# Notes

## Carbonate cemented pillars at Nesøya, North Norway: Proposal for an alternative model of formation

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This is a comment on the paper 'Lithified Holocene shallow marine carbonates from Nesøya, North Norway' by Jenö Nagy and Henning Dypvik.

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Nagy & Dypvik (1984) describe some interesting pillar-like structures composed of lithified shell gravel ('beach rock') occurring on a raised beach on Nesøya, North Norway.

In their discussion of the geological history leading to the formation of these tantalizing features, the authors present an interesting model of formation. However, they seem to fail in providing a convincing explanation of two important aspects:

a) How the special beach morphology developed; on a normal beach one would expect benches or terraces to form, not local mounds.
b) How the precipitation of carbonates has been achieved; one would not expect precipitation of carbonates in reducing seawater environments. Therefore their model is not consistent with the crucial aspect that carbonates do precipitate, not because of seawater, but in spite of the presence of seawater.

An alternative development model for the formation of the lithified pillars at Nesøya is hereby offered, which I hope the authors will consider during their further studies.

The model is based on two important assumptions:

- That a dynamic hydrological environment exists in the basement rock (gneiss) underlying the beach.
- That the artesian liquids are mineralized with a high carbonate content.

Figure 5 of the discussed paper shows a lithified pillar (no. 7) which is situated over a crevasse in the gneiss bedrock. It is therefore highly possible that there exists a dynamic hydrological environment capable of transporting mineral-rich liquids which may percolate from the bedrock up through the beach deposit.

In their discussion of the formation of recent marine carbonate and hematite cements in a gravel at Islay, Scotland, Adams & Schofield (1983) arrived at the following conclusion: The cementation must have occurred below a layer of loose sediment where the alkalinity of the local pore waters was increased sufficiently to precipitate calcium carbonate. They assumed that the layer of cementation was buried, cemented and then exhumed by erosion.

Also Jørgensen (1976) suggested a special physicochemical environment to be present for the formation of high magnesian calcite/aragonite cementation of beach sediments. He assumed the precipitation took place by the mixing of bicarbonate-enriched meteoric water and seawater.

Discrete discharge of ground water through the sea floor has recently been observed and reported from the prodelta at the head of Cambridge Fjord, Baffin Island (Hay 1984).

In the North Sea at water depths over 100 m recently lithified patches of seafloor have been

