Imbricate thrust stack model for glacial rafting in an ice margin: an example from north Norfolk, UK.

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Introduction

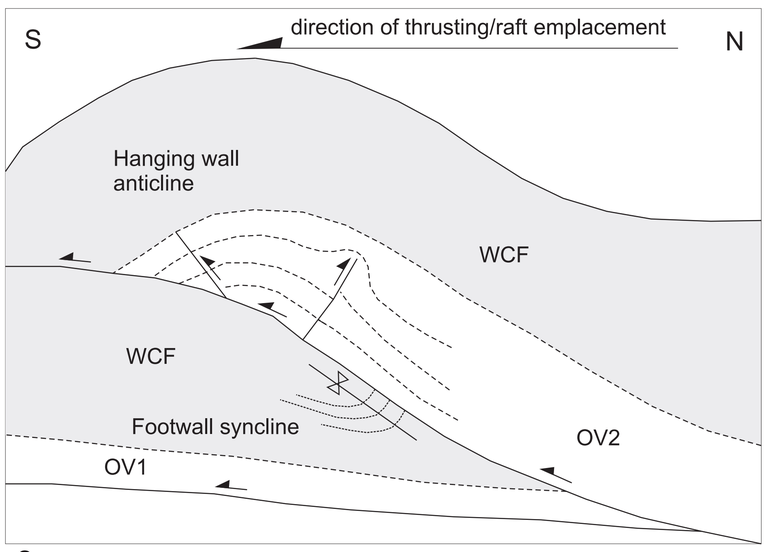
Glacial rafts, 'floes' or 'megablocks' are defined as dislocated slabs of bedrock and/or unconsolidated sedimentary strata that have been transported from their original position by glacial action. Such rafts are typically composed of thin slabs of material that may have been transported over distances ranging from tens of metres to hundreds of kilometres. They generally occur as single, horizontal slab-like features, but may be stacked within structurally complex ice-pushed moraines. Internally, rafts often appear undeformed. But on a larger scale, they can form parts of large nappe-like fold structures, be cut by shear zones, faults and brecciated/clastic zones.
Several different models have been proposed to explain the generation of glacial rafts, including the freezing of the raft onto the underside of cold-based glacier ice. Alternative studies suggest that failure, leading to raft detachment, is associated with elevated pore water pressures. Rafts have also been shown to be generated as a result of thrusting associated with proglacial deformation.

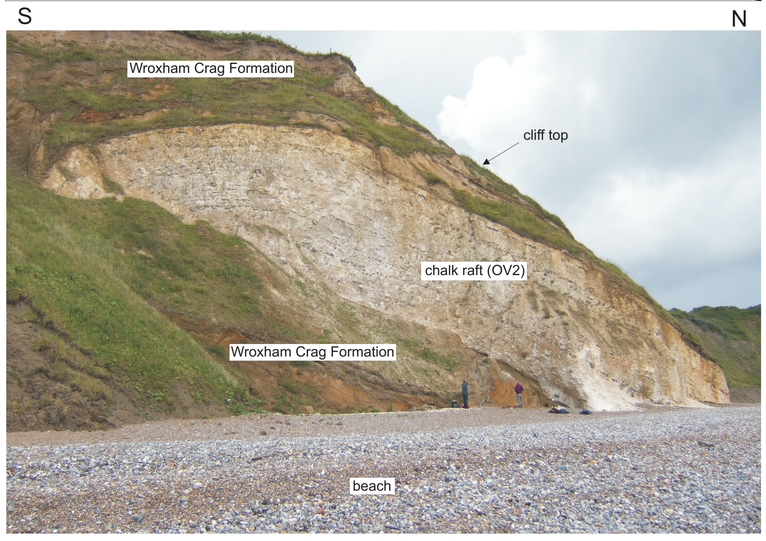
Regional Setting

The geology of northeast Norfolk comprises the easterly dipping Upper Cretaceous (Upper Campanian to Maastrichtian) chalk bedrock, unconformably overlain the shallow marine sands and gravels of the Wroxham Crag Formation. These are inturn overlain by a thick sequence of Middle Pleistocene sediments comprising tills, lacustrine and glacial outwash deposits. These tills were previously referred to as the North Sea Drift (Cromer Tills), and widely attributed to the presence of Scandinavian ice in eastern England during the Middle Pleistocene Anglian Glaciation.
On the north Norfolk coast these glaciogenic sediments are locally highly disturbed (the 'Contorted Drift') and contain large rafts of chalk elevated above the chalk bedrock surface. Disturbance of this sequence has been largely attributed to soft-sediment deformation and mixing during proglacial and subglacial deformation.
Three sites were examined along an 8km section of the north Norfolk coast: Overstrand in the east, East Runton and West Runton in the west. These sites enabled a detailed study of large and small scale deformation structures associated with the emplacement of the chalk rafts.

