Konark Temple of Odisha: Some Geological Aspects of This Grand Heritage

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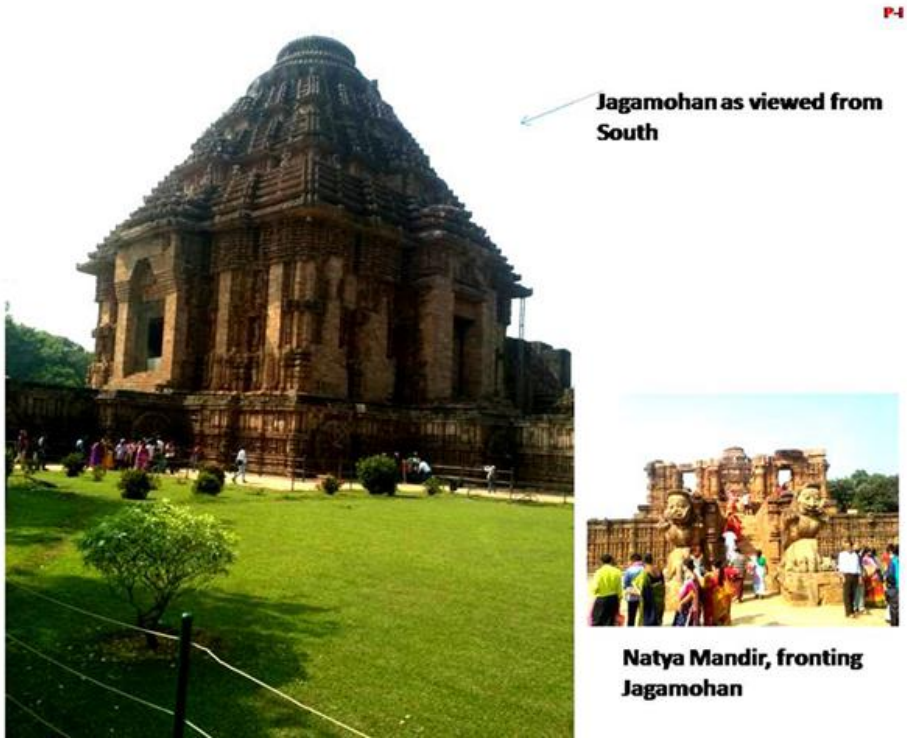
Abstract: Konark, the outstanding marvel of Kalinga architecture of the 13th century, is one of the world heritage sites of the state of Odisha, with its sculptural embellishment carved in khondalitic rock. It has a sublime geological quest that envisages its location, characteristics and source of rock, mode of transport, ease of carving, withstanding the climate, stability of the foundation, etc. The fast-growing Debi River (distributary of Mahanadi River) prodelta towards offshore, immediate northeast of Konark has made a bay-like coastal feature on the beach and dune of which the 'Sun temple' was constructed. Since then, the bay has filled up, and the shoreline has migrated offshore in the order of a few kilometers. The abundance of khondalite in the nearby Eastern Ghat Mobile Complex could be the reason for its utilization in monumental structures, including sculptors. However, the exact source of the rocks used and their mode of transport from the source to the construction site is yet to be deciphered. The progradational shoreline attests to the stability of the longstanding foundation, but its nearness to the sea could be a reason for the disfigurement of the artistic sculptors due to airborne saline water. Besides, water percolation along the minor or miniscule fracture, the grain boundary, and the decomposition of reactive feldspar minerals could be added reasons for disfigurement. However, many of the geological enigmas and riddles need to be studied in detail.
Keywords: Konark, Geological aspects, Heritage.

Introduction

Konark (P-I), the world heritage site for its sculptural marvels built in the thirteenth century on the seashore of the east coast of India, is the pride of Odisha. This monumental site is embedded with several legends, histories, and mythologies; many of those may or may not be corroborated by scientific studies. The available literature creates ripples in the mind without reaching for a definite conclusive thought. The museum of the Indian Oil Foundation in its vicinity has attempted to recreate some sculptures to their originality and has given shape to the history of the temple clubbed with various legends in vogue.

