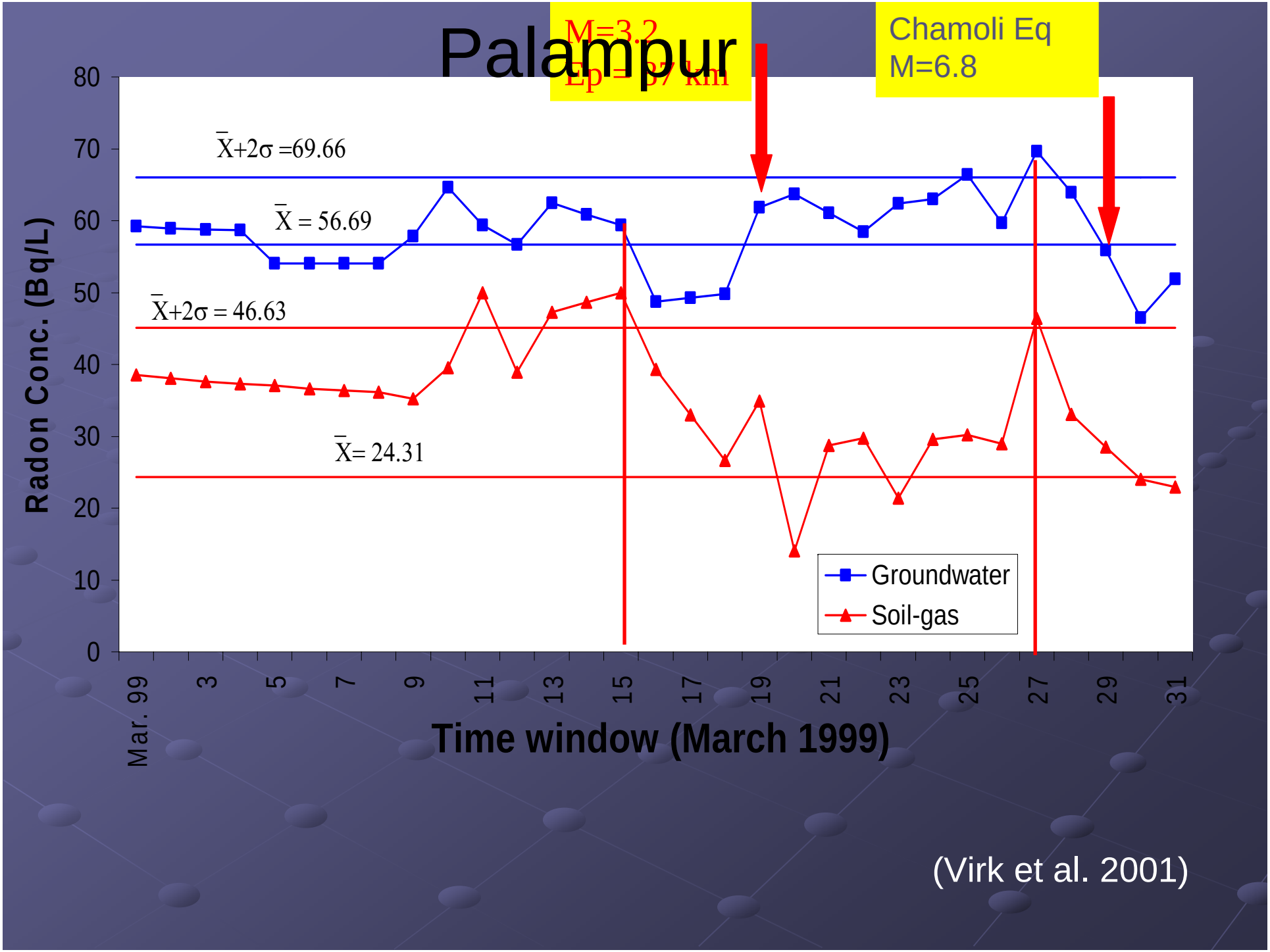
• Anomaly occur simultaneously (same day) with seismic event is called Co-seismic

• Anomaly after the seismic event is Post-seismic


M=6.6
80
40
0
$\bar{x}+2\sigma$=50.53
$\bar{x}$ =27.55
Soil
Rn-Activity (Bq/L)
M=6.6
80
40
0
$\bar{x}+2\sigma$=78.64
$\bar{x}$=48.86
Water
9/91
10/91