Deformation Structures and Thrust Stack Model

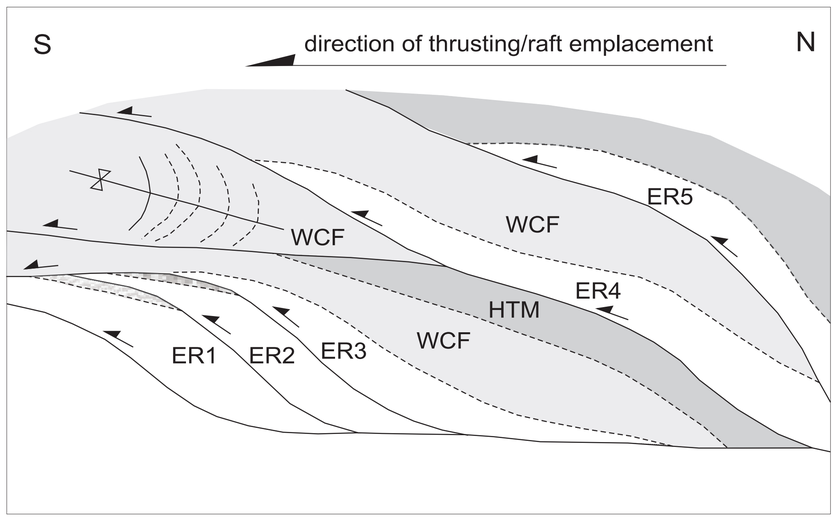
Overstrand

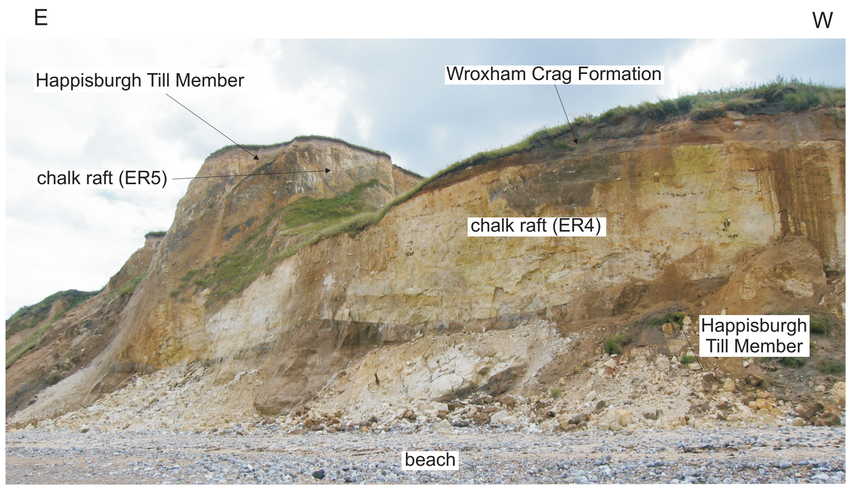




Large, north-westerly dipping raft of chalk thrust over the well bedded sands and gravels of the Wroxham Crag Formation. Bedding within the chalk raft is deformed by an open hanging-wall anticline. Kinematic indicators within the thrust at the base of the raft record a sense of displacement towards the south.

