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GEOLOGICAL EVOLUTION OF KUCHAMAN LAKE, DISTRICT NAGAUR, RAJASTHAN

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ABSTRACT

Kuchaman lake occupies an area of about 8.5 sq.kms in Nagaur District of Rajasthan. The study of Kuchaman lake deposit depicts five distinct litho-units (Units E to A). The oldest unit E is the calcrete and calcified boulder conglomerate and is resting over the Delhi Group of rocks. It is followed by Unit-D which consists of grey laminated clays and then the Unit-C a hard lithified carbonate layer. Unit-C is considered a marker horizon, as it indicates a break in sedimentation due to aridity. The other two units i.e; Unit-B consists of laminated clays with high dolomite content and Unit-A consists mainly of silt.

The occurrence of thick calcified boulder conglomerate bed at the base of the Kuchaman lake deposits and its presence 5 kms upstream in a major palaeochannel indicates that probably a significant fluvial regime existed prior to the development of lacustrine regime. An attempt has been made to work out the sedimentation history of the Kuchaman saline lake.

INTRODUCTION

Kuchaman lake is a continental saline lake located around Kuchaman city, Nagaur District, Rajasthan. The Phulera-Jodhpur section of the Northern Railway passes 8 km south of Kuchaman lake (Fig.1). It is connected to Parvatsar in the south, Nawa in the south-east and Didwana in the north-west by the metalled roads. It is about 8.5 sq. kms in area and is bound by 380 M contour line. The present status of the lake is that of a playa.

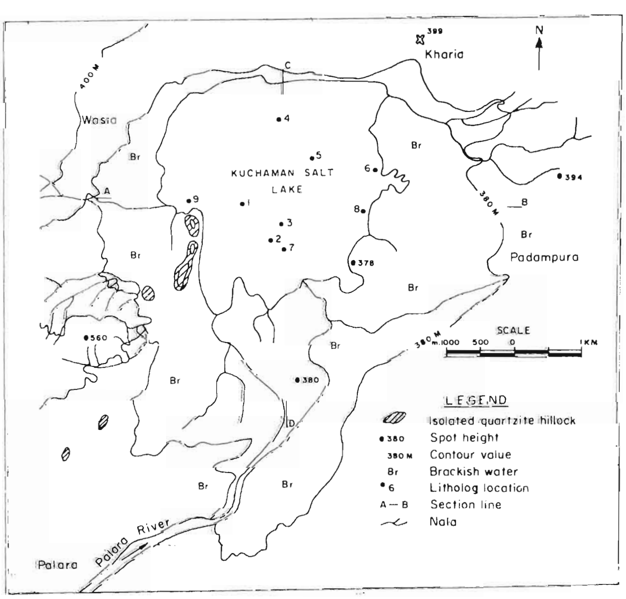

Fig. 1. Map around Kuchman lake showing litholog locations and geological section lines.

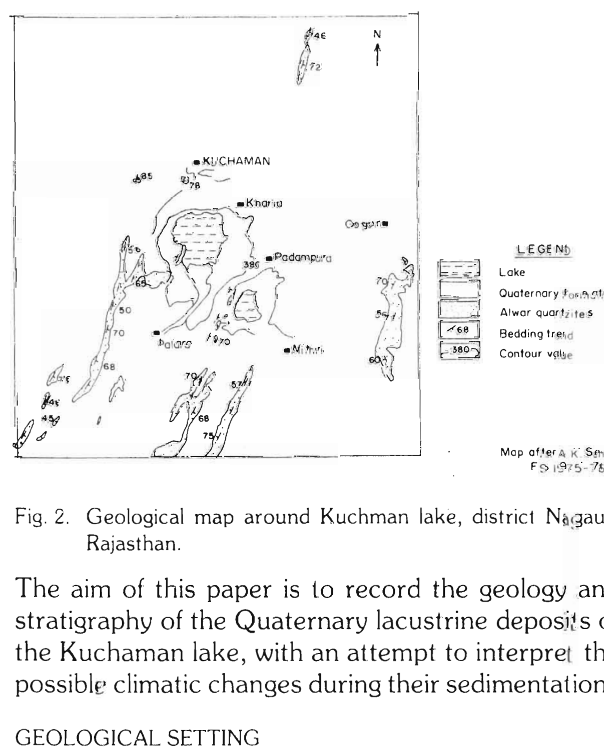

Fig. 2. Geological map around Kuchman lake, district Nagaur, Rajasthan.