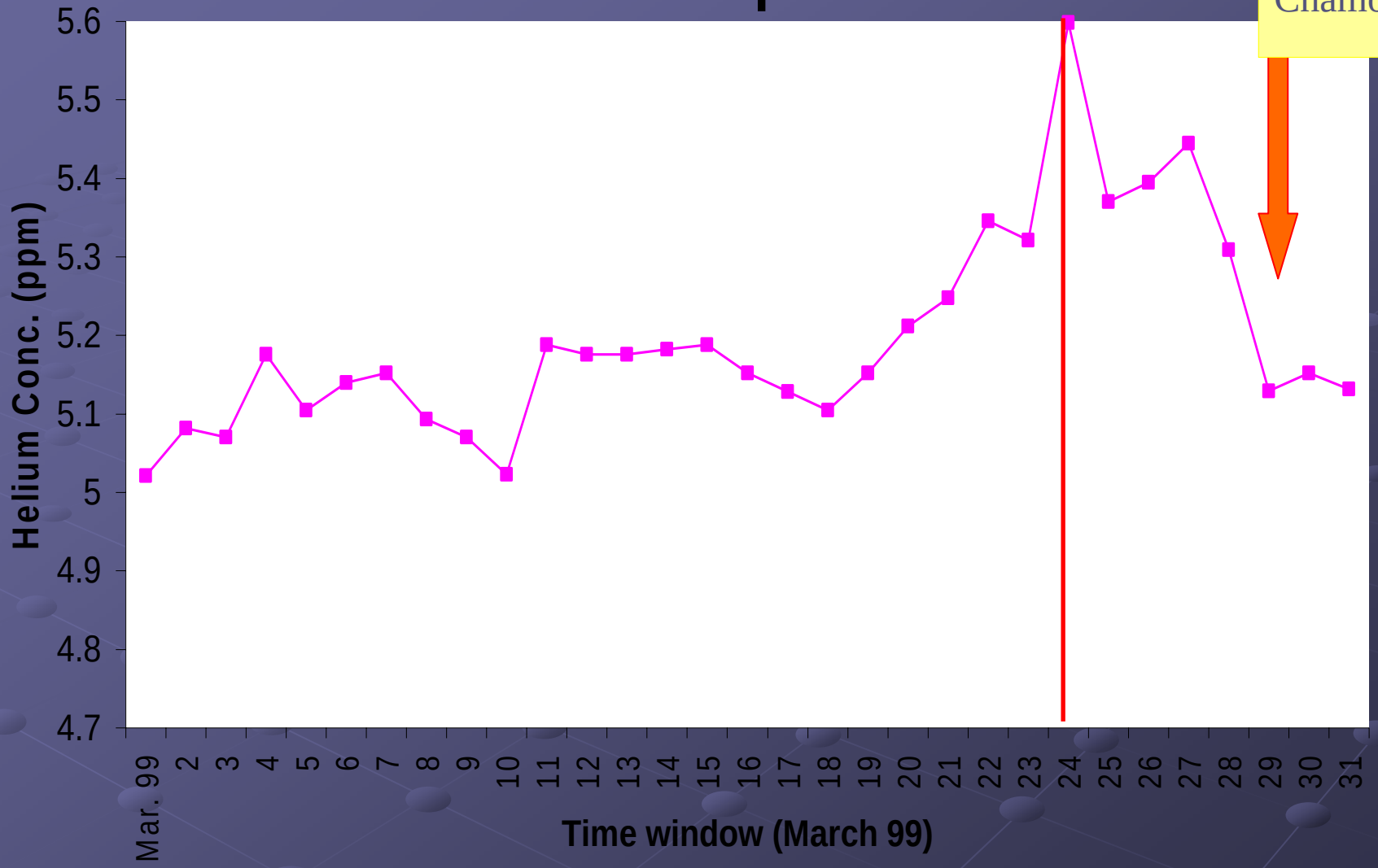

Dalhousie
Chamba
Eq. (M=5.1)
Radon Conc. (Bq/L)
12
10
8
6
4
2
0
$\bar{x}+2\sigma=4.73$
$\bar{x}+2\sigma=4.52$
$\bar{x}$
$\bar{x}-2\sigma$
Soil-Gas
Groundwater
MAR'95
4
7
10
13
16
19
22
25
28
31
Time Window (March 1995)
(Virk et al., 1995)

