CALCRETIC AND FERRICRETIC DURICRUSTS OF THE THAR DESERT: THEIR GENESIS, PALAEOCLIMATIC IMPLICATIONS AND GEOTECHNICAL EFFICACY AS PAVEMENT AGGREGATES

SUMMARY OF THE
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SUMMARY

BACKGROUND INFORMATION

The arid and semi-arid terrains in northwestern India, "The Great Desert of Thar" attains vast significance from the point of view of its past geological history in particular between Pleistocene - Recent i.e. Quaternary period. During this period, the area has witnessed manifold transformations ranging from well knitted perennial drainage, blooming river valley civilization, fertile pastoral land, to a barren hostile terrain of present day

The Quaternary geological record of the study area comprises a thick pile of non indurated sediments of varied nature viz. aeolian sands, fluvio - lacustral sediments, residual soils and duricrusts. The duricrusts like, calcretes, ferricretes and gypsicretes etc. are successfully employed in evaluating the past climatic changes. Being a border area, it is supposed to have a good logistic network which is, a pre-requisite for the nation's defence. But, the paucity of adequate road paving aggregates in the sandy desertic tracts jeopardize the road construction. The author's realization that widely distributed and easily available calcrete and ferricrete aggregates may lead to cost effective road construction has prompted to evaluate their geotechnical characteristics.

STUDY AREA

The study area predominantly encompasses the Marwar, Barmer and Jaisalmer basins, covering the semi -arid, arid and hyper arid terrains of the Thar desert. The study area is bounded between the north latitudes 25° 30'-28° 00' and east longitudes 70° 30'- 73°30'.

AIMS AND OBJECTIVES

The present endeavour aims :

1. To study the genesis and development of calcretes and ferricretes and their utility in understanding the palaeoclimatic changes.
2. To appraise the geotechnical feasibility of these duricrusts in the road construction as pavement aggregate.

The study aims at the following objectives :

(i) To map the distribution of calcretes and ferricretes in space through ideally exposed sections.

(ii) To bringout the chemistry, mineralogy, micromorphology of calcretes and ferricretes.

(iii) To illustrate the significance of calcretes and ferricretes in deciphering micro environmental changes leading to palaeoclimatic inferences.

(iv) To evolve models for the genesis and development of these duricrusts.

(v) Evaluation of the geotechnical characteristics of calcretes and ferricretes and their utility as road paving aggregates.

APPROACH AND METHODOLOGY

The author's endeavour to solve the intricate, but potential research objectives necessitated to design and adopt a multidisciplinary approach and methodology. Entire study has been carried out in the following phases.

Phase I

Creation of data base through compilation of available literature, preparation of base, regional geological and geomorphological maps, mapping the distribution of duricrusts etc.

Phase II

A detailed fieldwork along selected traverses with special emphasis on all field based studies for the duricrust and sampling (both disturbed, undisturbed and oriented) for the detailed laboratory studies. Special field based tests and undisturbed core sampling of duricrust for geotechnical studies are also part of this phase.

Phase III

Involves a detailed laboratory studies through advanced, high resolution instrumentation techniques such as EPMA, ICP-MS, AAS etc on the following lines.

(i) Detailed chemistry on major oxides, trace elements (by AAS) and REE (by ICP-MS)
(ii) Mineralogical studies using XRD and thin sections.
(iii) Preparation of soil thin sections and subsequent micromorphic studies.
(iv) Sub microscopic studies (by EPMA).
(v) Geotechnical evaluation of duricrusts through standard tests.
(vi) Statistical analyses of chemical and geotechnical parameters
(vii) Compilation and correlation of laboratory and field data.

LITHO-STRATIGRAPHY AND MORPHOTECTONIC SETUP

The geology of the study area ranges from post Delhi Malani Intrusives to the Recent aeolian sands. The study area and its neighbourhood is characterized by a thick pile of sedimentaries viz. Marwar Supergroup (Cambrian), Bap-Badhura Formations (Permian), Lathi, Baisakhi, Jaisalmer Formations (Jurassic), Habur, Pariwar, Fategarh Formations

(Cretaceous) Bandah, Khuyala, Palana, Kapurdi Formations (Tertiary) with Malani's as their basement.