The aim of this paper is to record the geology and stratigraphy of the Quaternary lacustrine deposits of the Kuchaman lake, with an attempt to interpret the possible climatic changes during their sedimentation.

GEOLOGICAL SETTING

The geology and the structure of the area was worked out by Sen and Ramalingam (1976). The unconsolidated deposits of the Kuchaman lake are overlying the rocks of the Delhi Super Group.

A major fluvial regime has existed during the Pleistocene which is shown by the presence of subrounded to rounded quartzite boulders (upto 20 cm. in length) on the lake floor (encountered at point 1,

Table 1. Chemical analysis results of Kuchaman Lake Brine

P.R. No.	Location point No.	Specific conductivity at 25°C Micro-siemen/cm	pH	TDS at 180°C	SiO_2	Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	CO_3^{--}	HCO_3^-	SO_4^-	NO_3^-	F^-	B	TH as $CaCO_3$
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
6544-1	K-1	68700	7.2	58800	40	380	850	20600	90	28300	Nil	540	6750	10	7.60	15	4450
6544-2	K-2	101000	7.1	112400	10	170	600	40000	150	59200	Nil	380	15000	5	4.00	35	2900
6544-3	K-3	128200	7.1	132200	10	190	450	50000	180	63600	Nil	530	18200	10	5.00	35	2300
6544-4	K-4	112500	7.2	116200	10	200	550	43000	160	5700	Nil	440	16150	5	4.00	30	2750
6544-5	K-5	101500	7.0	91600	10	1400	2500	28800	100	51200	Nil	260	3500	180	2.40	10	13800
6544-6	K-6	97000	7.1	82600	10	300	900	30400	110	44200	Nil	480	6600	50	2.40	25	4450
6544-7	K-7	118300	7.3	113400	10	70	180	43000	140	56600	Nil	1480	13200	5	7.00	35	900
6544-8	K-8	105600	7.1	108500	10	160	300	43000	120	54200	Nil	650	12950	5	5.00	30	1650
6544-9	K-9	145000	7.3	149500	10	265	545	55500	150	73550	Nil	600	19800	20	3.00	30	2900
6544-10	K-10	145000	7.2	145700	5	330	620	53000	160	72550	Nil	380	17500	10	5.0	20	3350
6544-11	K-11	83600	7.7	71300	30	380	670	25500	90	35300	Nil	660	9200	15	7.0	20	3700
6544-12	K-12	109800	7.1	—	—	75	190	—	—	50200	Nil	600	—	—	—	—	—
6544-13	K-13	79500	7.7	—	—	80	190	—	—	33300	Nil	675	—	—	—	—	—
6544-14	K-14	126600	7.5	—	—	65	170	—	—	71550	Nil	1450	—	—	—	—	—
6544-15	K-15	31200	7.1	—	—	865	765	—	—	14300	Nil	250	—	—	—	—	—
6544-16	K-16	123000	7.2	120200	10	200	420	44000	120	60600	Nil	520	14000	170	4.0	20	2230
6544-17	K-17	2200	8.0	—	—	5	5	—	—	300	Nil	825	—	—	—	—	—
6544-18	K-18	2400	7.8	—	—	5	5	—	—	300	Nil	825	—	—	—	—	—
6544-19	K-19	4000	8.1	2700	30	70	60	800	40	475	Nil	970	500	200	1.0	5	420
6544-20	K-20	127000	7.5	124300	10	330	620	45000	150	60600	Nil	470	15350	30	5.0	25	3400

photo 2) and the presence of thick boulder/conglomerate bed from the palaeo-channel of the Palara river south of Sirlas village (27°3′-74°49′) (photo 1). The onset of aridity made the fluvial system defunct on account of the blocking of river course by dune formation in the north-east with due support by eastern and western limbs and resulted in the formation of closed basin with centripetal drainage.

GEOHYDROLOGY AND GEOCHEMISTRY

The basin has a centripetal drainage with Palara river being the major incoming drainage with the present status of a bayou. The playa is also fed by E-W trending drainage around Kakaria and Hirani meeting at Kharia. A drainage south of Wasra also feeds the basin.

Fig. 5 shows the brine location map of the Kuchaman lake. Table 1 shows the chemical analysis results of the brine samples. Location point 19 falls along a palaeo-course of the Palarā river outside the plate boundaries.

