Geochronology of Palaeolithic Cultures in the Hiran Valley, Saurashtra, India

M. Baskaran, A. R. Marathe, S. N. Rajaguru and B. L. K. Somayajulu

(Received 30 September 1985, revised manuscript accepted 6 May 1986)

The U and Th concentrations of 16 miliolite samples from the Hiran Valley in Saurashtra ranged from 0.3 to 2.14 ppm and 0.12 to 0.82 ppm respectively. The $^{234}U/^{238}U$ activity ratio ranged from 1.09 to 1.16, with a mean of 1.12 ± 0.02. It agrees well with the seawater value of 1.14 ± 0.02 within the quoted errors. Nine of the samples were datable by the $^{230}Th/^{234}U$ method and the ages ranged from 56.8 to 190 Kyr. The problem of chronology of Palaeolithic artifacts is interlinked with the miliolite and other coastal formations. The present investigations permit the development of a chronological framework for the Palaeolithic cultures in the Hiran Valley in particular, and generally in Saurashtra Peninsula. On the basis of radiometric dates and relative chronology, the Lower Palaeolithic cultures fall in a time-bracket of 190–69 Kyr bp. The Middle Palaeolithic industry is much older than 56.8 Kyr bp. The dates obtained for the Lower Palaeolithic cultures are perhaps the oldest reported to date.

Keywords: Miliolite Formation, Palaeolithic Tools, U Series Dating, Sea Level Changes.

Introduction

Lower Palaeolithic tools were discovered as early as 1861 on the coast of Tamil Nadu (Foote, 1916) and the researches carried out during the last 50 years have proved the existence of Lower Palaeolithic culture in all parts of the Indian subcontinent. The contribution of earth sciences to the interpretation of archaeological finds is limited by the nature of the excavated sites and most of the sites suffer from multiple shortcomings. In spite of the lack of biological data and chronometric control, Indian archaeologists have tried to infer chronology of Palaeolithic culture in various parts of the subcontinent. However, intensive studies along these lines are few and the areas where such studies have been undertaken have proved archaeologically relatively sterile (Rajaguru, 1970; Guzder, 1980). However, in Saurashtra the semi-arid climate and the general configuration of the landscape have together produced a unique situation where the sedimentary facies have preserved the record of the interplay between marine and fluvial processes along with records of Early Man.
"Early Stone Age" tools of Acheulian character were found for the first time in the Saurashtra region during 1962 (Sankalia, 1965) in a pebble conglomerate at Rojadi, now renamed as Shrinathgadh, on the river Bhadar. Also the discoveries by Pandya & Subbarao (1959), Rao (1959), Soundara Rajan (1967), Lele (1972) and Chakrabarti (1978) have proved the existence of Early Man in the Peninsula since Lower Palaeolithic times. Moreover, these discoveries have established conclusively that the theories of submergence of the entire Peninsula during the Palaeolithic period are no longer tenable, although the exact chronological framework for the Palaeolithic cultures was lacking.

The problem of chronology of Palaeolithic cultures in Saurashtra is interlinked with the Quaternary carbonate deposits, namely miliolites. These deposits cover a fairly large area of the Hiran Valley and of peninsular Saurashtra, especially the coastal regions (Figure 1). These carbonate deposits, discovered well over a century ago in Saurashtra (Carter, 1849), attracted the attention of geologists and other earth scientists, particularly regarding their age and origin (Srivastava, 1968; Biswas, 1971; Lele, 1972; Govindan et al., 1975; Sperling & Goudie, 1975; Rajaguru & Marathe, 1977; Varma & Mathur, 1977; Agrawal et al., 1978; Allchin et al., 1978; Hussain et al., 1980; Merh, 1980; Baskaran et al., 1983). The Hiran Valley in particular has attracted the attention of archaeologists due to the occurrence of Stone Age tools in association with miliolites (Sankalia, 1965; Rajaguru & Marathe, 1977; Allchin et al., 1978; Merh, 1980; Baskaran et al., 1983).