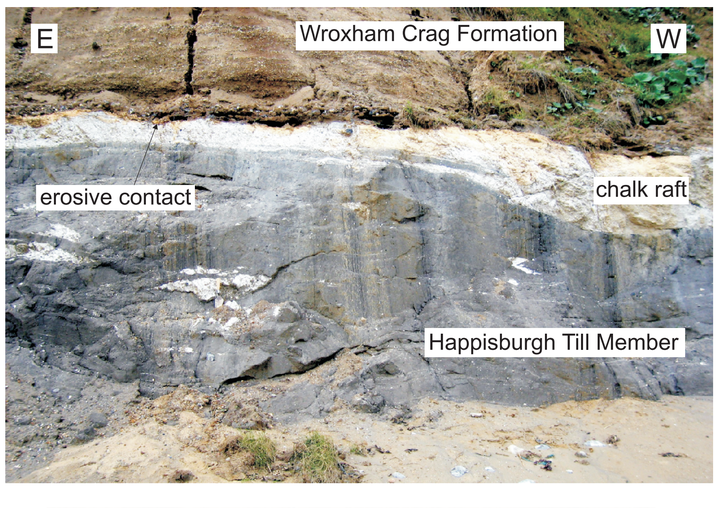
East Runton

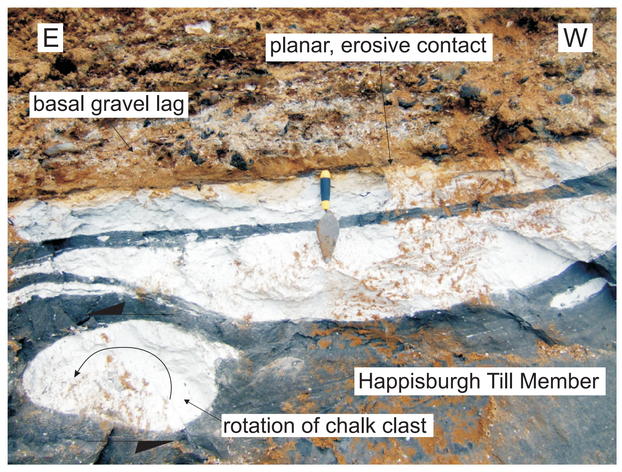




Northerly dipping, thrust-bound rafts of chalk stacked with the variably deformed sediments of the Wroxham Crag and Happisburgh Till forming a large duplex-like structure. Two phases of thrusting have been recognised: **(1)** resulting in the emplacement of the lower rafts ER1 to ER3; and **(2)** out of sequence thrusting leading to the emplacement of rafts ER4 and ER5. The sense of movement of both sets of thrusts was towards the south.

West Runton

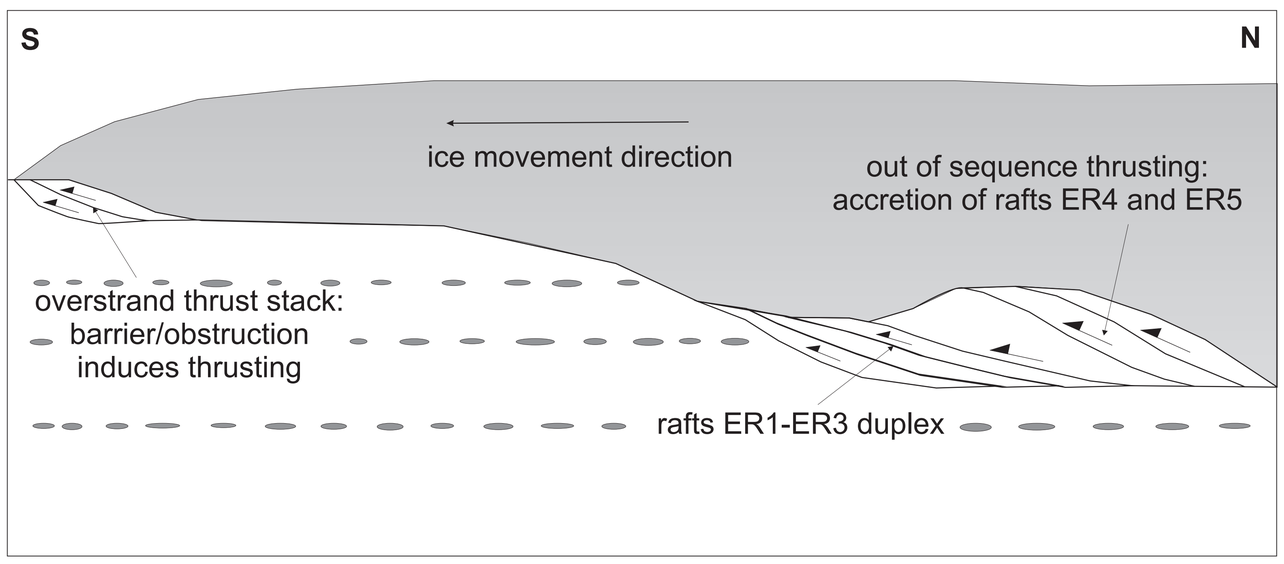




Highly deformed rafts of chalk included within the Happisburgh Till. Although deformed, the original stratigraphic relationship between the Wroxham Crag and underlying chalk is still preserved within the raft. This primary relationship is commonly preserved at the top of the rafts at all three sites studied along the north Norfolk coast.

increasing intensity of deformation

Imbricate thrust stack model for the emplacement of chalk rafts in northeast Norfolk. Thrusting and imbrication at Overstrand was accompanied by the later phase of out of sequence thrusting at East Runton.



Main Conclusions

- The northerly dipping basal thrust planes, bedding and jointing within the rafts, coupled with the overall increasing intensity of deformation from Overstrand to West Runton, are indicative of a north to south ice advance.
- An imbricate thrust stack model is used to explain the glaciotectonic rafting. At Overstrand, the rafts are stacked in a simple thrust duplex. At East Runton, rafts were emplaced by a combination of a simple thrust duplex (ER1-ER3) and out of sequence thrusting (ER4, ER5). At West Runton, the rafts have been fragmented and incorporated into the Happisburgh Till, suggesting that perhaps they are furthest travelled.
- The style of deformation at Overstrand suggests that the rafts were transported and accreted in an ice-marginal (e.g. proglacial) setting whilst those at East and West Runton were transported and accreted subglacially.