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Luminescence chronology of a fossil dune at Budha Pushkar, Thar Desert: Palaeoenvironmental and archaeological implications

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Chronological studies on a fossil dune at Budha Pushkar in Thar desert suggest that the existing hypothesis of a *wetter* Middle Palaeolithic period in the region is not tenable. The present study suggests a revision of the stratigraphic framework of this regionally correlatable sequence in the Thar desert and questions the earlier archaeological inferences.

IT is now well established that several dune-sections in the marginal areas of Thar Desert have preserved a long record of Early Man and Environmental Change[1–3]. The intermontane dune sequence at the fringe of the freshwater lake Budha Pushkar (74°36'E, 26°30'N.) is an important geoarchaeological site that has been extensively studied and eloquently debated. The debate ranges from basic differences on the stratigraphic locations of various sub-horizons to the association and typologic classification of lithic artefacts within various aeolian/palaeosoil sub-units. Even more contentious has been the controversy on the presence of a 'Rotlehm'-type red-brown soil and its interpretation on the amplitude of environmental change. This controversy still persists due to lack of a chronological framework which so far has been limited to a few radiocarbon dates on pedogenic calcrete nodules of somewhat dubious validity[4]. We describe here the results of a detailed luminescence dating programme and discuss its bearing on the previously suggested timing and amplitude of palaeoenvironmental changes in the Thar during the late Quaternary.

Pioneering studies by Allchin *et al.*[1, 2] led to the discovery of several Stone Age sites, particularly in the context of aeolian stratigraphy of the Thar desert. At Budha Pushkar, the authors reported the presence of Lower-, Middle-, Upper-Palaeolithic artefacts and Mesolithic tools and used these to ascribe chronology to their deductions on the environmental change. Based on the presence of a dark-brown 'Rotlehm' type soil along with a proliferation of Middle Palaeolithic artefacts, the authors suggested that during the Middle Palaeolithic period, the Thar witnessed a major wet-phase, especially since this red-brown soil was traceable to sites in the South (Pawagarh) as well. Agrawal *et al.*[4] and Wasson *et al.*[5] however, indicated that the ages based on Middle Palaeolithic artefacts could not be used since they occurred only on the surface of reddish brown dune and not in the dune matrix. They also doubted the cultural assignment of these artefacts since invariably the larger artefacts were found in association with the microliths. Chemical studies by Agrawal *et al.*[4] further indicated that the horizon designated as 'Rotlehm' soil was alkaline and did not show any convincing evidence of strong leaching and that the pedogenesis merely consisted of a marginal organic accumulation (< 1%), iron oxidation and a rather weak carbonate leaching. Based on these facts, the very designation of the horizon as Rotlehm soil was questioned with an implicit bearing on the deductions on climatic change. More recent micromorphological studies on the red-soil horizon by Achyuthan and Rajaguru[6] have indicated the presence of easily weathered minerals such as hornblende and plagioclase, which also suggest absence of any intense weathering. The authors argue that the soil only represents a weak weathering that suggests a semi-arid climatic regime. Figure 1 provides the general stratigraphy as suggested by Allchin *et al.*[1, 2] and as deduced by one of the present authors (S. N. Rajaguru).

The dune-sands were dated using the luminescence dating method[7, 8]. The experimental procedure was identical to that described by Chawla *et al.*[9] with the following variations:

(i) The purity of 106–150 μm quartz grains was checked using an 880 nm infra-red stimulated luminescence system (IRSL) and only the samples that did not exhibit an IRSL were chosen. Samples exhibiting IRSL were retreated with 40% HF for 10 min.
(ii) TL analysis was made using a Schott UG-11 filter that enabled an isolation of optically easy-to-bleach 325°C glow-peak of quartz[10].
(iii) The equivalent doses were estimated using the total bleach method[7], the total bleach-regeneration method[11, 12] and the partial bleach method[13]. In the total bleach method, two bleaching times of 30 min and 13 h

