Where Was Odantapuri Located?*
Archaeological Evidence Using Remote Sensing, GIS and Photogrammetry

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Historical records reveal that *Odantapuri Mahavihara* was an important centre of Buddhist learning. It was established in the 8th century by Gopala (the first Pala Emperor), and for several centuries, it was part of a network of Mahaviharas in eastern India (the most famous being Nalanda, along with Vikramaśila, Somapura and Jaggadala). Archaeologists have conclusively identified the locations of all these Mahaviharas except Odantapuri. The best guess (based on tenuous evidence) is that Odantapuri Mahavihara was located in the modern town of Bihar Sharif. There has been very little exploration at this site, and no investigation has revealed remains of an in situ structure comparable to a Pala Mahavihara. This article discusses a chance finding while analysing a region one kilometre north of Nalanda (about ten kilometres southwest of Bihar Sharif). Using stereoscopic remote sensing data from satellites, photogrammetry and geographical information systems (GIS) software, we identified a large (400 m × 450 m) structure buried below the village of Begampur, virtually at Nalanda’s doorstep. Its shape is startlingly similar to both Vikramaśila and Somapura (both built by Dharmapala, the successor and son of Gopala). Further, AMS dating of bricks from a portion of this site (another chance finding) suggests that they may be as old as Odantapuri Mahavihara. This new evidence allows us to update our best guess for Odantapuri Mahavihara’s location, but a careful archaeological investigation is necessary to confirm this hypothesis.

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1. Introduction

Odantapuri (in Tibetan records) or Uddandapura (in Sanskrit inscriptions), was an important seat of Buddhist learning during the Pala period (8th to 12th centuries AD). Odantapuri was established by the first Pala Emperor Gopala in the 8th century and was part of a network of Mahaviharas in eastern India (Figure 1). The other prominent Mahaviharas were:

i. Nalanda (the oldest, believed to have been active from 4th/5th century to the 13th century AD) has excavated ruins of six temples and eleven monastery structures and an area of about 0.3 km². It is protected by the Archaeological Survey of India (ASI).

ii. Vikramaśīla in Bihar, built by the second Pala king Dharmapala (780 to 820 AD), has a central cruciform monument surrounded by a 320 m × 330 m quadrangle with monastic cells. It has an outer wall with semi-circular bastions (Figure 2).

iii. Somapura (in Bangladesh) was also built by Dharmapala. It is architecturally similar to Vikramaśīla, but it has a slightly smaller quadrangle (280 m × 280 m) (Figure 3).

iv. Jagaddala (also in Bangladesh) was built by Ramapala (1077 to 1124 AD), and excavations have revealed Buddhist monastic structures at this site.

Odantapuri seems to have played a role in introducing Buddhism into Tibet and in influencing the architecture of Samyé—Tibet’s first Buddhist monastery [1]. Around the 11th century AD, while Nalanda was struggling for survival. Odantapuri “had a rival institution functioning under the royal patronage of Palas” [2]. Taranatha wrote that during the time of the four Sena kings (12th century AD), the number of foreigners increased in the region and “to protect Odantapuri and Vikramaśīla, the king even converted these partially into fortresses and stationed some soldiers there” [1]. This perhaps explains the semi-circular bastions on Vikramaśīla’s outer wall (Figure 2). Odantapuri met with an abrupt end in the 12th century AD. The medieval chronicle Tabakāt-i-Nāširi mentions that in 1197, troops led by Ikhtiyar-ud-Din Muhammad
(son of Bhaktiyar Kalji), destroyed a fort, killed all the inmates, and burnt a library (this event is often erroneously attributed to the decline of Nalanda [3]), later realizing that the place was not a fort but a vihara [4]. It is believed that this vihara sacked by the invading army was Odantapuri [2].

### 1.1 Bihar Sharif

Although no physical structures have been identified for Odantapuri, the records of the Tibetan monk Dharmaswamin (who was at Nalanda in 1234–36 AD) indicate that Odantapuri was in close proximity to Nalanda. However, the distances and directions he mentions are inconsistent [5]. An inscription found in Gaya mentions that Gaya was located in ‘Uddandapura desa’\(^2\), which suggests that the name Uddandapura referred to a larger administrative area like a district [6]. Hence, the vihara bearing that name could have been anywhere within the region. Odantapuri is identified with Bihar Sharif based on three kinds of evidence. First,

\(\text{Figure 1. A map showing the locations referred to in the present study (prepared in QGIS using Stamen OSM Terrain).}\)

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\(\text{\(\text{\(2\)The region or district of Ud-}
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\(\text{\(\text{dandapura.}\)}\)
Figure 2. Vikramaśīla Mahavihara: The central shrine, monastic quadrangle and the bastions. (Above: field photograph; Below: satellite view).

