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# Occurrence of fibrous calcite in miliolite limestone of the Katrol Hill Range, Kachchh, Western India: new evidence of tectonic activity along the KHF

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**Abstract**
*The miliolite limestone of Kachchh and Saurashtra areas of the Gujarat state, western India is a unique sedimentary sequence of the Middle to Late Pleistocene age that has been studied mainly for its relationship with sea level changes and local tectonics. In Kachchh the Katrol Hill Fault (KHF) is considered as an active fault characterized by earthquake occurrences. The occurrence of fibrous form of calcite in miliolite limestone of the Gangeswar area in Katrol Hill Range (KHR) has been described in this study using thin section and SEM-EDS, and considered as manifestation of active tectonics during the deposition and diagenesis of the miliolite limestone in the study area as its morphogenesis is linked with elevated radon in moist environment. Thus, the study provides a new tool to assess the earthquake prone areas.*

**Keywords:** *Lublinite, Radon, Miliolite, Neotectonics, KHF, Kachchh.*

## Introduction

Late Quaternary geological history of the Gujarat state, western India has been studied in detail from three major areas viz., (i) Mainland Gujarat[1,2] (ii) Saurashtra[3,4] and (iii) Kachchh[5,6]. The region of Kachchh (Fig. 1) has received a special attention in recent time for its Late Quaternary records due to active seismicity such as 2001 Bhuj earthquake and associated active faults like Allahaband Fault, Kachchh Mainland Fault (KMF) and Katrol Hill Fault (KHF), and also for vast sedimentary sinks like the Great Rann and Little Rann of Kachchh. As the overall landscape of the Kachchh region is constituted by the rocks of Jurassic to Miocene age, the Quaternary record could be seen only in specific areas. One of the most important members of the Late Quaternary sedimentary sequences of the region is miliolite limestone. So named by Carter [7], this rock is a conspicuous stratigraphic unit (Miliolite Formation) of Middle to Late Pleistocene age in the region, and readily provides a time marker in unraveling the contemporary geological processes, largely controlled by the climate change and tectonics. It is consisting of medium to fine grained granular, slightly friable well sorted dirty white coloured rock unit that has primary been deposited as obstacle dune deposits on the slopes of the east-west trending structural hills in Kachchh, and associated with these dune deposits there also exist valley fill and fluvially reworked sheet deposits containing the miliolitic sands[8]. So far the general physical structures, composition and diagensis of these rocks have been discussed [9]. The manifestation of neotectonic activities along the KHF in these deposits were described [10] and its occurrence prior to 3 ka has also been suggested [11] using OSL ages. Bhattacharya [12] have provided the OSL geochronology of a fluvial reworking event of these deposits between 11.8 and 7.8 ka. However, for the first time the present study is reporting the occurrence of fibrous calcite cement in the miliolite that leads to an evidence of seismicity in the region during the diagenesis of the miliolite dune deposits.

**Study Area**

The Katrol Hill Range is a prominent east-west trending physiographic high that attains a height of about 260 m above mean sea level at Gangeswar, and is marked by a fault scarp associated with the KHF on its northern side. The KHF is one of the most significant faults in Kachchh, which show several evidences of active tectonics during the Quaternary time[10,13,14,15]. For the present study the Gangeswar area (GA) was investigated for the occurrences of the miliolite deposits occurring as obstacle dune deposits (O), valley fill deposits (V) and fluvial sheets (F) as shown in figure 1. The study area lies between latitudes 23°.10' to 23°.12'N and longitudes 69°.41' to 69°.46'E and is also referred to as the Gangeswar dome due to a typical radial drainage emerging from its peak. The sandstone and shale of the Jhuran and Bhuj Formations of Jurassic to early Cretaceous age constitute the local lithology over which the miliolite occurs with a profound unconformity. The KHF shows offset along its length due to a number of transverse faults. Other than the miliolite the Late Pleistocene and Holocene sediments occur in patchy manner as colluvium, fluvial gravels and reworked carbonate sand.

**Material and Methods**

The study area was investigated using Survey of India topographic sheets No. 41E/, 11 and 16 on 1:50,000 scale for the occurrences of Quaternary carbonate deposits. Samples of miliolite collected from the field site were examined under the petrological microscope for its textural and compositional analysis. Those samples which were of friable nature and could be easily disintegrated were subjected to the standard mechanical sieving for its grain size analysis. The sample GR-8 from the Gangeswar area has shown the presence of fibrous calcite as cement around the grains (Fig. 2A). This was further studied using Scanning Electron Microscope of Hitachi make equipped with the energy dispersive X-Ray Spectroscopy (EDS) detector from the Oxford Instruments, UK. The sample was scanned at various magnifications and EDS spectrum of the fibrous calcite was obtained at an appropriate magnification (Fig. 2B).

