Integrated microstratigraphic investigations and the potential of coastal archaeological soils and sediments to record past land use and cultural activities in Norway and the UK.

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Investigations of past coastal environments have included soil micromorphology, chemistry and microfossil recording of soils and sediments in the UK at Lower Palaeolithic (e.g., Boxgrove) to Historic sites, and in experiments (Macphail et al., 2010). Experiments include Wallasea Island, Essex, where the sea wall was purposely breached, and previously reclaimed grassland and arable were inundated. The effect of sea water on terrestrial soils (Na⁺ soil dispersion) and the development of laminated saltmarsh sediments produces, for example: typical calcitic microfabrics, a strongly raised specific conductance, and a distinctive suite of microfossils (e.g. foraminifera and pollen record saltmarsh species; pollen also includes enhanced amounts of tree types probably derived from the North Sea). Findings characterise the effect of both early Holocene sea level rise and what may be expected if sea levels start to rise significantly in the future. These data also aid the reconstruction of past coastal land use and exploitation, and were specifically applied to the sites of Roman salt working at Stanford Wharf, Thames Estuary, Essex, UK and the Viking Period Gokstad Ship Mound Burial, Sandefjord, Norway.

ROMAN SALT WORKING, STANFORD LE HOPE, ESSEX, UK

‘Redhills’ or ‘Salterns’ as sites of coastal salt working have been recorded since the 19thC in the UK, but their exact makeup has never been elucidated. Romano-British redhill deposits and associated features, and Late Roman structures were analysed in detail from Stanford Wharf, Essex (http://oxfordarchaeology.com/case-studies/29-environment/98). Here, 49 thin sections were studied employing soil micromorphology and associated SEM/EDS (Energy Dispersive X-Ray Spectrometry), X-Ray microprobe and FTIR (Fourier Transform Infrared Spectrometry)(Macphail, Crowther and Berna, 2012). 24 carefully correlated bulk samples from the same monolith sequences also provided complementary chemical and magnetic susceptibility data, including information on organic matter (LOI), phosphate, salinity (specific conductance) and heavy metals (Cu, Pb and Zn). A control sequence recorded the effects of marine inundation on the terrestrial Neolithic and Bronze Age palaeosols formed in brickearth. Salt water sodium ions (Na⁺) led to soil dispersion and structural collapse. This did not affect large charcoal and flint flakes within the soil, but finer charcoal and surface charcoal were probably liberated and floated locally. The uppermost soil was truncated, and this charcoal-rich material formed basal laminae in the marine alluvium affecting the site, and which underlies redhill deposits in places. These redhill sequences are dominantly composed of red burned mineral materials that have the highest magnetic susceptibility values at Stanford Wharf. Sometimes this was in the form of briquetage employing marine clay and/or brickearth, but redhill is predominantly made of burned salt marsh sediment which had been incidentally gathered alongside marine wetland monocotyledonous plant fuel. Fragments often show relict root channels that formed in this vegetated and rooted ripening sediment; rare examples may preserve algal (seaweed) stained laminae typical of modern salt marsh sedimentation (Fig 1). Articulated phytoliths and ‘white ash nodules’ which are partial siliceous pseudomorphs of this (slow burning) monocotyledonous plant fuel occur throughout, and charred probable Juncus maritimus was found in an associated hearth structure (Cath Turner, pers. comm.). Redhills probably formed rapidly due to the dumping of this minerogenic fuel ash waste, a formation process similar to farm mound
accumulations where minerogenic peat was used as a fuel. General fragmentation occurred because
the spreads formed ephemeral trampled ‘occupation surfaces’.

Examples of ‘green glaze’ on briquetage were also analysed (Fig 2). The briquetage is ‘manufactured’
from estuarine sediments with a mica-smectite clay component. Sections through the green glaze
briquetage record the increasing effects of heat upwards, causing, 1) ‘rubefication’ (400°C-700°C),
with the upper blackened part being more strongly heated (>700°C). The green glaze itself is a
strongly heated silicate glass (minimum 700-800°C to around1000°C). The dominantly siliceous glaze
contains statistically significant (Mann-Whitney U test; \( p < 0.05 \)) greater quantities of Na (sodium), P
(phosphorus) and Fe (iron) compared to the briquetage. Fe possibly gives it a greenish colour, and P
is probably concentrated from burned fuel. It is possible that Zn (zinc) may also have a similar origin
(marine plants and sediment may have concentrated Zn from sea water). Amounts of Na are
anomalously high but diminish away from the glaze surface; this can be viewed as supporting a salt
(NaCl)-making origin for this green-glazed briquetage. Floors in Late Roman building were also
studied. Here, on-site estuarine sediments were strongly influenced by occupation deposits, including
latrine waste, and a series of beaten floor deposits had formed in the structure under generally moist
conditions. The floors also record alternating: a) hearth and kitchen waste from internal trampling, and
b) incorporation of alluvial clay from outside. More importantly very high lead enrichment (3580 µg g\(^{-1}\)
Pb) was found to be associated with ‘iron’ staining of the floors (EDS maximum 54.1% Pb, Fig 3),
clearly indicating use of lead vessels, as suggested for late Roman salt making generally. Small
amounts of Sn (tin) imply other metal vessels may have been used here, and intertidal sediments
continued to affect the sites.

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**Fig. 1**: Salt making Redhill deposit (Context 6379); a burned fragment of ripened, generally iron-poor
marine sediment, showing original probable algal layers (arrows) and rooting (r); this is sediment was
accidentally gathered along with rooted wetland plant fuel. PPL, frame width is ~4.62mm.