the older names of the town were Dandapur, Dand Bihar or Bihar Dandi [2, 7, 8]. Second, the remains of a fort were extant in the 19th century [9]. Third, a few small artefacts that mention the name Uddandapura have been found at Bihar Sharif. We discuss each one of these to assess the overall strength of the evidence in favour of identifying Bihar Sharif as the location for Odantapuri:

The town’s old name: Beglar (1878) first suggested that Bihar Sharif was the location of Uddandapura, based on the name which appeared to refer to the vihara of Uddandapura [7]. The Islamic chronicle Tabakāt-i-Nāsiri mentions a place called Adwand Bi-
har in the list of victories [4]. This was also identified with Bihar Sharif because of the similarity between the names Adwand Bihar and Dand Bihar. Identification based on such similarities can prove to be incorrect. For instance, Beglar relied on similar names to identify Silao as the location of Vikramaśila, but this was subsequently proved wrong after the latter was excavated in the Bhagalpur district, more than 190 km east of Silao. Silao did have some antiquarian remains, but so did many other settlements in the region.

The fort: *Tabakāt-i-Nāsiri* mentions that Khalji’s troops mistook a vihara for a fort [4]. Bihar Sharif did have a fort, parts of which were still visible until the mid-20th century [2]. Subsequent ur-

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**Figure 3.** Somapura Mahavihara: Satellite view of the central shrine, monastic quadrangle and the bastions.

3 A village near Nalanda.
banization has left no traces of this fort on the ground (see Figure 3.12 in Rajani 2021 [10]). Forts, too, are hardly unique in the area, so the mere presence of a fort is not conclusive.

**Small artefacts**: Many Buddhist and Hindu images and carvings have been found in Bihar Sharif [2, 11], and Buchanan recorded numerous brick and stone remains [9]. The most prominent of these artefacts are:

- A 6-inch brass image of a goddess with four hands and a votive inscription (mentioning that a certain Rānaka Tharuka, who was a resident of Uddandapura, donated this image) was discovered in about 1915 in Bihar Sharif [12, 13].

- Two sculptures of Buddha (about 30 inches tall), currently in the Indian Museum (Kolkata), have identical inscriptions recording the consecration of these images in the vihara of Uddandapura [12, 14]. These sculptures were originally part of the ‘Broadley Collection’ in Bihar Museum (located in Bihar Sharif). A M Broadley was stationed in Bihar Sharif, and he built up a large collection of sculptures⁴. Beyond this, their provenance is unclear due to imprecise museum records [15].

It is important to note that none of these objects were found in situ in their original position. Since they are not very large or heavy, they could easily have been transported to Bihar Sharif from the place of their origin. Very limited archaeological exploration has been conducted in Bihar Sharif thus far. No investigation has been systematically documented, none has revealed a large in situ structure (or traces thereof) comparable to a Pala Mahavihara, and no monastic seals have surfaced.

### 1.2 Begampur

A recent geospatial analysis of the landscape around the archaeological remains at Nalanda indicated a large archaeological structure (or a complex of structures) buried under Begampur [16]. The ruins of this structure were still visible when Buchanan visited in 1812. In his journal, Buchanan mentions that Begam-
pur was on a “considerable space elevated with the fragments of brick” [9]. Curiously, no subsequent explorers or archaeologists have recorded investigations of this feature.

It is possible that this structure could have been part of the Nalanda complex, but we hypothesize that it belonged to Odantapuri. The rest of this article will present two types of evidence supporting this hypothesis. First, by analysing a digital elevation model (DEM) of this region (Sections 2, 3 and 4), we find that the size and orientation of this structure closely resemble those of the contemporaneous Mahaviharas at Vikramaśila and Somapura. Second, using AMS dating (Section 5), we find that the age data of material remains from this site are in line with Odantapuri’s dates.

2. Digital Elevation Models

Several significant archaeological breakthroughs have recently been made by examining the landscape and topography surrounding archaeological sites using the high-resolution digital elevation models (DEMs) to discover and understand hitherto unknown features [17, 18]. Processed DEMs are available ‘off-the-shelf’ at low resolutions (e.g., 90 m and 30 m per pixel from SRTM). But these resolutions are typically too coarse for identifying new features of potential archaeological interest. A popular remote sensing technique is LiDAR (light detection and ranging), which uses light (in the form of a pulsed laser) from an aerial platform to measure distances of points on the Earth’s surface. LiDAR can create very high-resolution DEMs (a few cm per pixel), but the lack of LiDAR data for our study area (and its high acquisition cost) necessitates an alternate approach. Fortunately, DEMs of sufficient resolution for archaeology (2 m to 4 m per pixel) can be created by applying photogrammetric techniques to stereoscopic data.