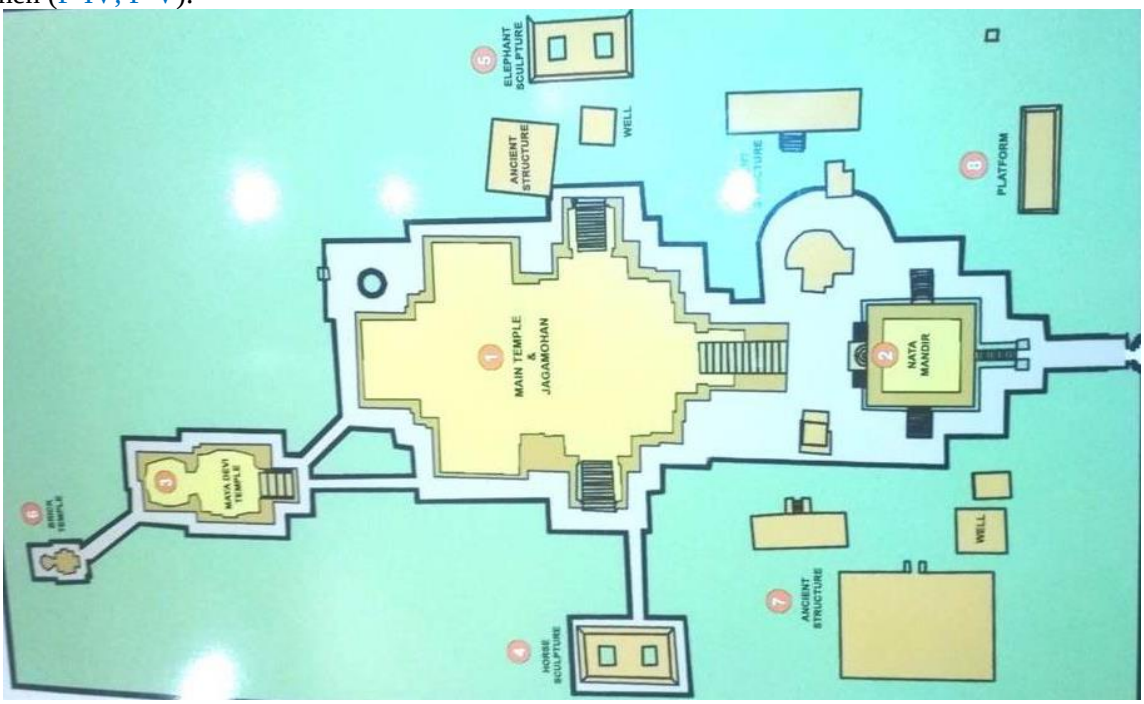


An attempt is made here to decipher a few of the geological aspects related to this monumental historical temple that remains inconclusive but without the support of laboratory studies. It's understood that many scientific studies are undertaken by many erudite scholars to focus on the nature of rocks, architecture, the crafting of the sculptures, and the iron beams used. This write-up is only a glimpse and not a scientific account of any specific aspects and is liable for correction, if any. The book by Sri Anil Dey, a monumental Oriya book, "*Arka Kshetra –Konark*" is of immense help in gathering various aspects of Konark and further reading through cited references.

P-II

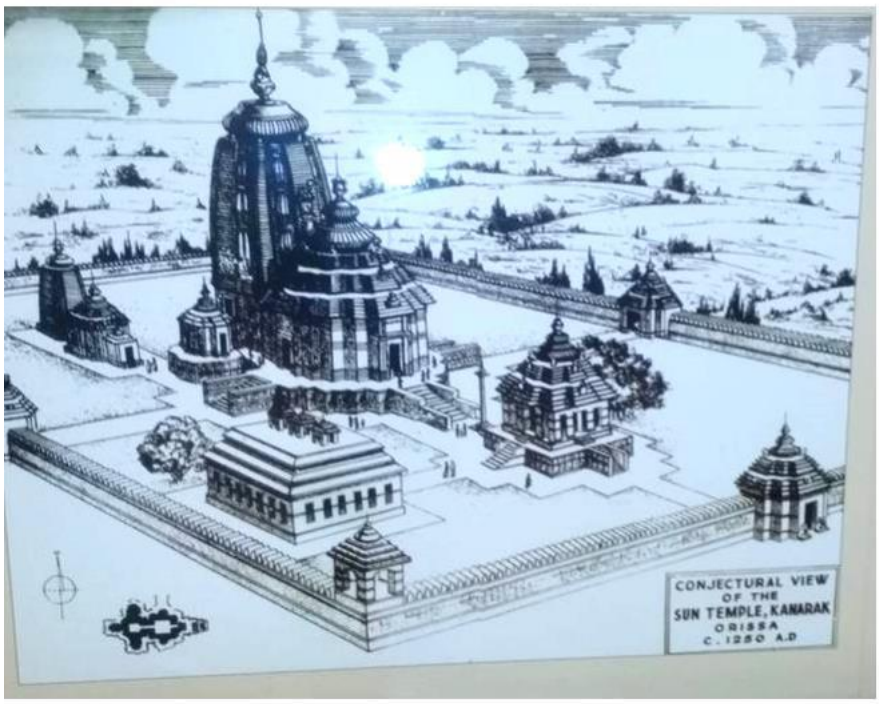
Konark as drawn in 1837 by architect artist Fergusson