The drainage inputs are composed primarily of non-carbonate alkali (Na^+ & K^+) exceeding 50% i.e. chemical properties are dominated by alkalis and strong acids (CL^- & SO_4^{--}). The alkaline earths (Ca^{++} & Mg^{++}) are the secondary constituents. The

Table 2. Generalized stratrigraphy of Kuchaman lake deposit

Litho-unit	Shallower Portion bounded by merging rocky pediment	Deeper portion	Shallower portion bounded by sand-dunes
Unit A	Grit/Colluvium	Silt	Silt
Unit B	Intercalated silt/clay sequence with occasional grit	Dark/Clay	Silt/clay Interlaminated sequence
Unit C	Hard lithified carbonate layer	Hard lithified carbonate layer	Hard lithified carbonate layer
Unit D	Pebble/Sand	Laminated Clay with carbonate Intercalations	Silt/clay Inter laminated sequence
Unit E	Colluvium with calcareous cement (Calcrete)	Reddish Sand/Silt with calcareous cement	Reddish silt with calcareous cement

water samples from the Palara river show the dominance of CO_3^{--} and HCO_3^- over Cl^- and SO_4^{--} and are rich in Ca^{++} & Mg^{++}. During the chemical evolution of the basin SO_4^{--} and $CO_3^{--} + HCO_3^-$ are eliminated from the system with the enrichment of Cl^- Similarly Na^+ & K^+ are enriched with the concentration of Ca^{++} & Mg^{++}.

LACUSTRINE STRATIGRAPHY

All the possible litho-successions (Fig. 3) in the area were studied to decipher the lateral and vertical variations in the lithology of the lacustrine deposits. A generalized section can not be a true representative of the lake stratigraphy because there would be facies variations from the periphery to the centre in space and time. The lateral continuity of sedimentary units encountered in the open well sections allowed correlation of stratigraphic levels. Generalised stratigraphy of the lake is given in Table 2. The detailed description of the various litho-units is as follows:-

CALCRETE (UNIT E): Thick calcrete deposits upto 3 m in thickness is developed along the pediment of the Palara river which is the major feeder to the Kuchaman lake. The weathered, basement is also cemented

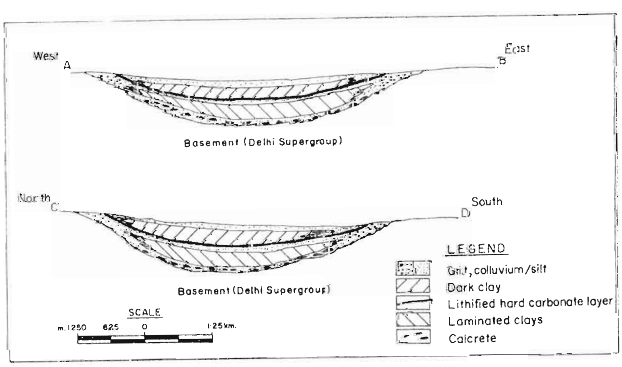

Fig. 3. Schematic sections of Kuchman lake along A-B, C-D lines.

by $CaCO_3$ as a chemical precipitate. The calcrete deposits are in general, faintly bedded, and are massive to pisolitic in nature. The position and development of calcrete in vertical and lateral sequence is highly variable. The best development of calcrete is along the palaeo-drainage course. The calcrete is seen thinning out away from the channel towards the pediment. The colluvial material present along the pediments and the fluvial clastic material, prior to the initiation of lacustral phase is also cemented by calcareous material.

LAMINATED CLAY WITH CARBONATE INTERCALATIONS (UNIT D): This unit is made up of laminated silt and clays with intercalations of sediments rich in sulphides, sapropels and carbonates. The lower clay unit is rich in saline minerals and indicates the first lacustral event. Chemical precipitates include both Ca-Mg carbonates and saline minerals like Halite. nite is the predominant clay mineral whereas Kaolinite along with Calcite occur in small accounts (5-10%).

LITHIFIED HARD CARBONATE LAYER (UNIT C): A hard lithified carbonate layer upto 10 cm in thickness is found occurring below 5 to 7 m in the central portion and at shallower levels in the peripheral part. This unit is considered a marker, as it is present in the central as well as in the peripheral portion of the lake without any change in lithological composition and is easily traceable in the basin. Chemically Ca is the predominent cation over Mg. Silica is upto 15% and halite content is upto 20%. This layer indicates a break in sedimentation due to extreme aridity which possibly produced the calcareous hard pan layer due to capillary action (Photo 3 & 4). The presence of burrows in this layer (Photo 4) are indicative of biotoic activity for surviving the adverse climatic conditions due to aridity which resulted in the gradual lowering of the ground water.