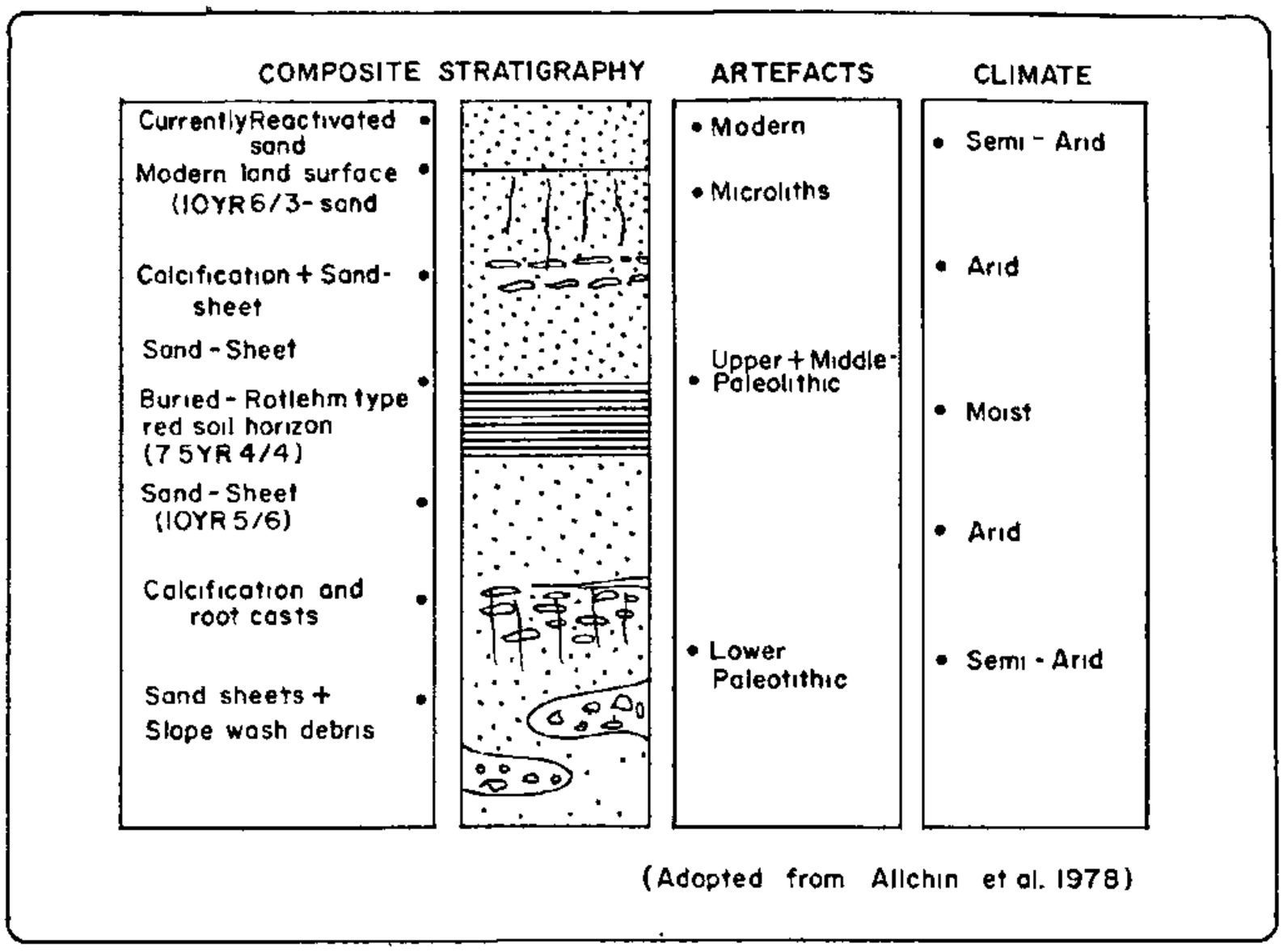

Figure 1. Budha Pushkar Composite stratigraphy, archaeological data and climatic inferences based on Allchin *et al.*, 1978