Location: It's a matter of fact that the visible structure has only two components of the original temple: Jaga Mohan and Natya Mandir. As for the main temple, a part that was visible in 1837 (P-II, P-III) has collapsed since then (P-IV, P-V).



P-III: Planar View of Temple Complex, IOCL Museum.

The temple was undoubtedly constructed on the seashore, which can even be made out from the Google Earth image (P-VI, VII, VIII) by a distinct tonal contrast. The construction site was more or less on the shore of a bay immediately southwest of Debi River Mouth. During that period, the Debi River can be assumed to have advanced at a faster rate into the sea to build its river mouth delta, creating a bay in its southwestern part. The present shoreline has migrated 3 km in a sea-ward direction towards the east as the bay got filled with sediments. This abnormal filling and shoreline migration of 3 meters annually could be possible due to the migration of the deltaic lobe towards the southwest and severe climatic changes.



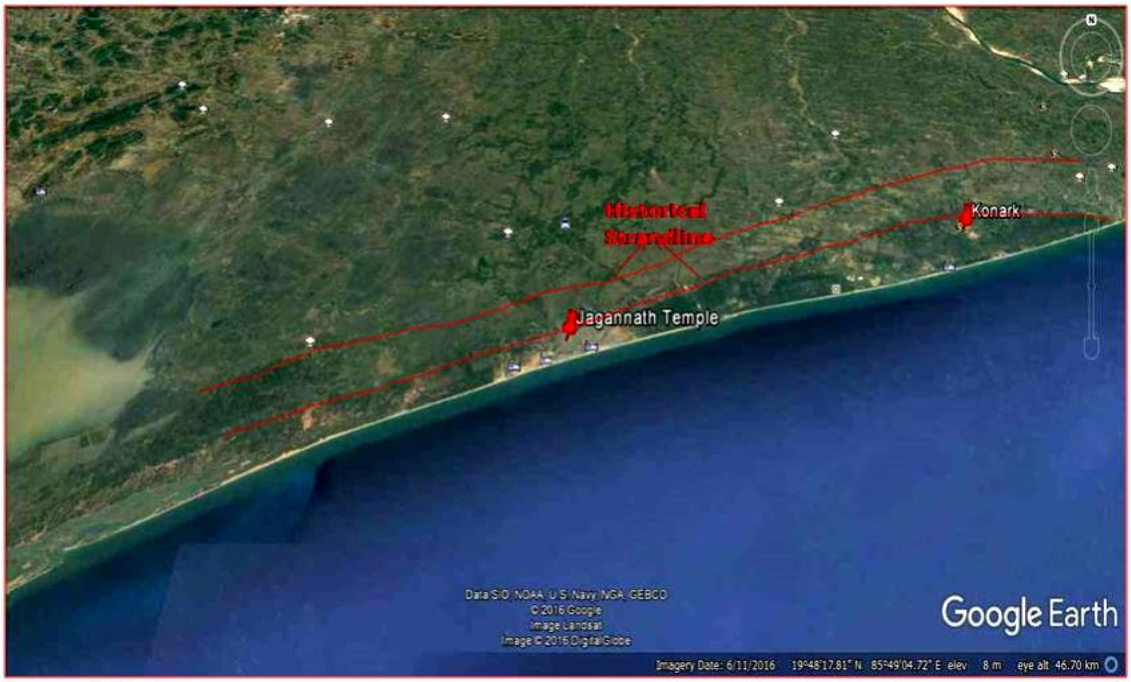
P-IV

Conceptual original Konark Temple ,
(IOCL Museum)