DARK CLAY UNIT (UNIT B): These are dark coloured clays with high dolomite, feldspar and quartz contents. Illite is the major clay constituent (20-30%) whereas kaolinite and montmorillonite occur in small amounts (5-10%). The organic content is very low and shows the oxygenated environment. The clay indicates a temporary increase in the rate of atmospheric precipitation after earlier arid phase (Photo 3). The bedded nature of these clay shows the presence of relatively greater humidity than the one prevailing at the time of deposition of Unit A. Two pedogenetic horizons are recorded within this clay unit.

SILT (UNIT A): This unit is the thinnest and is of aeolian origin formed with the advent of arid to semi-arid conditions. Sand is brought by the ephemeral streams at the playa margin. Some sheetwash material is also brought to the lake during the rainy season. Bedding traces are distorted due to capillary rise of salts. This unit is indicative of playa surface with pronounced surface change over short interval of time (Neal, 1969). Dessication fissures, dessication polygons and salt-encrusted wet surface are some of the surface features noticed in this unit.

On the basis of the detailed litho-successions (Fig. 4) from the Kuchaman lake area (Fig. 2), two geologi-

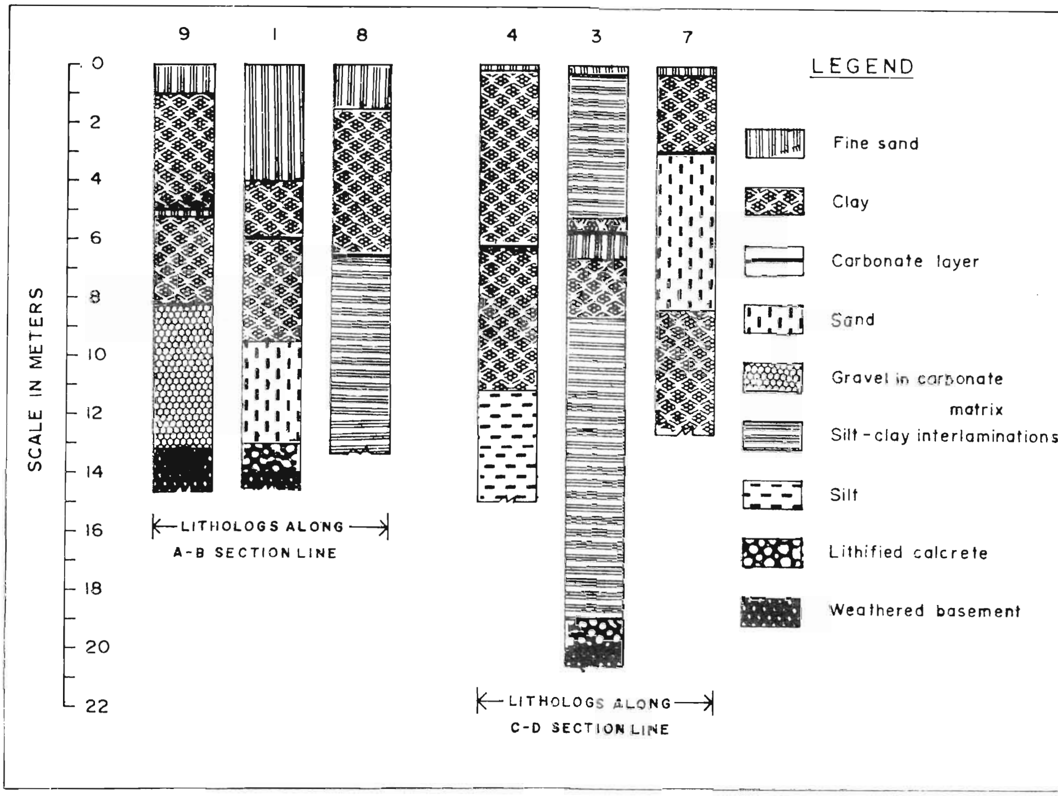

Fig. 4. Litholog of Kuchman lake section.

cal sections (Fig. 3) have been drawn to show the behaviour of sediments in the lake stratigraphy