Biswas (1971) has placed the coastal miliolite of Saurashtra as Late Pleistocene and Lele (1972) assigned an early Quaternary age to all the miliolites of Saurashtra on the basis of relative stratigraphy. Sperling & Goudie (1975) and Agrawal et al. (1978) on the other
Table 1. Details of the sites

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Sample code</th>
<th>Site</th>
<th>Location</th>
<th>Distance from coast (km)</th>
<th>Height (m amsl)</th>
<th>Thickness of the miliolite (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>Talala</td>
<td>On the left bank of the river Hiran</td>
<td>19</td>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>47-2</td>
<td>Jetpur</td>
<td>On the left bank of the river Bhadar</td>
<td>90</td>
<td>90</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>49-1</td>
<td>Adi Chadi Wao</td>
<td>At the base of Junagadh hills</td>
<td>63</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>49-5</td>
<td>Adi Chadi Wao</td>
<td>At the base of Junagadh hills</td>
<td>63</td>
<td>120</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>57-1</td>
<td>Umrethi dam site</td>
<td>On the left bank of the river Hiran</td>
<td>16</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>57-2</td>
<td>Umrethi dam site</td>
<td>On the left bank of the river Hiran</td>
<td>16</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>Umrethi dam site</td>
<td>On the left bank of the river Hiran</td>
<td>16</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>60-1</td>
<td>Badalpur</td>
<td>On the right bank of the river Saraswati</td>
<td>2</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>68</td>
<td>Sasan</td>
<td>Sasan–Junagadh road</td>
<td>41</td>
<td>198</td>
<td>1</td>
</tr>
</tbody>
</table>

hand have placed the inland miliolite in the Late Pleistocene on the basis of archaeological evidence and $^{14}$C dates, respectively.

Our investigations (Marathe et al., 1977; Marathe, 1981) have proved the marine origin of miliolites occurring up to 20 km inland from the coast and 75 m amsl. We have also established that there exist two miliolite formations which belong to two transgressive phases of the sea during the Quaternary. Lower and Middle Palaeolithic tools have been discovered in the fluvial gravels underlying the earlier miliolite (M-I) and the Late Pleistocene miliolite (M-II) respectively; and recently the miliolite has been dated by Th/U decay series methods to 95 Kyr bp (Hussain et al., 1980).

Materials and Methods

Against the above background we selected the Hiran Valley where archaeological potential in relation to the Quaternary history had already been established (Marathe, 1981). However, the observations were not restricted to the Hiran Valley but also extended to adjacent regions (Figure 1). Miliolite samples were collected during three field trips (1981–1983).

Sixteen miliolite samples were collected for dating by the Th/U decay series method ($^{230}$Th/$^{234}$U: Ku, 1977; Ivanovich & Harmon, 1982), 10 from Hiran Valley, one from the Saraswati Valley near Badalpur, four from Adi Chadi Wao in Junagadh and one from Jetpur in the Bhadar Valley.

Field Observations

A general description of the fluvial, marine and coastal formations in relation to valley morphology, chronology and archaeology is given in brief (Table 1, Figure 2) in order to establish the lithological relationships of the samples. Miliolite samples were collected from nine different sites: six in the Hiran Valley; a site each in the Bhadar Valley, in the Saraswati Valley and one in the foot-hills of Girnar. The sections observed at Umrethi, Junagadh, Jetpur and Badalpur are significant from the point of view of dating the Lower and the Middle Palaeolithic industries in Saurashtra.
In the excavated trench at Umrethi, three unrolled Lower Palaeolithic handaxes (Figure 3) were discovered from the gravel underlying miliolite I, and a few Lower Palaeolithic artifacts were recovered from a gravel underlying miliolite I at Junagadh. These artifacts are made of basalt and are mainly the product of flake techniques, although the final finishing and retouching was done by a cylinder hammer technique. Typo-technologically, the Lower Palaeolithic culture in the Hiran Valley is Acheulian.