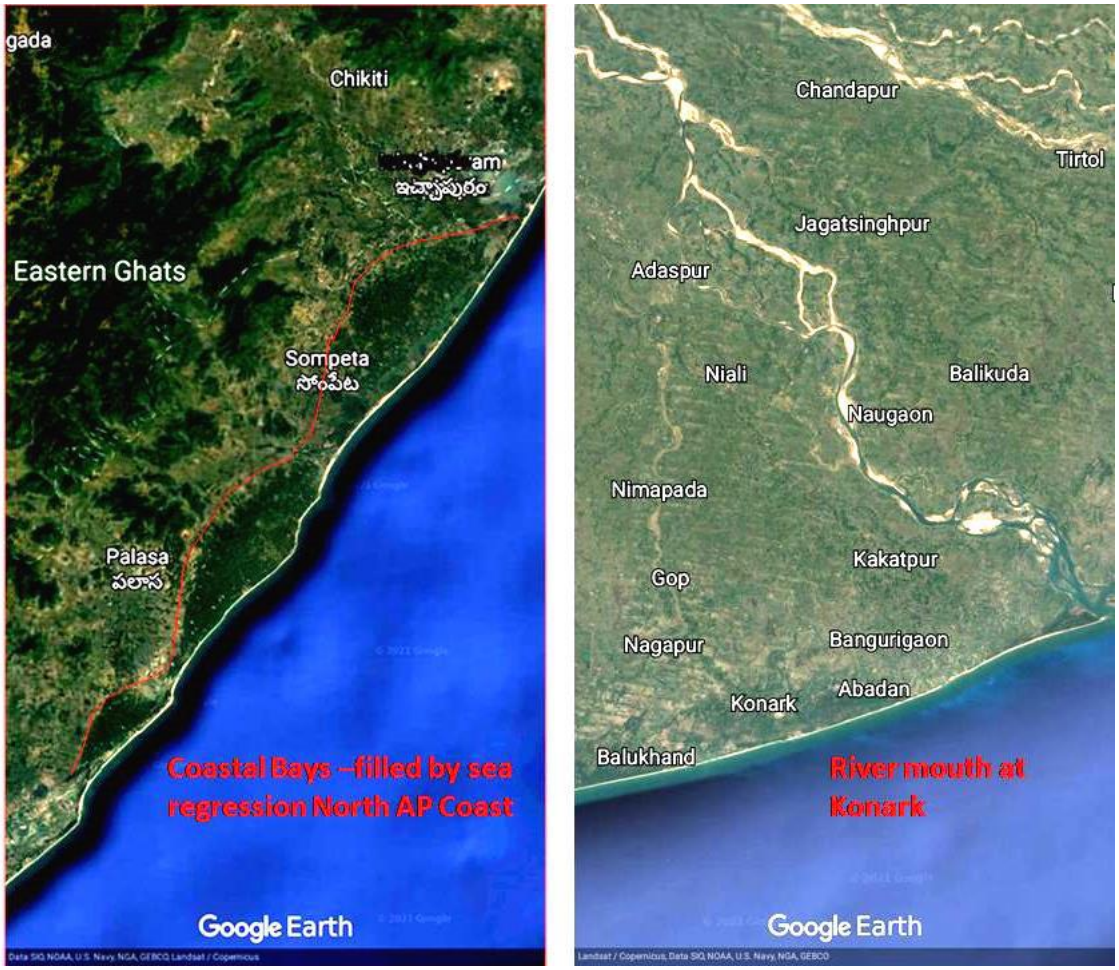
P-IV: Conceptual model-IOCL museum.

This migration and bay filling are not uncommon in this part of north Andhra Pradesh and Odisha Coast (P-VII). Both Jagannath and Konark Temple have identical setups, being located near the sea coast. Parallelism in the bay filling can be drawn from the shifting of deltaic lobes in the Godavari Delta due to active sedimentation during the last 1000 years (Rao et al., 2015). A scientific study indicates a strong monsoon during the Mediaeval Climate Anomaly (1100 AD-1300 AD) and the Current Warm Period (1750 AD-present) and showed multiple shifts during the Little Ice Age (1300 AD-1750 AD). Two major floods occurred during the period 1210 AD-1320 AD inundating a large part of India (Gupta et al., 2019). High sedimentation input to the coast and rapid progradation of river deltas could have been possible due to the prevailing anomalous climate.