EVOLUTION OF THE BASIN

The litho-units encountered in the lake sections can be assigned to specific environment of deposition and also to palaeo-climate. It is assumed that during the arid phase the lake would either be dry or with shallow water level indicating playa status and during this phase the clay will not be deposited. During the humid periods lake will be deeper retaining water depending upon the basin capacity, precipitation and the catchment area. This phase would be ideal for clay deposition. The fluctuating environments and climate through time would also leave its imprint on the nature and lithology of the lacustrine deposits. During this phase the clay will not be deposited. During the humid periods the lake will be deep and the depth of water column would depend upon the basin capacity, precipitation and the catchment area. This phase would be ideal for clay formation by detrital and chemical action. The fluctuating environments would also leave its imprint on the nature and lithology of the lacustrine deposits and would favour the deposition of inter-laminated silt clay sequence.

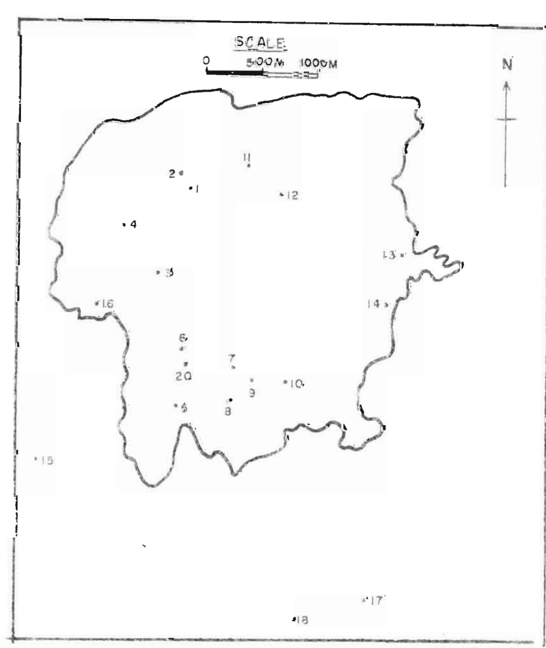

Fig. 5. Location map of brine samples.

The onset of aridity after Würm glaciation (Ca 17000 yrs BP) is widely accepted throughout the globe, which lasted till the begining of Holocene (Ca 10000 yrs BP). Dry arid climate favoured the calcification of depressions (valleys and lake basins), whether they were occupied by weathered hard rock or by terrigenous clastics. Calcrete (Unit E) was probably formed during this phase. The aridity was interrupted by humid climatic conditions which indicated the formation of true lacustrine deposits. The lower interlaminated clays sequence (Unit D) was probably deposited during this humid phase with fluctuating conditions. This humid phase was followed by extreme arid conditions, during which the lake was completely dry and the ground water lowered to considerable depths and carbonate hard pan layer was formed throughout the basin. This arid event can be correlated to a period of about 3000 yrs BP worked out by Singh et al (1972) by radio carbon methods and by studying the flora of Sambhar lake sediments, which is located quite near to the Kuchaman lake. The arid phase was interrupted by extreme humid climatic conditions when the lake enlarged in area with depth of water column attaining a maximum depth of 4 to 5 m, resulting in the deposition of thick massive clays (Unit B). This phase was the most humid phase during the entrie lake history. The humidity was followed by present day semi-arid climatic conditions when saliferous silt (Unit A) showing playa features were deposited. This phase is continuing till present.

CONCLUSIONS

The formation and evolution of the Kuchaman lake is largely controlled by variation of climate in a denudational basin along a palaeo-drainage course. The calcification of the boulder conglomerate in the catchment and the widespread presence of calcrete pieces most probably corresponds to the post Würm arid phase (Ca 17000-10000 BP) The initiation of humid phase resulted in the formation of laminated clays heavily impregnated with carbonates, suphides and salts. The humid phase was followed by extreme arid conditions as reflected by carbonate pan formation. The aridity was followed by humid climatic conditions when clay rich in dolomite and felspar was deposited. The present climate is semi-arid and lake deposits are minor silts, with salt encrustations showing the playa status of the lake.

The inputs to the playa system are Ca^{++}, Mg^{++}, SO_4^{--}, HCO_3^{-} rich waters, whereas the concentrated brines of the lake are Na^{+}, Cl^{-}, SO_4^{--} rich waters. There is a gradual decrease of Ca^{++}, Mg^{++}, HCO_3^{-} with increase in brine concentration. SO_4^{--} decrease with respect to Cl^{-} during the later stage of crystallization.