Palampur

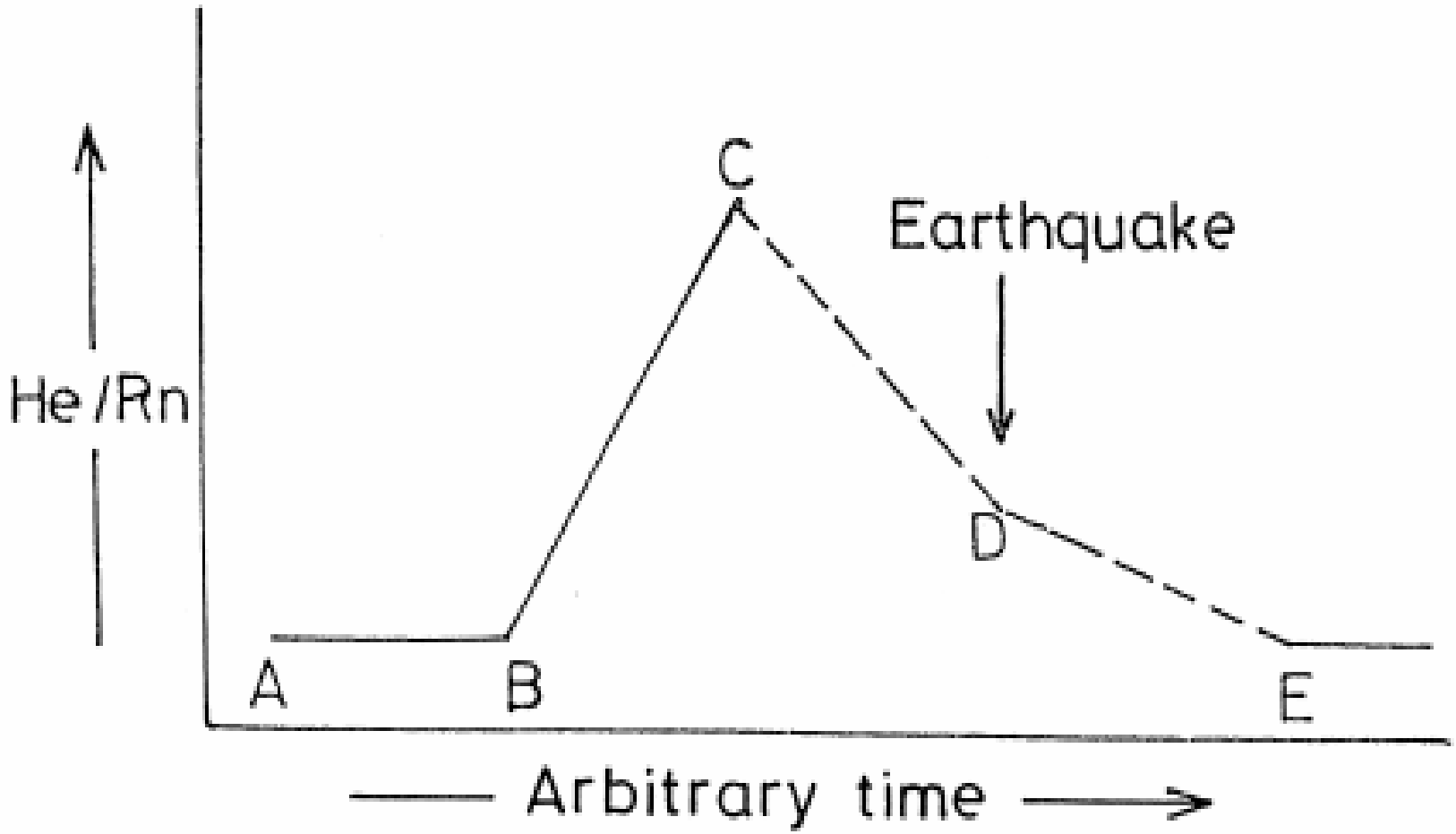


(Virk et al. 2001)

Palampur



(Virk et al. 2001)