P-V **Konark in 1867, prior to conservation**



P-VI: Tonal Contrast at the Konark-Palaeo strandline.



P-VII: a. Buried bays in North AP coast b. Chandrabhaga River-mouth at Konark.

P-VIII: Prachi Valley and Chandrabhaga River.

Rock Types

There are nearly three types of rocks that have been used within the complex: a. Khondalite, "*Kanda pathar*" in Oriya for the main temple Jaga Mohan, and Natya Mandir, endowed with engraved sculptors. The khondalite term, derived from the Kond (also called Khond) tribe of Odisha, was first coined by T. L. Walker (1902) for the rocks having mineralogy such as quartz, felspar, garnet, and sillimanite. The choice of khondalite is due to its availability in the vicinity and preference over laterite for ease of sculpting. The use of khondalite in a saline environment is a matter of debate, but its characteristics of banding, mineral composition, and availability could have been factors favoring the selection of this type of rock (Dey, 2012). The term '*Khondalite*' was not used by Ganguly (1912), who coined the terms metamorphites and crystalline for the type of rocks used in Konark.

Architectural marvels in Khondalite with decomposition of felspar and garnets

P-IX: Fine sculptures in Khondalite, Jaga Mohan.

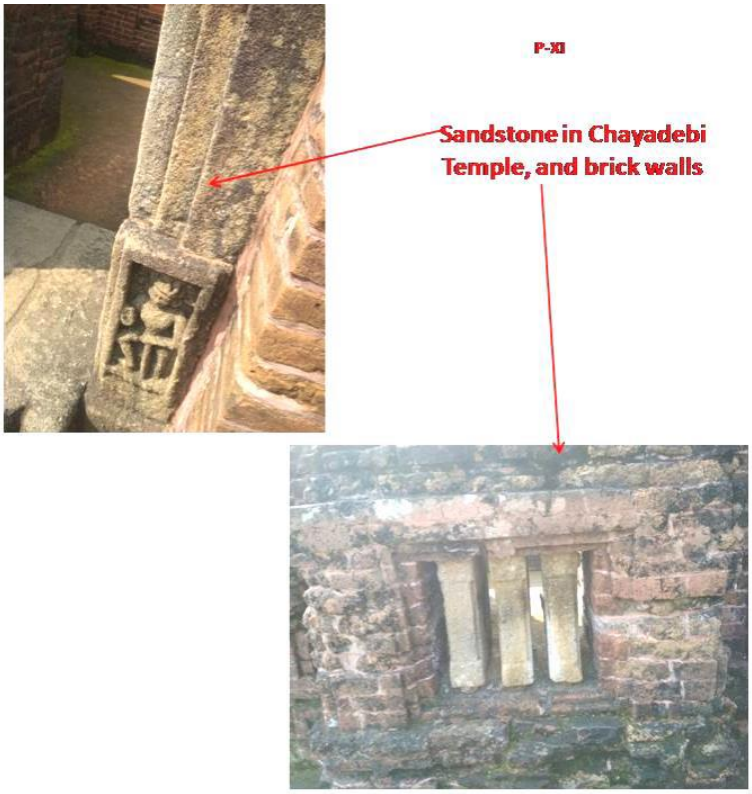
a. Laterite

Out of the three types of rocks, laterite is used for foundations and side walls. Laterite, a typical derivative of in situ alteration from variable original parent rocks under tropical climatic conditions, is a porous, pitted, and clay-like rock with a hard, limonitic protective crust containing a substantial quantity of iron oxide and some aluminum oxide. In Odisha, these are used for building purposes as a substitute for bricks in the districts of Cuttack, Nayagarh, Khurda, Puri, and Ganjam. There are ferruginous and aluminous laterites, depending on the parent rocks. The laterites were possibly mined from Khorda or Chaudwar (Behera, 2005).