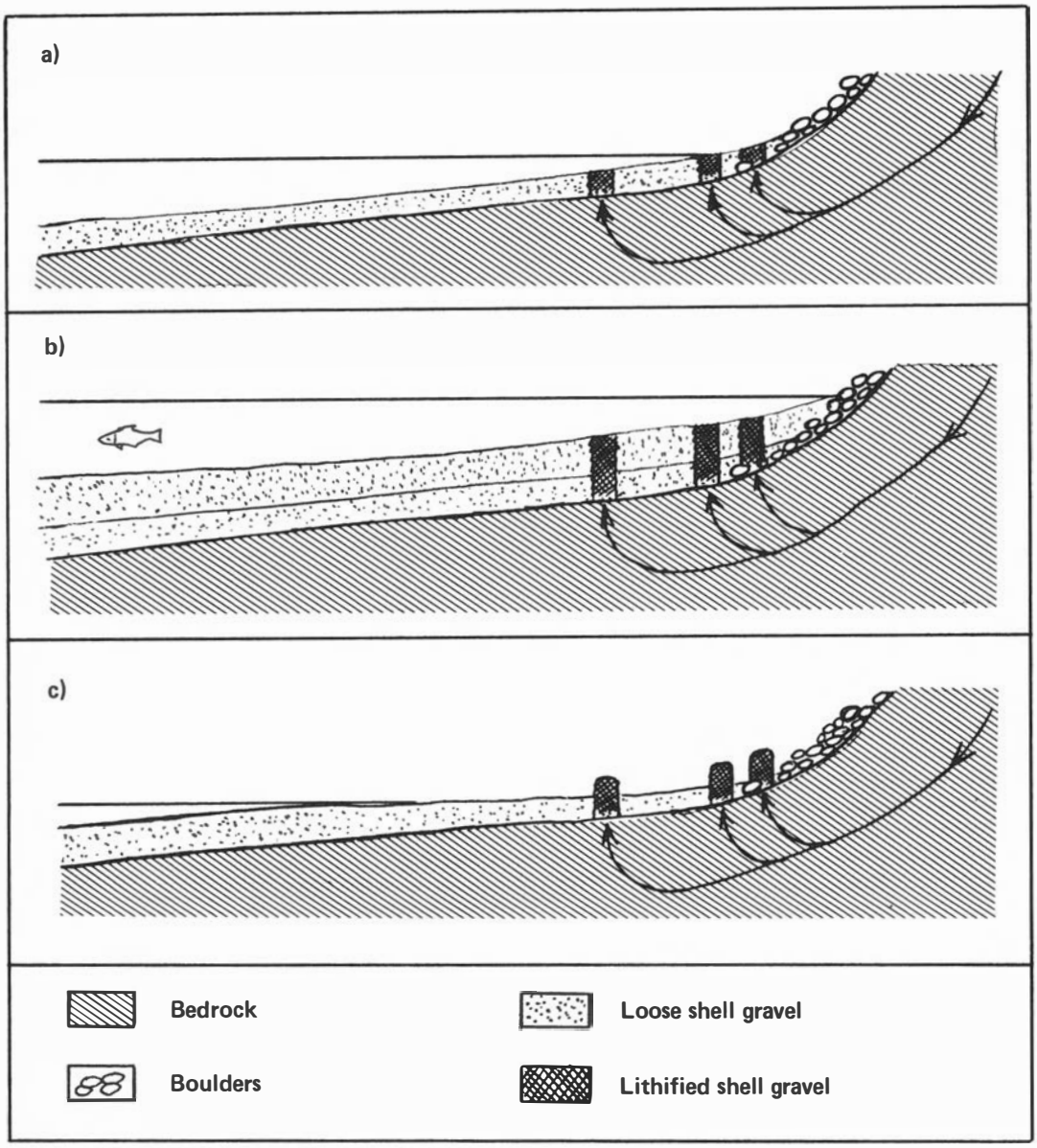


*Fig. 1.* Proposed alternative model for the formation of lithified pillars. The arrows indicate assumed ground water flow.
a) Accretion of beachgravel induces cementation in columns over assumed artesian seeps.
b) The beach deposit thickens, cementation in the columns continues.
c) The beach becomes raised. Loose material is transported away while the columns remain as lithified pillars.

described by Hovland et al. (1984). The carbonate cemented patches occur inside seafloor pockmarks (craters) assumed to be caused by expulsion of liquids and gases (King & MacLean 1970, Hovland 1984).

Although the patches on the seafloor are found inside depressions, while the structures at Nesøya are positive features, the processes responsible for the lithification could be similar.

The following development model for the formation of lithified pillars at Nesøya is thus proposed (Fig. 1):

1) A layer of beach gravel and boulders is initially accreted on top of the substratum (gneiss bedrock).
2) Mineral-rich artesian water seeps out from cracks and fissures in the substratum.
3) The alkalinity of the intrasedimental pore waters is locally increased sufficiently to precipitate carbonates.
4) Beach accretion continues and more gravel is deposited on top of the initial layer. The seepage continues at the same locations as previously. Artesian liquids seep upward through the initially lithified material (which has a reported porosity of 11 to 21 %) and some of the artesian water is forced to seep up around the originally lithified body. However, the second beach gravel layer becomes cemented to the original one at the same location, whereby a lithified intrasedimentary column is formed.
5) As the relative sealevel decreases and the beach becomes elevated, the lithified sediment column sustains erosion while the loose beach material is washed away. The lithified columns are now exposed as pillars.
6) The beach location is presumably exposed to high energy waves also, which over time will break down some of the pillars, so that loose blocks of lithified shell gravel appear.

From the pictures presented by Nagy & Dypvik (1984) it is clear that horizontal zonation (layering) occurs in the pillars. The layers should, according to this theory, be syncronous and could possibly be correlated from one pillar to the neighboring one, and may thus be used to reconstruct a lithostratigraphy for the eroded beach at Nesøya.

As pointed out by the authors, a detailed discussion of $Ca^{2+}$ and $CO_3^{2-}$ sources, dissolution of micritic carbonates, weathering of basement carbonates, bacterial activity etc. must wait for isotopic analysis. However, a hydrogeological and chemical analysis of ground water at the location would probably also be a fruitful avenue of research.

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