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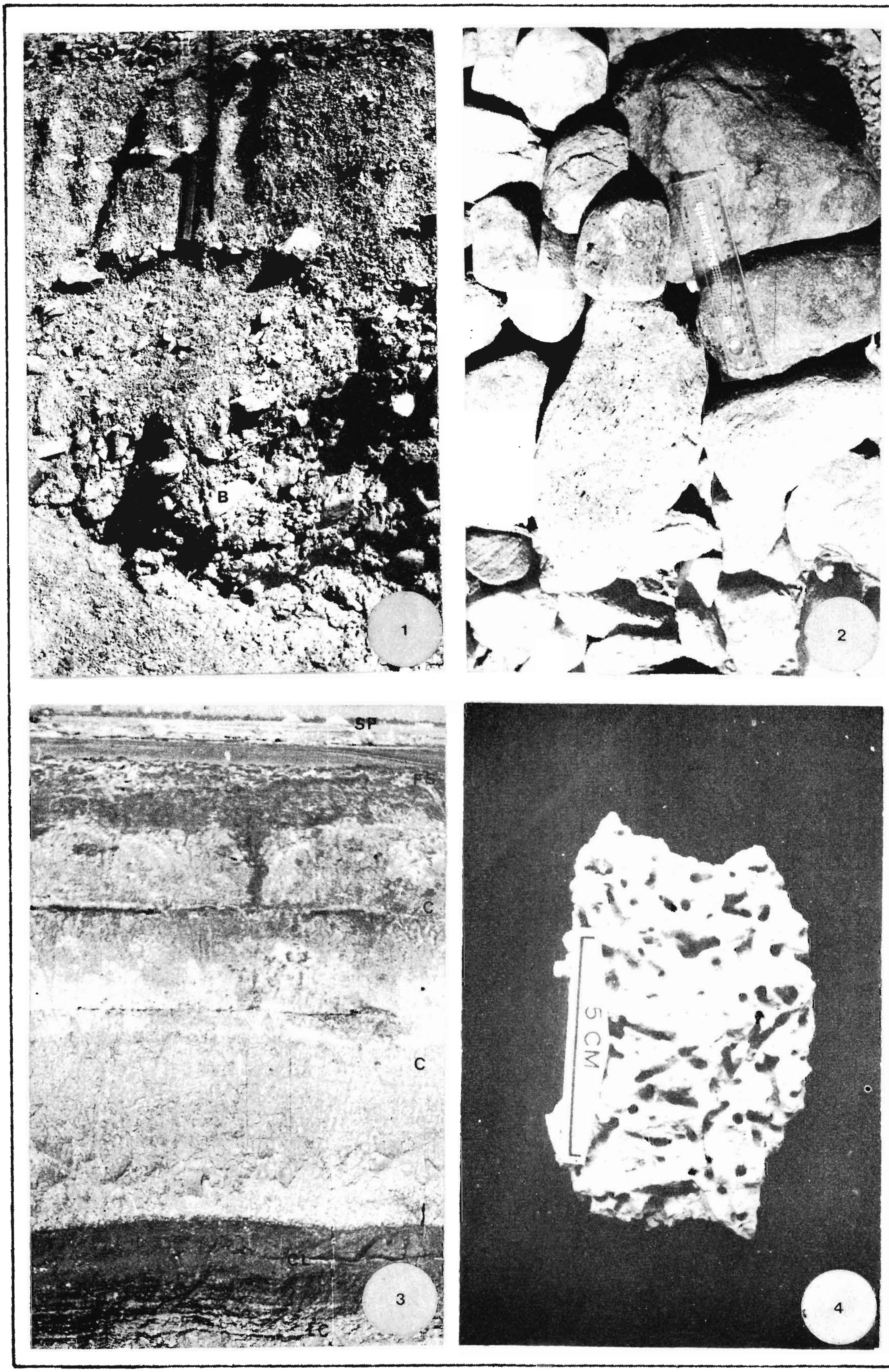
EXPLANATION OF PLATE

PLATE I

1. Calcareous grit (CG) overlying the horizon of calcified boulder bed (B) from the palaeo-channel of the Palara river, south of Sirlas village.
2. Semi-rounded to rounded quartzite boulders (upto 20 cm in length) excavated from a depth of about 15 M at pit point 1.
3. Section of a dug well showing salt pans (SP), fine sand (FS), clay (C) marker carbonate layer (CL), and laminated clay layer (LC).
4. Bioturbation in carbonate layer.

Plate I



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