P-X: Laterite as used (in Kitchen Complex?).

b. Sandstone

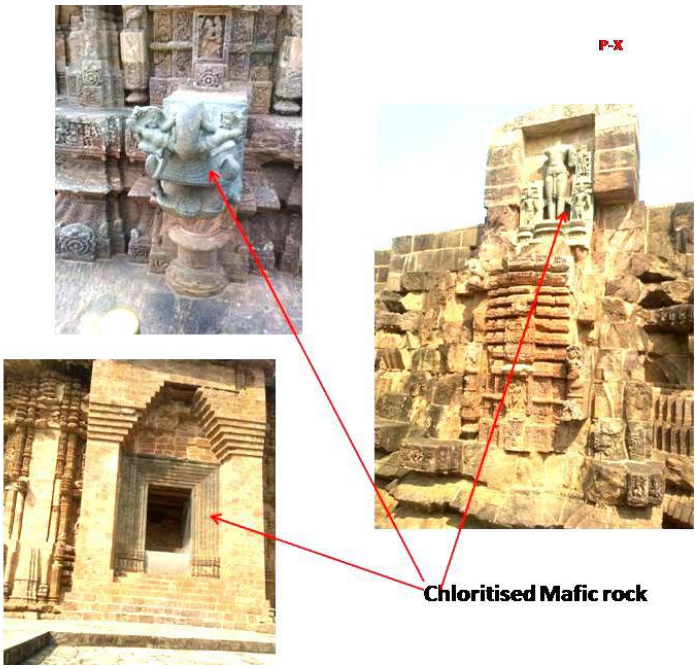
There are a few of the sandstones used in the ancillary temples of Chaya and Maya Debi. The Upper Gondwana sandstones of Odisha (Athgarh Sandstone) that occur in and around Bhubaneswar have been extensively used in the construction of all the temples of Bhubaneswar since the 7th century AD (P-XI).



P-XI: Uses of sandstone In SW ancillary temple.

c. Chloritised Mafic-ultramafics

The ultrabasic rocks commonly known as chlorite (locally 'muguni') are used for simhasan, cult icons, and occasionally for door frames, and the main deity "Surya" (Behera, 2005). These are invariably green in colour and fine-grained (P-XI).



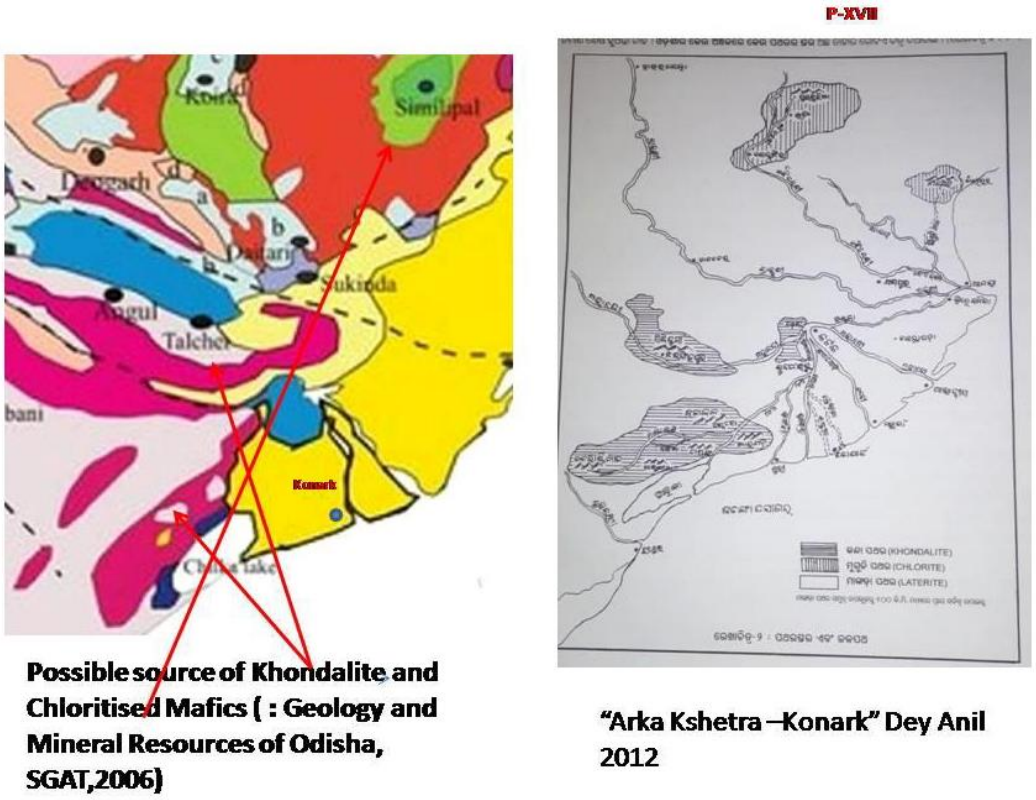
P-XI: Chloritised mafic rock.