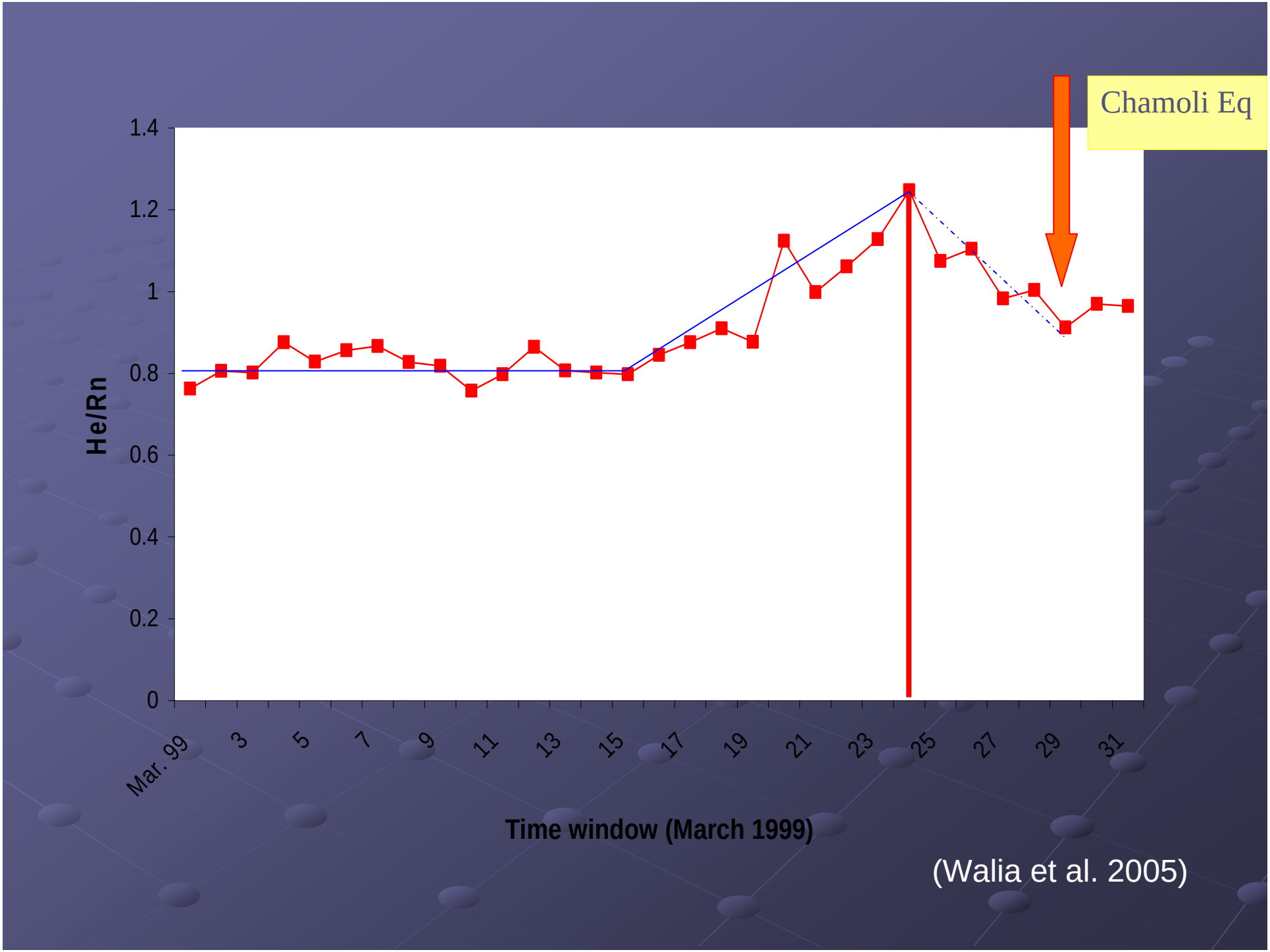
A-B : He/Rn ratio under normal condition