**Fig. 2**: Scan large ‘Green Glaze’ fragment (M4240A1, ditch 4226); it is composed of vesicular glass–
coated (arrows), plant-tempered briquetage. Sample underwent FTIR, SEM/EDS and microprobe
analyses. The whole thin section and detailed smaller area (rectangle) were mapped for elements.
Two quantitative line analyses (x100 100x100µm areas): Lines A and B. Uppermost rubefied dark
area underwent >700°C, with the glaze (arrows) being a strongly heated silicate glass (minimum 700-
800°C to around/below 1000°C). It has a significantly higher Na content compared to the briquetage,
consistent with a salt-making use.

**Fig. 3**: X-Ray backscatter image of Late Roman ‘iron-stained’ floor deposits; with 3.27% Fe (iron),
7.01% Sn (tin), 7.95% P (phosphorus), 9.31% Ca (calcium), 49.1% Pb (lead)(mean values). Use of
lead vessels for boiling brine is implied by this marked lead staining of the floor. Scale=300µm.
VIKING PERIOD SHIP MOUND BURIAL AT GOKSTAD, SANDEFJORD, VESTFOLD, NORWAY

Preliminary analysis of 27 thin sections, associated EDS and bulk soil studies from the Gokstad Mound and one small intact area of buried soils at Sandefjord, Vestfold, Norway found a landscape history of the following: 1) glacial till deposition, 2) late prehistoric intertidal soil and sediment formation with possible traces of burned rock middens, and 3) emergence and terrestrial pedogenesis. The early Holocene terrestrial palaeosol (2) records soil dispersion, as described for Stanford Wharf, and these soils and marine sediments were similarly rooted by intertidal plants. (In fact marine clay soils and till were later utilised to seal the well-preserved ~AD 900 Gokstad longship within the turf mound; http://www.khm.uio.no/prosjekter/gokstad/.) Unlike southern UK, however, post-glacial uplift influences Scandinavia, and sea level curves from the nearby Viking settlement of Kaupang indicate that Gokstad (9.7-11.0m asl) emerged ~700 BC (Cannell and Bill, 2012, Sørensen et al., 2007). The buried soil and several turf sequences from the mound thus provide information on coastal pedogenesis and land use on intertidal marine sediments after ~1200 years of exposure. Phosphate, magnetic susceptibility and soil micromorphology indicate that a cultural soil characterised by very fine charcoal had developed. All traces of the original marine sedimentation are missing from the upper profile. The turves are humic, stone-free and biologically homogenised Mull Ah horizon soils, and totally reflect terrestrial pedogenesis (Fig 4); no pollen of salt marsh/marine plants is present (Jan-Erik Wallin, MAL, pers. comm.). General soil phosphate concentrations, and moreover surficial secondary iron-phosphate impregnation of organic (dung?) stained soil and internal crust formation in individual turves, suggest contemporary Viking use of pasture by stock animals (Fig 5). This is consistent with pollen indications of a mainly open grassland environment. Turves were also collected from a nearby poorly drained pasture area just to the west of the mound, and these turves have a laminated Mull superficial horizon, where humifying grass litter is intercalated with thin organic excrements. In situ topsoil (turf) which remains under the mound in the North-East quadrant is a record of the Viking buried land surface. In comparison to undisturbed turf employed in the mound construction it appears to have some anomalous features associated with mixed soils between the base of the mound and the buried soil. For example, most voids are infilled with brownish clay (Fig 6) these can occur below compacted thinly layered soil immediately below the turf mound. This is tentatively interpreted as witnessing trampling at this specific location which was the hypothetical access point to the Gokstad ship burial during the construction of the grave mound (J. Bill, R. Cannell, pers. comm.)
GOKSTAD MOUND: Fig. 4: Junction between two turves in turf mound, with secondary Fe-P staining of surface humus, which may include dung traces. Fig. 5: SEM/EDS X-Ray backscatter image of iron and phosphate-stained turf (Fe-P) surface organic matter – dung inputs? (42.9-55.5% Fe, 1.56-1.97% P); scale=700 µm. Fig. 6: The turf topsoil in the only area of intact old ground surface (North-East Quadrant). Note anomalous brown clay void infills (C) as possible evidence of human trampling/disturbance associated with accessing the ship burial during grave mound construction.

CONCLUSIONS

The coastal zone is often a very dynamic sedimentary, pedogenic and cultural environment, which can be clearly elucidated employing microstratigraphic techniques such as soil micromorphology, microchemistry, and carefully correlated bulk sample analysis for chemistry and microfossils, for example. Although clearly different early Holocene soils formed in glacial geology at Gokstad, Norway and in brickearth at Stanford Wharf, UK, both were affected by sea level rise. These inundated soils were similarly dispersed by Na⁺ ions and marine alluvium was deposited at both locations. At Roman Stanford Wharf, the intertidal zone yielded both monocotyledonous plant fuel material and supplies of sea water for salt making. The resulting redhills are essentially minerogenic fuel ash waste accumulations from this activity. It is suggested that during the Late Roman period, briquetage was largely replaced by the use of lead vessels for heating brine. Bulk soil and microchemical identification of lead ‘staining’ of floors appears to confirm this. Uplift affected Norway and marine alluvium underwent some 1200 years of subaerial weathering and soil formation. Here, soils lost all evidence of their marine sediment origin, and were totally terrestrial by Viking times. Mull microfabrics and pollen data indicate pasture, while phosphate chemistry and microfeatures are consistent with a grazing land use. Palaeolandscape reconstruction indicates that both well-drained and poorly drained turf soil was employed in mound construction, the wetter soils around a paleochannel to the west apparently supplying ‘wetter’ turf to the west side of the mound. Other coastal sites have been studied from the Blackwater and Crouch River estuaries, Essex and Goldcliff, Gwent in the UK, while Viking coastal site studies are being expanded to Heimdal (on the Viking shoreline south of Gokstad) and to the Royal Manor at Avaldsnes, Rogaland.

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