The structures made up of chloritized or serpentinised mafic are better preserved and not prone to weathering or grain decay. However, chlorite as a mineral shall not appropriate in terms of its geological characteristic of

being a soft and friable rock. The chlorite (muguni) was used for ease of fine carving because of its resistance to decay by water and wind (Dey, 2012). Ganguly (1912) opined that the rock is not chlorite; the dark green rock is serpentinous or hornblendic, possibly brought from Nilagiri hills near the villages of Santragodia and Goojadeeha. This may not be strictly serpentine but rather admixed with some other clay mineral and could be impure varieties of talc. Massive mafic dyke swarms and a few ultramafic dykes are prominent in the districts of Mayurbhanja and Keonjhar. Besides, mafic-ultramafic intrusive as a sill (Amjhori Sill) with dunite, picrite, and peridotite. Newer dolerites reveal a few petrographic varieties such as quartz dolerites, norites, micro-pegmatitic dolerites, and gabbroic variants. They are mainly massive and often coarse-grained and their colour varies from black to dark green. NNE-SSW trending green to dark green-coloured, ultramafic dykes exposed near Keshargaria contain olivine and pyroxenes.

Sources of Rocks

The stones were carried from quarry sites to the place of work either by waterways or land routes (Behera, 2005) where chlorite was taken from Nilagiri, Mayurbhanja, Bonai-Keonjhar, or Champua (Behera, pp.96; Ganguly pp.247) Ghantasila, Naraj, Athagarh, Khiching, Tapanga, Narasingpur Nilagiri-Pitasuni, and Siddhadurga are possible sources of the rocks for the temple (Dey, 2012) Out of these sites, Ghantasila, Naraj, and Athagarh comprise Upper Gondwana's '*Athagarh Sandstone'*. Although a dolerite dyke is present at Naraj, these places are not the source of Khondalite. Khiching and Nilagiri could be the source of chloritised mafic or ultramafics for the idols, door frames, etc., while Narsingpur and Tapanga are possible sources of khondalite. If it is Narsinghpur, the transport is only through the waterways of Mahanadi and its distributary system passing through Cuttack, Nimapara Gop (P).



P-XII: Possible sources of Khondalite and chloritised mafics.

Weathering and alteration of minerals

The banding of segregated minerals is common with color contrast in used khondalite. The sculptors engraved are apparently at an angle to the bandings (P-XIII) or in a perpendicular direction to the bandings (P-XIII). Felspathic bandings are conspicuously altered by kaolinitisation (P). Garnet crystals are dislodged due to margin alteration. Textural observations indicated that the main weathering reaction was the alteration of feldspars and red garnet (almandine) to kaolinite and goethite (Raymahashay and Sharma, 1993).

P-XIII: Leaching of Iron oxide solution (from Garnets?).

PXIV: Alteration of feldspar bands.

Mostly alteration of minerals of feldspars and garnets has given rise to the disfiguring of the sculptors.

Foundation Settlement

A close examination indicating the absence of vertical cracks and horizontal cracks within the foundation rules out the concept of any differential subsidence of the foundation. In consideration of the structures in the immediate vicinity, an earthquake is ruled out (Ganguly, 1912). Although the Jagannath Temple was built in the 12th century at a distance of 25km from Konark, the temple still has withstood, natural weathering in a saline coastal area. The craftsmen of Konark must have gained enough knowledge to lay foundations in a regressive coastal area characterized by alternative marshy and sandy soil. Konark temple, with a presumed height of 228 feet (Dey, 2012) must have foundational anchoring in the critical soil (need further studies). However, the Chaya Debi/ Maya Debi and the brick temple (P-V) on the southwestern side of the main temple can't be attributed to an early period, as construction on the nearshore area without any solid foundation is a distant possibility. Rather, it could have been constructed in the early or later part of the main temple construction using the same foundation. A detailed study of this aspect may shed more light.