B-C : Rise in He/Rn ratio as stresses accumulate at depth

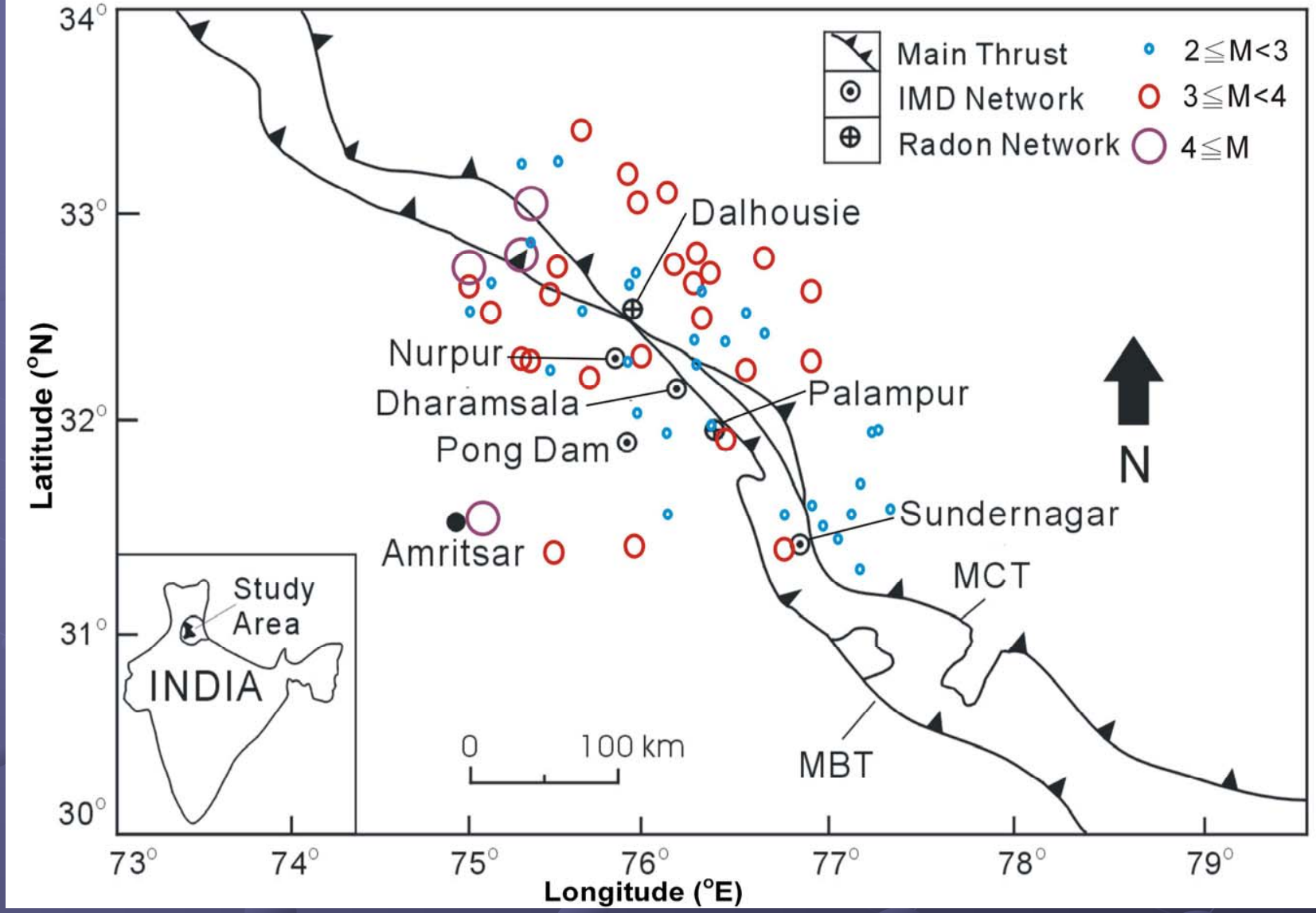
C-D : Drop in He/Rn ratio prior to triggering of the shock

D-E : Drop back in He/Rn ratio after the shock

Fig. 3. A conceptual He/Rn ratio model as a predictive tool for earthquakes.



(Walia et al. 2005)



- The total number of microseismic events correlated are 63.