The Quaternary geology of the study area comprises three phases of process controlled units viz. the fluviatile and fluvio-lacustral sedimentaries of the early Pleistocene period, the well stabilized, oxidized dunal and playa sequences associated with calcretes of middle Pleistocene to early Holocene The poorly stabilized or unstabilized dunal sands and lacustral sediments of Recent period

GEOMORPHOLOGY

Highly perplexing and heterogeneous geomorphological features of the study area are predominantly sculptured by fluvial and aeolian processes, though tectonism has also played a significant role in shaping the geomorphic forms In accordance to the dominance of the processes, the study area is divided into aeolian process dominated Jaisalmer block and fluvial process dominated Luni block. The landforms of the Luni block includes inselbergs, V-shaped valleys, gorges, terraces, cutoff meanders, active and defunct stream channels as erosional features While flood plains, older and younger alluvium, alluvial and colluvial fans, levees, channel bars as depositional features The landform characteristics of aeolian domain include inselbergs, desert pediplains, piedmont slopes, gravelly and rocky pavements, yardangs, hammadas, mesa and buttes, escarpments as erosional features; interdunal plains, colluvial fans, sandsheets, playas and a variety of dune types as depositional features

The geomorphic evolution through Quaternary period is marked with the first peneplanation surface by fluviatile erosion as well as generation of pediments. With the advent of aridity, the Pleistocene fluviatile landscape was considerably modified by aeolian activity. Pronounced and prolonged denudation of the fluviatile landforms lead to the retreat of hills and pediments, production of rocky pavements, broadening of pediplains, there by representing second phase of peneplanation. The sediments derived from the erosion of the Pleistocene peneplanation lead to the deposition over older alluvial and eroded peneplains as older dunes

The arid phase of early Holocene, was followed by an another phase of humid to sub-humid phase which gave birth to the younger alluvium of present day The dominant present day aeolian processes resulted in the deposition of sands, derived from earlier geomorphic surfaces that has resulted in the chocking of river courses and formation of wadis and playas

DURICRUSTS

I. CALCRETES

The salient conclusions drawn from the detailed field, chemical, mineralogical and micro-morphological studies of different calcretic profiles are

1 Two distinct genetic types of calcrete are noticed viz.(a) Pedogenic calcretes associated with dunes and interdunal plains, (b) Vadose water calcretes associated with alluvial flats and interdunal plains.

2. Presence of allothic nodules within the calcrete profiles indicate palaeo surfaces

3 REE fractionation and mobilization is evidenced within calcrete profiles

4 Multiphased dune building and stabilization.

5 Role of meteoric water or episodes of water logging is observed especially in the alluvial and interdunal flats

6 Besides the pedogenic features REE depletion is also proposed as a chemical criterion for the recognition of palaeosols

7 Mechanism of calcretization in coarse textured soils are different from that of fine textured soils

8 Mineralogy, neoformations, pedofeatures and geochemistry of calcretic profiles point to a dominant oxidizing, alkaline micro environmental conditions However, reducing micro environmental conditions are also evidenced at depth in the interdunal flats and palaeo Bt horizons

9 Though, the age of the calcretes are dated from 26 - 390 Ka B P by U/Th method, the applicability of dating methods for calcretes remain still debatable on

account of contamination by the processes of dissolution and reprecipitation of calcites.

II. FERRICRETES

Within the study area, ferricretes confine to narrow strip in the Jaisalmer basin These duricrusts occur as capings over the mesa's, buttes and highlevel rocky plains The chemical, mineralogical and micromorphological studies from different exposed profiles suggest that

1. The ferricretes of the study area are the product of lateritic weathering, mostly during the weekly lateritised stage of weathering.
2. The duricrust capings are mostly rich in Al-goethite than other iron oxides and oxyhydrates, pointing to the pedogenic origin.
3 The lateritic weathering may be ascribed to the Neogene period with relatively humid and warm climatic conditions.
4. The dismantling of ferricrete profiles and subsequent deposition of Shumar formation (comprising ferricrete clasts) indicate a relatively wetter phase with the dominance of erosion than residual accumulation during late Neogene - early Pleistocene period.
5 The onset of aridity is responsible for the two phases of calcretization of ferricretes.
6 Increase in the intensity of calcretization resulted in the digestion of ferricretes

DURICRUSTS AND PALAEOCLIMATIC IMPLICATIONS

The correlations among the different calcrete profiles on the basis of pedostratigraphic principles in combination with the existing works on the chronology defining palaeoclimatic changes in the study area has enabled the author to draw following inferences .