Collapse of the Main temple

Striling (1825) opined that the collapse of the main temple was due to the impact of some external forces, such as an earthquake or lightning, and that the collapse might have damaged the structures adjacent to it. He described a 120 feet high, portion of the main temple, the sketch of which was drawn by Fergusson in 1837 (P-II) implying the existence of the main temple before 1825 at least. A recent scientific study by Jana et al. (2021) suggests neo-tectonic activity (an earthquake due to seismicity) for the collapse of the main temple. However, the reasoning put forth by Dey (2012), Ganguly (1912), and Behera (2005) is more reasonable and acceptable. As per Ganguly (1912), "a close examination indicating the absence of vertical cracks and horizontal cracks within the foundation rules out the concept of any differential subsidence of the foundation. In consideration of the structures in the immediate vicinity, an earthquake is ruled out". A similar observation by Behera (2005) states the damage due to a coastal cyclone in 1848, but it is not confirmable with the sketch drawn by Fergusson in 1825. As per his version, "the undamaged Jagamohan rules out of the impact of any earthquake as no long cracks were detected. The thorough survey by ASI since 1952 has not detected any instability in the foundation. Differential settlement due to foundation mostly occurs in the initial stages of construction; however, no visible cracks from the differential settlement are noticed. Expert surveys by UNESCO in 1987 have found a sound foundation." The location of the temple near the shore, sandblasts, saline water, the growth of plants and weeds, and heavy monsoonal rain might have caused the decay. The khondalite and iron dowels might have been adversely affected by the prevailing climate and lack of care by the worshippers without any political patronage (Behera, 2005). However, political patronage beyond the mightier Gajapati dynasty, after say 1530 AD, is a plausible proposition. The characteristic variation of the composition of Khondalite could be one of the reasons that can be attributed to the damage to the sculptors and the main temple structure. Lemaire LM, an expert appointed by UNESCO, in his 1981 report, opined that "the condition of stones is good despite areas of erosion; stone has a tough matrix; no immediate erosional feature may happen (Behera, 2005).

Climate Change during the Medieval Period

Within the last millennium, notable climatic variations have been studied and recorded. Even the downfall of some of the mightier kingdoms has been relegated to this historical climate change. "Abrupt shifts in Indian summer monsoon (ISM) precipitation largely affected regional hydro-meteorology, accelerating socio-economic and cultural adaptations of agrarian economies in South Asia in the last millennium" Gupta et al. (2019). However, the political instability in Odisha's history occurred after the Gajapati Kings postdated 1540 AD, which rules out the impact of severe climate variation during the 15th century and the earlier half of the 16th century at least.

Conclusions

The Konark Temple was built on the seashore in the thirteenth century with a sound foundation in a coastal sandy and marshy land. Any construction prior to the temple in such an environment appears unpracticable. The source of the major rock Khondalite needs to be established as no such rock mining in the historical past has been reported. The river Chandrabhaga flowing into the bay near Konark could have been used as a mode of transport for huge rock slabs from the source, which could be Narsinghpur or Satakoshia. So, Mahanadi and its distributaries originating at Cuttack could have been used as a waterway mode of transport through its distributaries. The green-coloured rocks used are possibly chloritised mafic or ultramafic rocks (personal communication with Sri BK Jena and JK Nanda) from the Nilagiri or Khiching area of Balasore and

Mayurbhanja District. The decay of sculptures is due to the alteration of feldspar to kaolin and the decomposition of garnets, giving rise to ferrous solutions. The impact of wind abrasion cannot be ruled out. Cracks due to moss accumulation can be ascertained from some sculptures lying on the museum campus (P-XIII).

In view of the stability of the foundation and undisturbed structure of the Jagamohan, the main temple collapse can be relegated to natural weathering, erosion, water action, and a lack of patronage from the worshippers, including political dispensation. A close examination indicating the absence of vertical cracks and horizontal cracks within the foundation rules out the concept of any differential subsidence of the foundation. In consideration of the structures in the immediate vicinity, an earthquake is ruled out (Ganguly, 1912). Although the Jagannath Temple was built in the 12th century at a distance of 25km from Konark, the temple still has withstood natural weathering in a saline coastal area. The craftsmen of Konark must have gained enough knowledge to lay foundations in a regressive coastal area characterized by alternative marshy and sandy soil. Konark temple, with a presumed height of 228 feet (Dey, 2012) must have foundational anchoring in the critical soil (need further studies). However, the Chaya Debi and Maya Debi and the brick temple (P-V) on the southwestern side of the main temple.

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