**Results**

**Thin Section Study**

The petrographic analysis suggests that majority of the miliolite grains are of sand size ranging from 0.9 phi to 2.5 phi, moderately to poorly sorted, finely skewed and having platykurtic to mesokurtic distribution. The miliolite composition is distinctly made of three components viz., allochemical grains, detrital grains and authigenic carbonate cement (Fig. 2A). The allochemical grains consists of mainly peloids, foraminifera, echinoid grains, coralline algae fragments, molluscan shell fragments and scattered coated grains described earlier by [9] as vadoids. The detrital grains are mostly quartz and rock fragments derived from the country rocks. The cement is mainly meniscus and rim cement of low magnesian micro-sparite and sparite (calcite). In some miliolites blocky void filling cement can be seen. However, the rock is highly porous showing primary inter-granular porosity in thin sections. The allochemical contents indicate its derivation from the shallow marine source whereas, the diagenetic imprints such as less compaction, moderate to high porosity, cement morphology and mineralogy etc. suggest meteoric water environment for the diagenesis of the miliolites (Bhatt and Patel, 1998).

**SEM-EDS Study**

The SEM imaging of the sample from Gangeshwar area (GR-8) that has shown the presence of the fibrous calcite cement in the thin section very clearly exhibited the geometry of the calcite crystals (Fig. 2B). The crystals are seen attached and oriented parallel to its c-axis and also shows slight curved nature which is described as *en echelon* arrangement by Stoops [17] who described such fibrous calcite precipitation as 'Lublinite'. The crystals in the present case show an average width of about 8 to 12 microns and length from 20 to 50 microns. It is also seen that the fibrous calcite forms thin layers with intercalated very thin (<8 microns) layers of very fine granular rhombohedral calcite

grains. The EDS spectrum indicates dominant presence of Ca, O and C followed by minor peaks of Si and Al along with that of Au which has come from the gold coating. This suggest that the fibers are typically of the pure calcite and the dust seen in the EDS spectrum box shown in figure 2B might have contributed the minor Al and Si peaks.

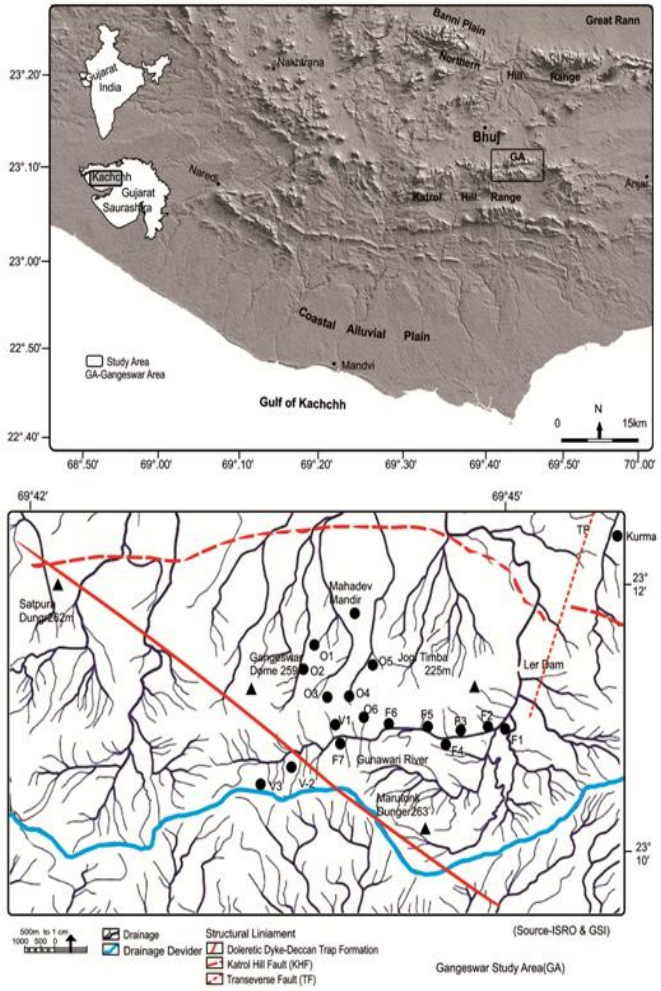


**Fig. 1** Location map of the study area in Katrol Hill Range (KHR), Kachchh with reference to India. GA-Gangeswar Area. O, F and V indicate Obstacle dune, Valley fill and Fluvial reworked sheet types of miliolite occurrence. Country and state boundaries are not on scale.