There is a rich archive of stereoscopic images taken by the satellite CARTOSAT-1, amply covering all of India. CARTOSAT-1 carries two panchromatic (PAN) cameras that take black and white stereoscopic pictures (at a spatial resolution of 2.5 m per
pixel) of the Earth’s surface in the visible region of the electromagnetic spectrum. The cameras are mounted on the satellite and tilted along the direction of the satellite’s path in such a way that one looks forward (+26°) and the other rearward (−5°). Therefore, an area with a swath of around 30 km is imaged by the fore camera first, and then the satellite moves and ‘looks back’ at the same area through the aft camera (Figure 4) after a very short delay (about 52 seconds [19]). These two images of the same area taken from two different angles allow the generation of three-dimensional maps.

When one acquires CARTOSAT-1 stereo pair imagery, they are supplied with the respective RPC (rational polynomial coefficient) files. These provide a compact ground-to-image geometry, which facilitates photogrammetric processing without requiring a physical camera model [20]. When these files are processed together with stereo images, the software generates a DEM by identifying 50–100 common points on the two images. These points are automatically detected based on pixel value distributions, and the resulting DEM usually has reasonable accuracy ‘globally’ for the 30 km coverage of the image. However, the DEM may not be ‘locally’ accurate (within a few meters or tens of meters), which is often the scale of features of archaeological interest. For instance, local undulations may be smoothened incorrectly.

The DEM for the present study was first generated on ERDAS LPS ATE software using CARTOSAT-1 stereo pair for 5m spatial resolution. This DEM was then corrected manually by visualizing images such as Figure 5 to include details of smoothed undulations. In this manual process, a stereoscopic image is projected as an anaglyph and the DEM as white and yellow contour lines. (Figure 5a shows a hilly area with steep slopes, hence there are many concentric contour lines. In contrast, Figure 5b shows a plain with fewer contour lines.) Anaglyph images are used to provide a stereoscopic 3D effect analogous to binocular vision when viewed using colour coded anaglyph glasses (also known as 3D glasses). The two stereo images are superimposed—the fore image (to be viewed with the left eye) is projected in red, and the
After image (to be viewed with the right eye) in blue and green, creating an RGB colour composite image. Then, using photogrammetric tools, we check if the apparent topography matches the contours. Mismatches must be corrected (a painstaking task), but the greater the density of points in the stereo images, the better the topographical integrity.

The heights were further verified by comparing elevations of permanent land features (such as road intersections, hilltops, etc. whose latitude/longitude and height are not expected to change
Figure 5. Anaglyph stereo image (to be viewed with anaglyph glasses) superimposed by contours from the DEM.

for long periods) with standard reference digital topographical data such as the SRTM DEM. The corrected DEM was then used for identifying topographical features of an archaeological nature.
3. Analysis of the DEM at Begampur (Nalanda District)

The digital elevation model (DEM) revealed a large mound on which the settlement of Begampur sits, which includes a 400 m × 450 m topographical relief feature with protruding ends on the
Figure 7. Ground photo of the area covering the southeast corner of Begampur mound.

Figure 8. Residents of Begampur examining the stereo image of their region.

northwest, northeast and southeast extremes. These protrusions are consistent with three corners of the buried foundations of a four-pointed structure (Figure 6). The protrusions themselves could correspond to bastions of a fort, but their size is more consistent with smaller structures, perhaps stupas, one at each corner separated from the large central square (similar to the architecture of the Samye monastery). If these hypothetical structures
had collapsed, their debris could have formed heaps that merged with the isolated structures in the corners with the main square in the middle (as observed in Figure 6). The shape and dimensions of the mound suggest that the structure within was large enough to comfortably accommodate the vihara structures of both Vikramaśila and Somapura, which are tellingly oriented in a similar way. (Figure 6)

The fourth (southwest) corner of the mound does not match the shape of the other three, possibly because debris from other structures (ancient or modern) built close to this corner formed additional heaps that obscure this corner’s shape. A suggestive extent of the southwest corner is marked as a smaller dotted line in Figure 6.

4. Ground-based Investigation

A field exploration was undertaken to seek evidence for this topographical feature. Since this is a spatially large feature (400 m × 450 m) and its elevation is only around 4 m to 5 m higher than the surrounding area, it was appropriate to search for undulated surfaces or exposed old walls along the periphery of this feature rather than in the middle. Any archaeological feature found in the middle may or may not be part of the large square feature. For instance, Kangar Khan mound is a conspicuous square mound of much smaller dimension (50 m × 50 m), which is situated south of the centre of the large Begampur mound (Figure 6c), was excavated by ASI [21] where they found remains of many successive layers. As Figure 6 makes clear, the northern section of the large Begampur mound, including its northeastern and northwestern corners, lie below the settlement of Begampur. The southeast corner, being agricultural land, was, therefore, the most promising starting point. This area was explored carefully using GPS navigation, but nothing remotely indicative of the feature of interest was observed (Figure 7).