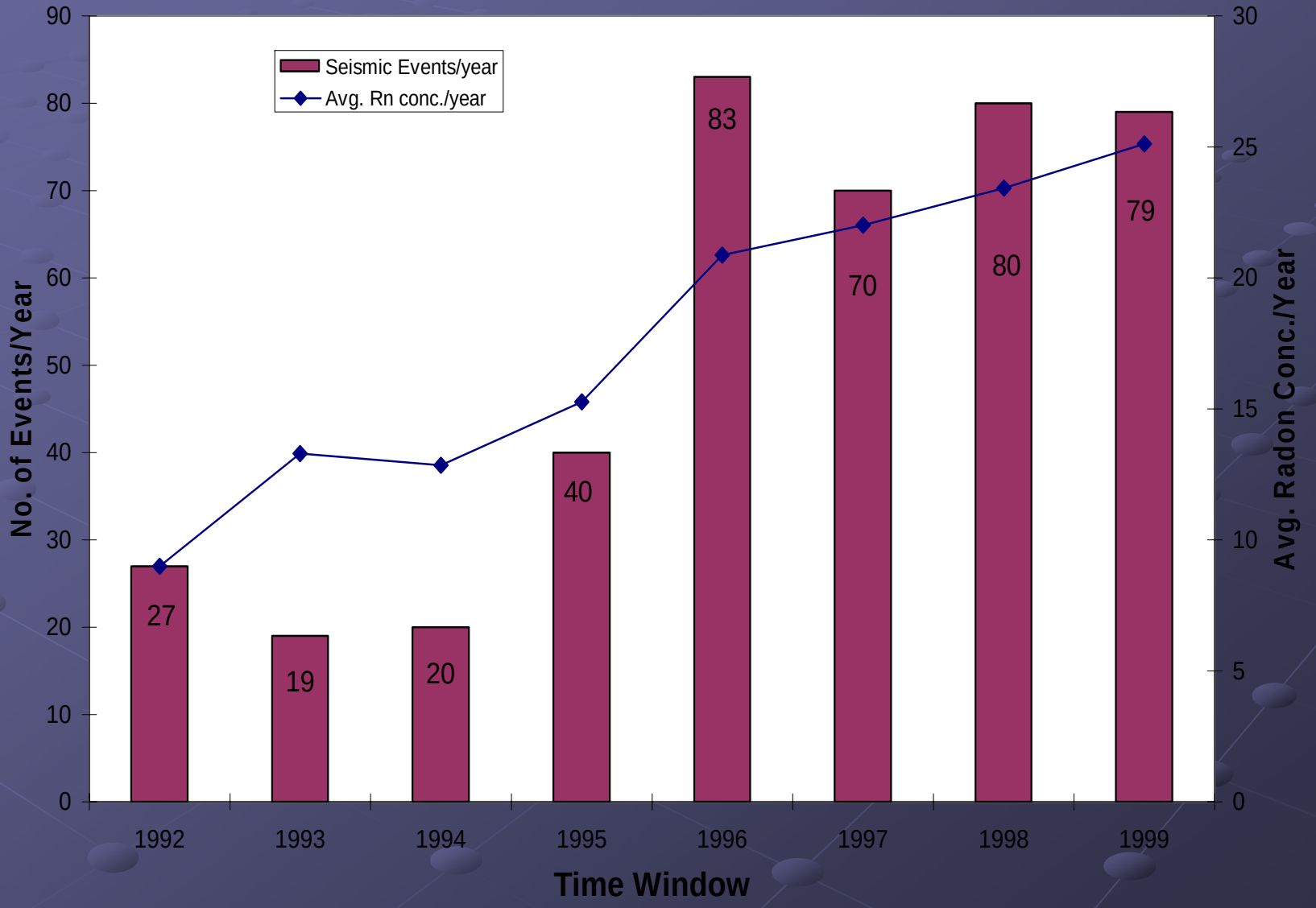
Station		Total no. of radon anomalies (a)	No. of anomalies correlated with events (b)	No. of anomalies not correlated with events (c)	Signal (%) (b/a)	Noise (%) (c/a)	Confidence level (signal/noise)
Palampur	I. Soil-gas	36	21/27	15	58	42	1.38
	II. Water	26	18/23	8	69	31	2.23
Dalhousie	I. Soil-gas	29	19/24	10	66	34	1.94
	II. Water	25	14/15	11	56	44	1.28

- Palampur station is found to be relatively more sensitive than the Dalhousie station as a total number of 40 seismic events correlated with radon anomalies are observed at Palampur as compared to 36 events at Dalhousie in both the media.

- A total of 116 radon anomalies were observed in the whole grid during the given time window and out of it 74 are correlated with seismic events.

- Most of the anomalies are pre-seismic 76% whereas only 14% are co-seismic and 10% are post-seismic.

Variation of Radon Conc. with Microseismicity in the region



- About 142 cases of radon anomalies in soil-gas and groundwater correlated with earthquakes of magnitude range between 2.1 to 4.8 and having epicentral distances less than 200 kms during time period 1992-1999.

- Whereas single earthquake of magnitude 4.7, 4.8, 5.1 and 6.8 were correlated with radon anomalies during the period.

- The radon behaviour observed in soil-gas and groundwater indicate that the transport phenomenon entirely different.

•The behaviour of Palampur and Dalhousie stations across the MBF is almost reciprocal. This may be due to relative motion of crustal blocks producing compressional strain on one side and dilatational strain on the other.

•Radon measurements carried out for earthquake precursory study seem to be one of the promising technique.

Thank You !!!