After the recession of Tertiary sea, the rocky upland underwent ferricretization in warm, humid conditions during the Neogene period. A wetter and well knitted drainage

supported early Pleistocene period with fluvio-lacustral sedimentation histories. responsible for the dismantling of ferricrete profiles and deposition of Shumar formation (comprising clasts of ferricretes)

The onset of the first phase of aridity during middle Pleistocene was indicated by the dated dunal sediments (390 ± 50 Ka) An ameliorating middle Pleistocene - late Pleistocene period (26 Ka - 17 Ka) with interludes of aridity and semi aridity that caused pedogenesis and stabilization of earlier phases of dunal accumulations First phase of calcretization of ferricretes can be attributed to this period

A period of maximum aridity indicated by the dune accretion around 14 - 15 Ka that continued up to 13 Ka A relatively wetter early Holocene period (10 - 5 5 Ka) with a rainfall of 200 mm above the present one The wettest period (5 5 - 3 5 Ka) with fresh water lakes followed by an arid phase between 3.5 and 1 5 Ka. resulted in drying of lakes A period of wet phase akin to 5.5 - 3 5 Ka during 1 5 - 1 Ka period Existence of the prevailing climatic conditions since the past 1 Ka

The fluctuations in climate are also recorded within the soil profiles, wherein, the micro features such as insitu fractured quartz (aridity), manganans, sesquans, ferricutans and dendrites (wet and water-logged), different forms of pedogenic carbonates (semi arid), non-pedogenic carbonates, clay illuviation (wet) have been considered as climatic indicators Chemistry of calcrete profiles especially REE depletion of illuviated palaeosol horizons indicate the palaeo Bt horizon, a characteristic feature of wetter phase Likewise, rubification of some of the profiles due to insitu weathering of iron bearing minerals indicate a semi-arid climatic conditions Enrichment of Mn indicate a well oxidized environment in the upper parts and poorly drained and reducing environment in the lower horizons Ameliorating in palaeoclimatic conditions from the warm humid during Neogene (characterized by ferricrete formation) to a wetter period of early Pleistocene (dismantling of ferricretes, fluviatile sequences) followed by arid - semi arid fluctuating climate during middle Pleistocene is envisaged

GEOTECHNICAL APPRAISAL

Careful study of various geotechnical characteristics of calcretes and ferricretes has proved that these aggregates fulfill the gradation and AIV specifications for most of the pavement types However, these aggregates have so far been rejected for their use as sub-base and base courses, only on account of their low CBR values in contrast to the specified values

The special properties of these aggeregates such as well graded and nonplastic nature, increase in CBR values after soaking, enhancement of CBR at higher energies of compaction, self-stabilization, made the author to realize the potentiality of these aggregates for sub base course and even for base course construction particularly for the Water Bound Macadam (WBM) roads Since the performance of these aggregates depend only on the compaction, with a good compaction control (100 percent γ_{dmax} of modified Proctor energy) these aggregates can best be utilised in the construction of sub-base courses and base courses of WBM pavements Estimation of pavement thickness compacted to 100 percent γ_{dmax} by North Dakota method are

Calcified soil / Powdery calcrete (Subgrade)	: 8 - 9 inches
Nodular calcretes (Sub-base)	3 5 - 4 inches
Ferricretes / calcretized ferricretes	5 inches

The author's present endeavour has divulged many fascinating hidden facts that remain as small addition to the existing wealth of information on the Thar desert Among the pedogenic deposits, the calcretes and ferricretes has enriched immensely the author's wisdom in apprehending their utility in palaeoclimatic studies and its geotechnical efficacy as a pavement aggregate It is beyond any doubt that the fossil dunes and associated pedogenic deposits are the most deserved sediments, still needs much attention of the scientific community