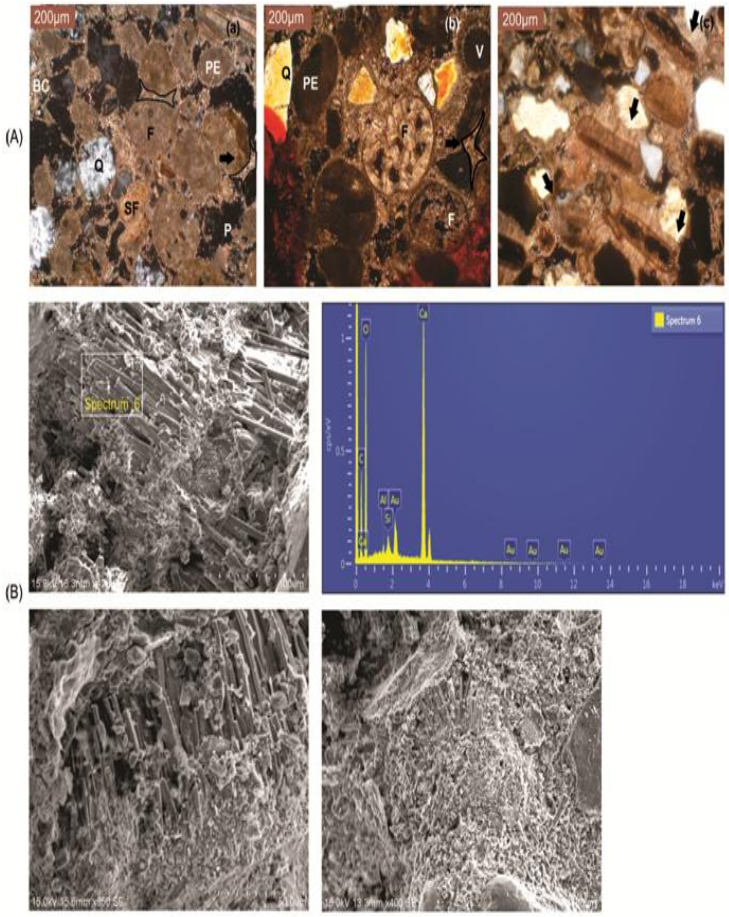


**Fig. 2** (A) Photomicrographs of the miliolite thin sections of KHR showing (a) various allochems, meniscus cement (shown by arrow) and porosity, (b) foraminifera, detrital quartz and microsparite cement and (c) fibrous form of calcite (shown by arrow).

BC- bioclast, PE-peloide, SF-shell fragment, F-foraminifera, V-vadoid, P-porosity, Q-quartz. Scale in micron shown in the upper left corner of the photos. (B) SEM images and EDS spectrum of the fibrous calcite seen in the miliolite sample GR-8.

## Discussion

The occurrences of the fibrous form of calcite have been described by many, largely from the present or ancient soils, caves, rock fractures and travertine [18,19,20,21]. Both, organic and inorganic origin of the fibrous calcite has been invoked and their detailed descriptions are available[18]. Although, the term 'Lublinite' was introduced first in AD 1906[22] to describe long thin crystals of calcite it became popular to describe fibrous calcite having an *en echelon* arrangement from the caves of Turkey[17]. Recently Gazda[23] related the morphogenesis of the

Lublinite to the damp environment with an elevated radon concentration. It is proven that the geogenic radon ($^{222}Rn$) is enhanced near certain tectonic features; the physical process is better understood as its co-precipitation either with ground water or carrier gases like $CO_2$, $N_2$ and $CH_4$ [24]. Waith [25] has presented a review on the application of the radon anomaly as earthquake precursors. The areas of Kachchh along with that of the many areas in Himalaya are being assessed for the radon anomaly. The Kachchh area belongs to zone-V as per the seismic zonation map of India and it has experienced many devastating earthquakes not in the ancient time, but also as recent as 2001. There also occur frequent earthquakes of moderate magnitude even today. The Katrol Hill Fault (KHF) is identified as one of the active faults in Kachchh and seismicity has been mapped along these structural elements too. The occurrence of the Lublinite in miliolite of the Gangeswar area in KHR is thus suggestive of earthquake activities in this part of Kachchh manifesting the active nature of the KHF.

## Conclusions

The morphogenesis of the fibrous calcite (Lublinite) has been found related with the increased radon. The radon anomaly is being used as one of the monitoring tools for earthquake precursors. Therefore, the occurrence of the fibrous calcite in miliolite of the Gangeswar area of KHR, Kachchh provides a new evidence of the active nature of the Katrol Hill Fault (KHF) during the formation of the miliolite. More studies on the occurrence of Lublinite in the rock fractures, caves and paleo-soil layers and their oxygen isotope studies along with the radon anomaly data in the active fault areas in Kachchh such as KMF and KHF would provide new information on the seismicity and it's monitoring.

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