A large number of Middle Palaeolithic tools (Figure 4) were collected from the gravel underlying miliolite I at Jetpur and the oyster bed at Badalpur. The most representative type of Middle Palaeolithic artifact is the scraper. The industry was mainly scrapers and used a light stone hammer technique. There are a few implements showing a Levalloisian technique. Edge retouching was done either by pressure flaking or by indirect percussion.

**Thorium and Uranium Isotope Measurements**

The thorium and uranium isotopic measurements were carried out following the detailed procedures described by Baskaran (1985). Briefly, powdered and oven-dried (110°C) samples (about 30 g in weight) were brought into solution in 5% acetic acid after \(^{232}\text{U}/^{238}\text{Th}\) spike addition. The residue was separated by centrifugation and washed, and the clear solution, along with the washings, was radiochemically processed for U and Th.
Figure 3. Lower Palaeolithic tools.

Figure 4. Middle Palaeolithic tools.
isotopes using standard procedures (Baskaran, 1985). The residue (no yield tracer was added) was dissolved in 9 M HCl after HF, HNO₃, HClO₄ and HCl treatments and was processed radiochemically for Th only (Krishnaswami & Sarin, 1976; Baskaran, 1985). The U and Th fractions from the leachate as well as the Th fraction from the residue were electroplated and the plates assayed for their α-activities using a surface barrier detector coupled to a 4096-channel analyser system.

The CaCO₃ content of the samples was determined by titration (Barnes, 1959) and carbonate mineralogy by X-ray diffraction (Baskaran & Somayajulu, 1986).

**Results of Analyses**

A total of 16 samples from the Hiran Valley area were analysed. The CaCO₃ content ranged from 52.8 to 99.3% with a mean of 87.9%. Most of the samples were pure calcite; in a few cases the aragonite concentrations ranged from 9.2 to 30.1% (Baskaran & Somayajulu, 1986). The U and Th contents of the samples ranged from 0.3 to 2.14 ppm with a mean of 0.89 ppm, and 0.12-0.82 ppm with a mean of 0.33 ppm respectively. The ²³⁴U/²³⁸U ratio ranged from 1.09 to 1.16, with a mean of 1.12±0.02, which within errors and considering the ages of the samples, is not distinguishable from the seawater value of 1.14±0.02 (Koide & Goldberg, 1965; Krishnaswami et al., 1970). Other studies also showed that the carbonate fraction was formed in a marine environment (Baskaran et al., 1982; Baskaran, 1985). The U/Th data and the field observations proved that the valley-fill miliolites in the Hiran Valley are essentially of littoral origin. Also, field studies in southern Saurashtra have shown that miliolites of marine or fluvio-marine origin generally occur at an elevation of about 40 m, while those occurring above this height are aeolian in origin, with the exception of Umrethi (75 m amsl).

**²³⁰Th/²³⁴U Dating**

Broecker (1963) analysed several marine carbonates, including corals, and has shown that the change of ²³⁰Th in equilibrium with ²³⁸U can be used as a dating technique. For marine carbonates such as the miliolites, there is a 14% excess of ²³⁴U over its parent ²³⁸U, which also contributes to ²³⁰Th growth. This was taken into consideration (Ivanovich & Harmon, 1982):

$$\frac{²³⁰\text{Th}}{²³⁴\text{U}} = \frac{1 - e^{-\lambda_0 t}}{²³⁴\text{U}/²³⁸\text{U}} + \left(1 - \frac{1}{²³⁴\text{U}/²³⁸\text{U}}\right) \frac{\lambda_0}{\lambda_0 - \lambda_4} (1 - e^{-(\lambda_0 - \lambda_4) t})$$