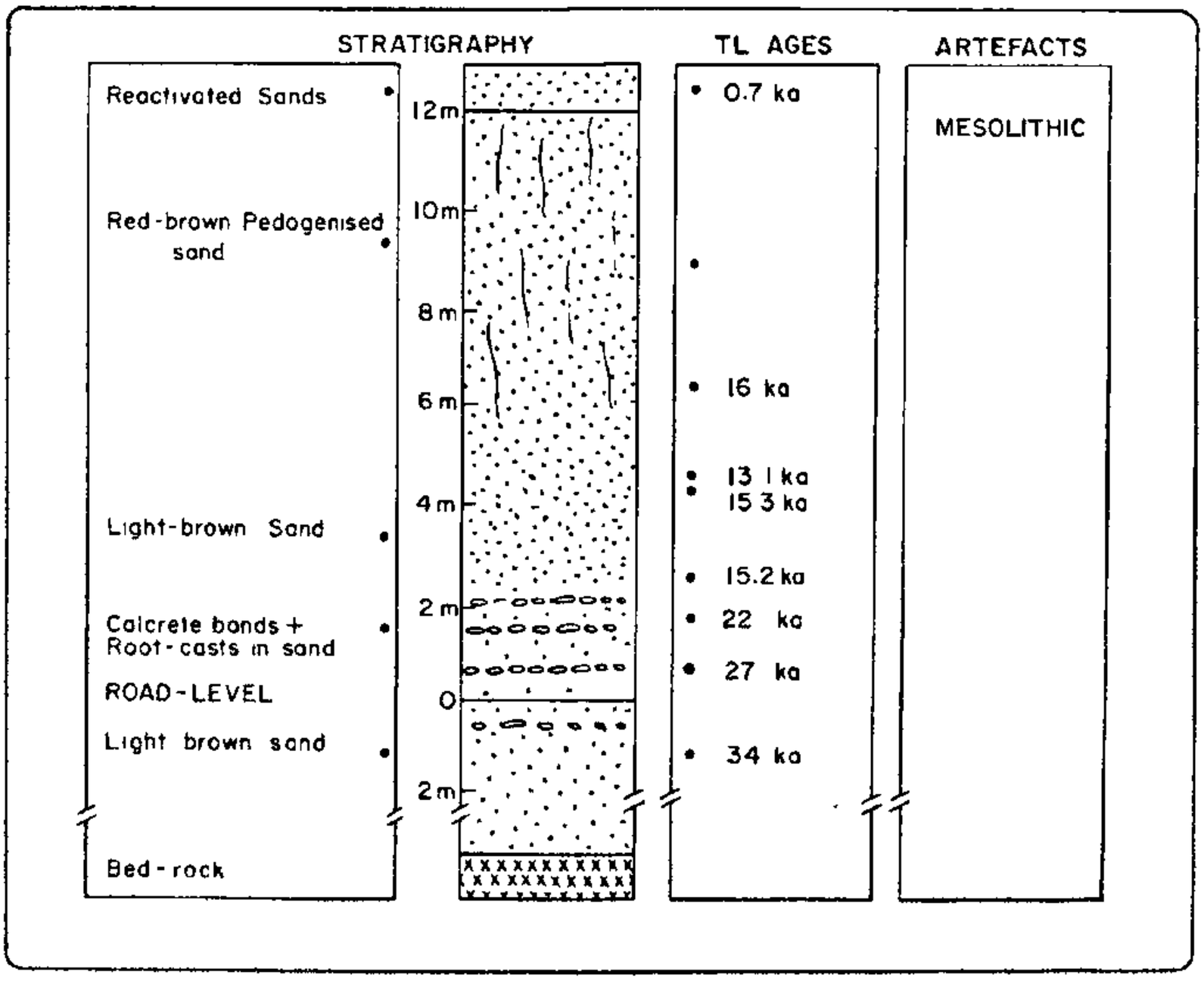

Figure 2. Budha Pushkar. stratigraphy, TL ages and archaeological data from present study. This stratigraphy is similar to that reported previously by Wasson *et al.*[5] except that here the upper pale-brown fine sand horizon was of only a marginal thickness.

sun exposure were employed so as to test the easy bleachability of the UG-11 selected quartz luminescence. All optical bleaching was done using the natural sunlight.