The residents of the village were extremely forthcoming with information on old structures in the vicinity, and they were par-
ticularly intrigued when they saw their local topography seemingly leap from the flat anaglyph images when viewed through 3D glasses (Figure 8). One resident reported that a small trench had recently been dug on his land. He offered to lead us there, and we arrived at a spot located almost precisely at the northeastern corner of the large mound (Figure 9). A brick structure—perhaps only the proverbial tip of the iceberg—had been discovered while the owner ploughed his field. This activity had accidentally dislodged several bricks, which lay scattered in the vicinity. We collected a few samples of these bricks for further investigation.

5. AMS Dating of Bricks

Radiocarbon dating is a method for determining the age of an object containing atmospheric derived carbon material using the radioactive properties of carbon (14C), an unstable isotope of carbon, which decays to stable nitrogen (14N) by beta decay. Radiocarbon dating is a method for determining the age of an object containing atmospheric derived carbon material using the radioactive properties of carbon (14C), an unstable isotope of carbon, which decays to stable nitrogen (14N) by beta decay (14C has eight neutrons, and when it decays one neutron turns into a proton and it loses an electron to become 14N). During the life of an animal or plant, organic material continuously exchanges carbon with its surroundings (the atmosphere or the sea), and it has a constant proportion of 14C. The process of acquiring 14C stops at death, but the existing 14C continues to decay. Hence, the ratio of 14C to 12C in the organic remains gradually decrease. Since the rate of decay of 14C is known, the proportion of radiocarbon can be used to determine the time since death. This method, developed in the 1940s by Willard Libby, revolutionized archaeological studies. However, its uses have been limited because it can only date certain kinds of material and because of the large quantity of samples and long processing time required. The emergence of accelerator mass spectrometry (AMS) technique for radiocarbon dating has broadened the kinds of materials that can be carbon-dated, and only a few milligrams of sample suffice. Further, the 14C atoms are directly counted without waiting for their decay.

The brick samples collected from Begampur were dated using
the AMS facility in Inter-University Accelerator Centre (IUAC) Delhi. Out of the two samples that were dated, one has yielded a date that fits with Odantapuri’s time: the 2-sigma range (95.4% probability) for the sample is between 695 AD to 1021 AD, with 886 AD as the median probability. (The other sample has yielded an earlier date ranging between 385 AD to 614 AD, with 489 AD as the median.) For further details on the AMS dating of these bricks, please refer to Das et al. 2019 [22].

For greater accuracy, brick samples for dating should be collected from an ongoing archaeological excavation where one can precisely ascertain the original locations of samples. We deliberately constrained ourselves to samples that were scattered while digging for agricultural purposes—we were careful to leave the brick structure untouched for a more systematic archaeological excavation. (Buchanan [9] and Cunningham [23] have recorded that ancient sites had become free sources of bricks for constructing buildings and paving the road in all the villages in the vicinity. Indeed, one of the compelling reasons that provided the impetus for the enactment of The Ancient Monuments Preservation Act
in 1904 was to stop local villages using ancient sites such as Nalanda as a free source of bricks for fresh construction.) Hence, although the evidence from dating these two samples is not conclusive, we note that these dates do not contradict each other in terms of the archaeological significance of the brick structure.

6. Concluding Remarks

One of the most exciting moments in conducting research is when new evidence provides an opportunity to re-examine prior beliefs. In many situations, researchers are not specifically seeking new evidence—they may stumble upon something curious by chance, as we did while conducting a geospatial analysis of the area around Nalanda. The key is to recognize the new evidence. In this instance, the anthropogenic shape revealed by the DEM aroused our curiosity to investigate further. We became aware that the monastery at Odantapuri was one of the major structures in the region for which no remains have been found, and we began wondering if it could be at this location. We further learned that Odantapuri was near-contemporaneous with Vikramaśila and Somapura, and we were thrilled when we superimposed to-scale shapes of these known structures over the DEM of Begampur and saw the stark similarities in their shapes, sizes and orientations. This gave us considerably greater belief in our hypothesis, but we wanted to understand the reasons for the traditional hypothesis more carefully. This involved further examination of the historical record, and we recognized that the evidence for associating Odantapuri with Bihar Sharif is weak. To bolster our own hypothesis, we visited Begampur (as part of a funded project investigating Nalanda and its environs). Thanks to a chance encounter with helpful villagers, we discovered a brick wall that strengthened our hypothesis in two ways: based on its location and based on the age of samples we were able to collect.

Our hypothesis, of course, can be overturned by fresh evidence—this is how science progresses. However, even if the structure below Begampur is not the celebrated Odantapuri Mahavihara, our
findings are enough to suggest that a large Pala period monastery is buried in this mound, which warrants further exploration.

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Suggested Reading