where $\lambda_0$, the decay constant of ²³⁰Th=9.22×10⁻⁶ year⁻¹, $\lambda_4$, the decay constant of ²³⁴U=2.79×10⁻⁶ year⁻¹, $t$=age in years and ²³⁰Th, ²³⁴U and ²³⁸U are in units of dpm/g sample. In the case of impure carbonates like miliolites, which contain non-negligible amounts of detrital material (≈10% in the present set of samples), a correction has to be applied for the leaching of ²³⁰Th from the detrital material by mild acetic acid (Ku & Joshi, 1980; Hussain et al., 1980). The correction is $²³⁰\text{Th}_c = ²³⁰\text{Th}_L - ²³²\text{Th}_L (²³⁰\text{Th}/²³²\text{Th})_R$, where subscripts C, L and R represent corrected, leach and residue, respectively and all concentrations are given in dpm/g. Since the residue (non-calcareous material) is on average ≈10% and its ²³⁸U content is 1–2 dpm/g, no correction is found necessary for ²³⁴U leached from the non-calcareous fraction (Ku & Liang, 1984). For further details of this dating method, see Ku (1977) and Ivanovich & Harmon (1982).

Of the 16 samples only nine could be dated after satisfying all the criteria proposed by Baskaran (1985); the ages of these samples are given in Table 2. The ages range from 56.8 to 190 Kyr. These ages are in good agreement with the few obtained by Hussain et al. (1980) by the same method.
Table 2. \( \text{U/Th data and } ^{230}\text{Th} / ^{234}\text{U ages} \)

<table>
<thead>
<tr>
<th>Sample code</th>
<th>( ^{238}\text{U} ) (dpm/g)</th>
<th>( ^{234}\text{U} / ^{238}\text{U} ) activity ratio</th>
<th>( ^{230}\text{Th} / ^{234}\text{U} ) activity ratio</th>
<th>Uncorrected activity ratio</th>
<th>Corrected activity ratio*</th>
<th>Age (x 10^3 years)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>0.65±0.01</td>
<td>1.16±0.01</td>
<td>5.62±0.14</td>
<td>0.82±0.04</td>
<td>0.57±0.02</td>
<td>96.5±7.5</td>
</tr>
<tr>
<td>47-2</td>
<td>0.23±0.01</td>
<td>1.11±0.02</td>
<td>1.92±0.05</td>
<td>0.84±0.03</td>
<td>0.41±0.03</td>
<td>56.8±5.1</td>
</tr>
<tr>
<td>60-1†</td>
<td>0.46±0.02</td>
<td>1.16±0.02</td>
<td>7.12±0.23</td>
<td>0.76±0.03</td>
<td>0.73±0.04</td>
<td>158±32</td>
</tr>
<tr>
<td>49-1</td>
<td>0.58±0.01</td>
<td>1.13±0.02</td>
<td>6.67±0.28</td>
<td>0.59±0.02</td>
<td>0.46±0.02</td>
<td>69.0±3.8</td>
</tr>
<tr>
<td>49-5</td>
<td>1.28±0.03</td>
<td>1.13±0.01</td>
<td>6.57±0.16</td>
<td>0.57±0.02</td>
<td>0.46±0.02</td>
<td>69.0±3.8</td>
</tr>
<tr>
<td>57-1</td>
<td>0.60±0.02</td>
<td>1.09±0.02</td>
<td>9.22±0.30</td>
<td>1.02±0.04</td>
<td>0.83±0.03</td>
<td>190±29</td>
</tr>
<tr>
<td>63</td>
<td>0.52±0.02</td>
<td>1.11±0.02</td>
<td>7.51±0.33</td>
<td>0.85±0.04</td>
<td>0.73±0.04</td>
<td>142±16</td>
</tr>
<tr>
<td>57-2</td>
<td>0.88±0.02</td>
<td>1.12±0.01</td>
<td>18.3±0.7</td>
<td>0.54±0.02</td>
<td>0.46±0.02</td>
<td>65.4±3.6</td>
</tr>
<tr>
<td>68</td>
<td>0.86±0.02</td>
<td>1.09±0.01</td>
<td>12.0±0.4</td>
<td>0.79±0.03</td>
<td>0.59±0.04</td>
<td>91.8±12.2</td>
</tr>
</tbody>
</table>

Errors quoted are propagated one sigma counting statistics.

*\( ^{230}\text{Th} \) corrected for detrital contribution.

†Ages calculated assume \( ^{234}\text{U} / ^{238}\text{U} \) initial activity ratio of 1.14, using equation given in text.