Table 1. TL analysis of sands from Budha Pushkar, Thar Desert

	Thermoluminescence data			Radioactivity data				
	Equivalent doses (Gy)			Annual dose components				
Sample	Regen (13 h)	Short bleach (30 min)	Long bleach (13 h)	Partial bleach (30 min)	Th(ppm)	U(ppm)	K%	Annual dose rate (μGy/yr)	Age (Weighted mean*)
PSH 92/1	–	29 9	–	34 5	4 75	0.81	1 49	2.21	15 ± 1 6
PSH 92/2	35.4	58 8	67 2	69.4	6 1	2 4	1.52	2 73	22 ± 2.1
PSH 92/3	36 7	54.4	61 2	65 3	5 05	0 82	1 5	2.24	27 ± 2 6
PSH 92/5	–	64 6	–	72.3	5**	1**	1 36	2.14	34 ± 3.3
PSH 92/7	–	35 7	–	40 5.	5**	1**	1 53	2 32	16 ± 2.5
PSH 92/8	–	31.3	34.5	36 4	4 98	1.09	1.45	2 25	15 ± 1 6
PSH 92/11	19.0	32 1	32.6	37.3	5.64	0 93	1.7	2 52	13 ± 1.4
PSH 92/12	0 8	1.7	1.4	5 4	4 36	1 24	1 61	2 41	0.7 ± 0 2

* Weighted average of short bleach, long bleach and partial bleach ED values were used for calculating the age. Water content (assumed) ~ 5%
** Assumed values

Table 2. Comparison of γ-dose contributions to the annual doses derived from laboratory measurements with those based on field γ-ray spectrometry

	Gamma dose (μGy/yr)		
Sample	Field spectrometry	Laboratory* estimate	Ratio (Field/Lab)
PSH 92/1	919	805	1.14
PSH 92/2	1324	1050	1.26
PSH 92/3	885	823	1.08
PSH 92/5	867	808	1.07
PSH 92/7	864	847	1.02
PSH 92/11	787	910	0.87
		Average	1.07 ± 0.13

* Using ZnS(Ag) alpha counting for estimation of U and Th (radioactive equilibrium assumed) and γ-ray spectrometry for K-estimation.

Tables 1, 2 provide a summary of TL data, radioactivity assay and a comparison of γ-doses derived from laboratory measurements with those based on field NaI(Tl)-γ-ray spectrometry.

Methodologically, a comparison of the equivalent doses by different methods indicates that the samples do undergo a TL sensitivity change on sun exposure. It is also interesting to note that with the sole exception of PSH-92/1, the sensitivity change is constant in all samples, as is evidenced by the ratio of equivalent doses (total bleach/regeneration) being 1.76 ± 0.09. Concordance of total bleach ages with 30 min sun-exposure and 13 h sun exposure not only points to the easy bleachability of 325°C peak, but it also indicates that these samples were sufficiently bleached prior to their deposition.

The results also afford interesting stratigraphical and palaeoenvironmental deductions. These are:

(i) The relative stratigraphic assignment of the red-brown and pale yellow-brown horizons by Allchin *et al.*[2] is not tenable. On the contrary, the present chronological data suggest that the red-brown horizon post-dates the yellow brown sand/calcrete horizon.

(ii) The results support the previously suggested pre-LGM antiquity of aeolian accumulation in the Thar[14] and imply that it occurred at Pushkar in two epochs around ~15 ka and ~25 ka. It is important to note that this sequence as also other sequences in western Thar[9, 14, 15] do not provide any signature of an enhanced accumulation during LGM as has been conventionally suggested[16].

(iii) The terminal date of 15 ka for the accumulation of red dune indicates that the so termed 'Rotlehm' soil should have formed in a less arid climate than the climate during the period 25 ka–15 ka. Chemical and mineralogical studies indicate that the soil formation took place only in the semi-arid climate with better rainfall than during a period when the dune-sand accumulation took place. This phase of better climate in all probability existed during the Holocene optimum specially since significantly higher precipitation has been inferred from the lacustrine records at nearby lakes at Sambhar and Didwana[17–19].

(iv) The implicit mid-Holocene antiquity of this red-brown horizon also makes the Middle Palaeolithic association of this horizon questionable and thus it is concluded that the typological classification of large lithic artefacts found in association with microliths was perhaps misleading. A similar suggestion has also been made by Agrawal *et al.*[4]. On the other hand, the inferred mid-Holocene antiquity of the red-brown soil horizon provides an age upper-limit to the overlying microliths and this agrees well with the ages on microlithic phases at other sites in the region. Microliths in Bagor have been dated to 4480 ± 20a BC, 3835 ± 130a BC, 3285 ± 90a BC, 2765 ± 105a BC, 2110 ± 90a BC (TF-

786, –1007, –1011, –1009, –1005) and 2040 ± 110a BC at Langhnaj (TF-744). Thus our inference on the red-brown soil horizon appears reasonable from both the climatological and archaeological viewpoints as also from the fact that the sand underlying this red-brown zone dates to 22 ka which makes it far too young to qualify as Middle-Palaeolithic.

To summarize, the present study indicates that,

(i) The dune-building activity at Budha Pushkar occurred during two periods at *ca* 25 ka and 15 ka.
(ii) The so-called Rotlehm soil and its association with the Middle-Palaeolithic is not tenable and consequently the earlier inference of a wet-Middle Palaeolithic phase at Budha Pushkar does not withstand the scrutiny of chronological studies.
(iii) The study also indicates that the stratigraphic position and assignment of Middle Palaeolithic artefacts at Budha Puskhar is erroneous.

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Fluorescence microscopy in estimation of organic matter maturation

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In fluorescence microscopy spectral wavelength (λ_{max}) of light emitted by excited palynomorph is considered for maturation level estimation. Case study of subsurface samples studied from well E–A of Bengal Basin has been illustrated. λ_{max} recorded from palynomorphs is correlated with the other two parameters: mean vitrinite reflectance and thermal alteration index recorded from the same samples.

QUANTITATIVE spectral wavelengths are measured on MPV-3 fluorescence microscope. Pollen, spores and other organic matter are excited with ultraviolet light of spectral wavelength range 200–400 nm and examined under the microscope to observe fluorescence colours in

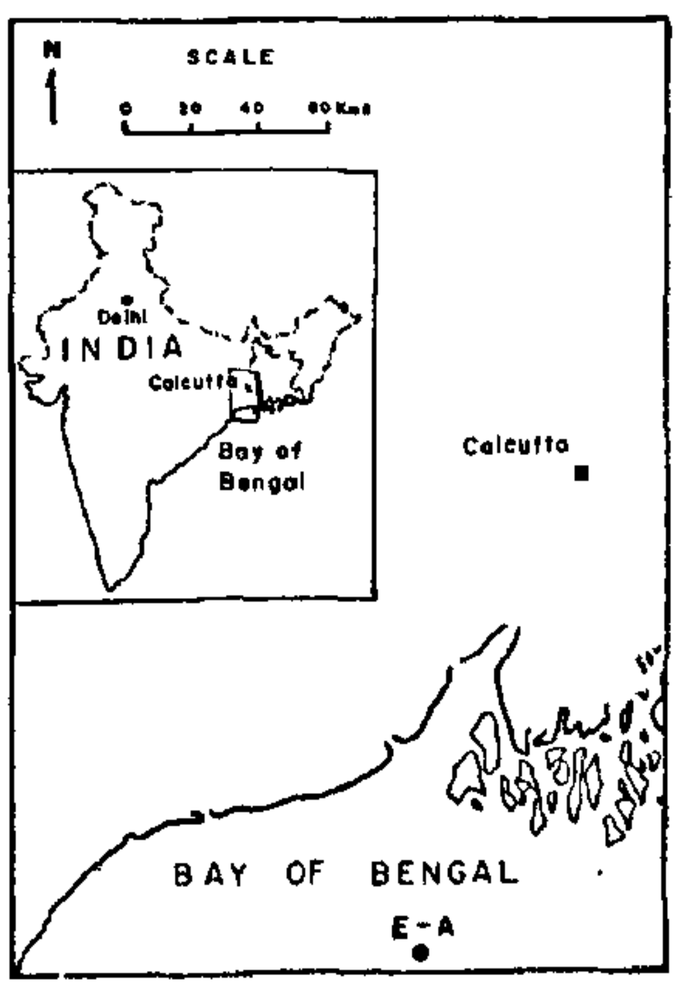

Figure 1. Location map of studied well in Bengal Basin