Discussion

The milolite \( ^{230}\text{Th} / ^{234}\text{U} \) dates from Jetpur, Junagadh and Umrethi are reassuring and significant from the point of view of dating the Middle and Lower Palaeolithic industries in the Hiran Valley. Middle Palaeolithic tools recovered from fluviat gravel beds, disconformably capped by milolite formation, designated M-II (Marathe, 1981) at Jetpur, dated to 56.8 Kyr bp. Middle Palaeolithic industry in India is generally dated to 39–25 Kyr bp on the basis of the \( ^{14}\text{C} \) method. Therefore, the Middle Palaeolithic industry at Jetpur is the earliest industry in the Indian subcontinent dated absolutely.

Similarly, the \( ^{230}\text{Th} / ^{234}\text{U} \) dates obtained for the milolite from Junagadh and Umrethi suggest that the age of Lower Palaeolithic industry is between 69 and 190 Kyr. These dates for Lower Palaeolithic industries synchronize well with the stratigraphical evidence (Marathe et al., 1977). In both instances, Lower Palaeolithic tools have been found in fluviat gravel resting unconformably on bed-rock basalt and overlain unconformably by a thick (∼20 m) milolite formation designated M-I (Marathe, 1981). Two dates obtained for samples from Umrethi lie slightly outside two standard deviations from the mean. These dates are the earliest radiometric ages obtained by an absolute dating method for the Lower Palaeolithic industry in the Indian subcontinent.

In Table 3 are given the chronology of geomorphic events and the corresponding cultural finds. The principal milolite formation in Saurashtra occurred during three periods, namely 50–70, 75–115 and 140–200 Kyr bp (based on about 45 \( ^{230}\text{Th} / ^{234}\text{U} \) dates; Baskaran, 1985). The nine dates associated with Palaeolithic tools encompass the whole range of 50–200 Kyr and it is not possible to clearly attribute each milolite age to a
Table 3. Chronology of geomorphic events and cultural finds

<table>
<thead>
<tr>
<th>Geomorphic events</th>
<th>Geomorphic/cultural finds</th>
<th>Age (years bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluctuating sea level</td>
<td>Mesolithic and Chalcolithic</td>
<td>Holocene</td>
</tr>
<tr>
<td>High sea level</td>
<td>Oyster shells</td>
<td>Late Pleistocene</td>
</tr>
<tr>
<td>at 6000 years bp</td>
<td>Miliolite</td>
<td>30 Kyr*</td>
</tr>
<tr>
<td>Major rejuvenation</td>
<td>Middle Palaeolithic</td>
<td>57 Kyr†</td>
</tr>
<tr>
<td>High sea level</td>
<td>Miliolite</td>
<td>69–196 Kyr†</td>
</tr>
<tr>
<td>at 60, 84, 105, 120 and 135 Kyr bp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low sea level</td>
<td>Lower Palaeolithic</td>
<td>69–196 Kyr†</td>
</tr>
<tr>
<td>11,100–16,000 years bp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Radiocarbon date.
†Present study using $^{230}$Th/$^{234}$U.
‡High and low sea level dates are based on corals and speleothems (Moore, 1982).
See text for discussion.

sea level stand, especially in view of recent evidence supporting tectonic instability of the Saurashtra Peninsula (Sood, 1983; Sood & Sahai, 1986). This aspect will be dealt with in detail separately.

In conclusion, it appears that the implications of $^{230}$Th/$^{234}$U dating of the miliolite samples are significant for an understanding of the Stone Age history of Saurashtra. The present work provides evidence for the need to study the geology and the environment of the Saurashtra Peninsula associated with Early Man in order to be able to establish a reliable chronological framework.

References


Kirshnaswami, S. & Sarin, M. M. (1976). The simultaneous determination of Th, Pu, Ra isotopes, $^{210}$Pb, $^{232}$Th, $^{230}$Th, $^{232}$Si, and $^{14}$C in marine suspended phases. *Analytica Chimica Acta* 83, 143–156.


