Proceedings of the Geologists' Association 126 (2015) 522–535

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

journal homepage: www.elsevier.com/locate/pgeola

The origin of relic cryogenic mounds at East Walton and Thompson Common, Norfolk, England

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ARTICLE INFO

Article history:
Received 30 April 2015
Received in revised form 19 June 2015
Accepted 21 June 2015
Available online 4 September 2015

Keywords:
Pingo
Lithalsa
Periglacial
Devensian
Geophysical

ABSTRACT

Contemporary pingo and lithalsa mounds are features which develop exclusively within cold climate environments in areas of continuous and discontinuous permafrost. The presence of pingo and lithalsa remnants as rampart enclosed ponds has been documented across temperate areas of the Northern Hemisphere and has been used to establish the extent of former permafrost. Two sites thought to be remnants of hydraulic pingo forms were investigated at East Walton and Thompson Common(s) in order to establish a precise origin. Through Ground Penetrating Radar and Electrical Resistivity Tomography the structure of ramparts and hollows has been investigated and interpreted. Linking this with physical and ground invasive techniques and a consideration of the hydrogeological setting it was apparent that the two sites had different origins. The topography, geology and hydrogeology of the East Walton area are a stereotypical setting for the development of hydraulic pingos. In contrast, the development of features within the Lowestoft Till and weathered Chalk Formations at Thompson Common implies that forms resulted from the heave of material through segregation ice lens growth. This has led to the creation of a model at East Walton which documents the development of remnant pingo ramparts and the strata which result. It is proposed that this model can be used in the study of similar landforms.

1. Introduction

During the Younger Dryas 12,800–11,500 years before present, large stretches of lowland Britain lay outside the limits of the wasting Devensian ice sheet within a vast periglacial domain. At the beginning of the Holocene, permafrost had receded northwards towards Scotland, to leave a suite of landforms across the south of the UK that were highly distinctive and characteristic of the former periglacial landscape. The ramparted ponds at East Walton, and Thompson Common(s) represent some of the most extensive and best preserved landscapes modified by the growth and decay of late Devensian perennial ground ice throughout the whole of N.W. Europe.

Sites across Europe containing relict cryogenic mounds have been investigated and interpreted, in Belgium (Pissart, 1974 and 2002), South Wales (Watson and Watson, 1974), Ireland (Mitchell, 1971), Finland (Seppälä, 1972), and East Anglia (Sparks et al., 1972). The interpretation of these sites was linked to the early work of Müller (1959) and Mackay (1962) who, proposed that massive ice lens formation sourced from groundwater under hydrostatic 'closed system' or hydraulic 'open system' pressure, governed pingo origin. These early observations are still relevant and explain the genesis of most pingo forms. For those which were difficult to interpret or did not conform to the pressure mechanisms identified, Worsley and Gurney (1996) proposed the term 'polygenetic'.

Since the 1980s research has challenged the original interpretation of these ramparted ponds as relict hydraulic pingos and favoured instead a lithalsa origin (Seppälä, 1988; Mollard, 2000; Pissart, 2002; Gurney, 1995, 1998; Ross et al., 2005a,b). Although almost identical in morphology, a decayed lithalsa forms in fine grained silt sediments where capillary water is supplied to the ice body by cryosuction. In comparison hydraulic pingos generally form at the foot of high ground in coarse grained colluvial valley fill sediments where ground water is driven to the surface under an artesian head to form a pingo spring.

Since the original study of East Anglian relic permafrost sites around East Walton, Norfolk by Sparks et al. (1972), new fieldwork techniques and improved knowledge of similar sites across the modern sub arctic and former temperate permafrost zones have resulted in the reinvestigation of many known European sites.

The chosen study sites in Norfolk, East Anglia (East Walton and Thompson Common) are the best examples of rampart enclosed

Abbreviations: GPR, Ground Penetrating Radar; ERT, Electrical Resistivity Tomography; AOD, above ordnance datum.

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http://dx.doi.org/10.1016/j.pgeola.2015.06.006
0016-7878/

depressions within eastern England and are sparsely documented (Prince, 1962, 1964; Sparks et al., 1972). Existing information on the East Anglian sites predates the key publications of modern active pingo research (Mackay et al., 1973; Mackay, 1988, 1998) and work on relic permafrost morphology (Flemal, 1970; De Gans, 1988; Pissart, 2002).

For this reason, this study reinvestigated these sites using traditional fieldwork methods of core sample collection, field mapping and topographical surveying, employed by Sparks et al. (1972), with geophysical methods employed by Ross et al. (2005a), in Llanpumsaint, Wales. The data collected was used to improve the knowledge of distribution, morphology, structure and origin of the features at East Walton and Thompson Common. The study also investigated the geological and hydrogeological setting of the sites. By proposing an accurate origin for the relict cryogenic mounds at both sites, it is possible to address the outstanding issue relating to the extent of the former permafrost zone within East England.

1.1. Area of study

The two study sites are located within Norfolk, England. East Walton Common, which can be located by National Grid Reference 316500^{E}–574400^{N}, is located within north Norfolk, approximately 10 km to the south east of Kings Lynn. Thompson Common, which can be located by National Grid Reference 593000^{N}, 29600^{E}, is located approximately 30 km to the southeast of East Walton, approximately 15 km north of Thetford (Fig. 1). A third location at Gayton Common, 2 km north of East Walton Common, was used to give spatial distribution of features in the fields surrounding East Walton Common, and has not been investigated in detail.

The regional geology of East Anglia is divided in two. The western part of the region covering west Norfolk and north Cambridgeshire is the Fens, a low-lying area consisting of marine derived glacial clay and silt overlying Gault Clay, dissected by sandy, gravel River Terrace Deposits. Flandrian peat deposits cover the fens and support the regions agriculture. In contrast, the eastern part of the region covering east Norfolk, and Suffolk and within which the study sites lie is the chalk high ground which rises to 100 m AOD and dips steeply within the western reaches at the geological boundary with the Gault Clay of the Fens.

The regional hydrology is dominated by the River Great Ouse and its tributaries the Little Ouse, Nar, Wissey and Lark. The middle and lower Chalk high ground within eastern East Anglia is the principle aquifer for Norfolk and west Suffolk, but contemporary groundwater levels are influenced by extraction pumping and thick Pleistocene Head and Till deposits that limit infiltration.

1.2. East Walton Common

East Walton Common is situated 3 km north of the village of Gayton, National Grid Reference 319200^{E}, 572700^{N} on the A47

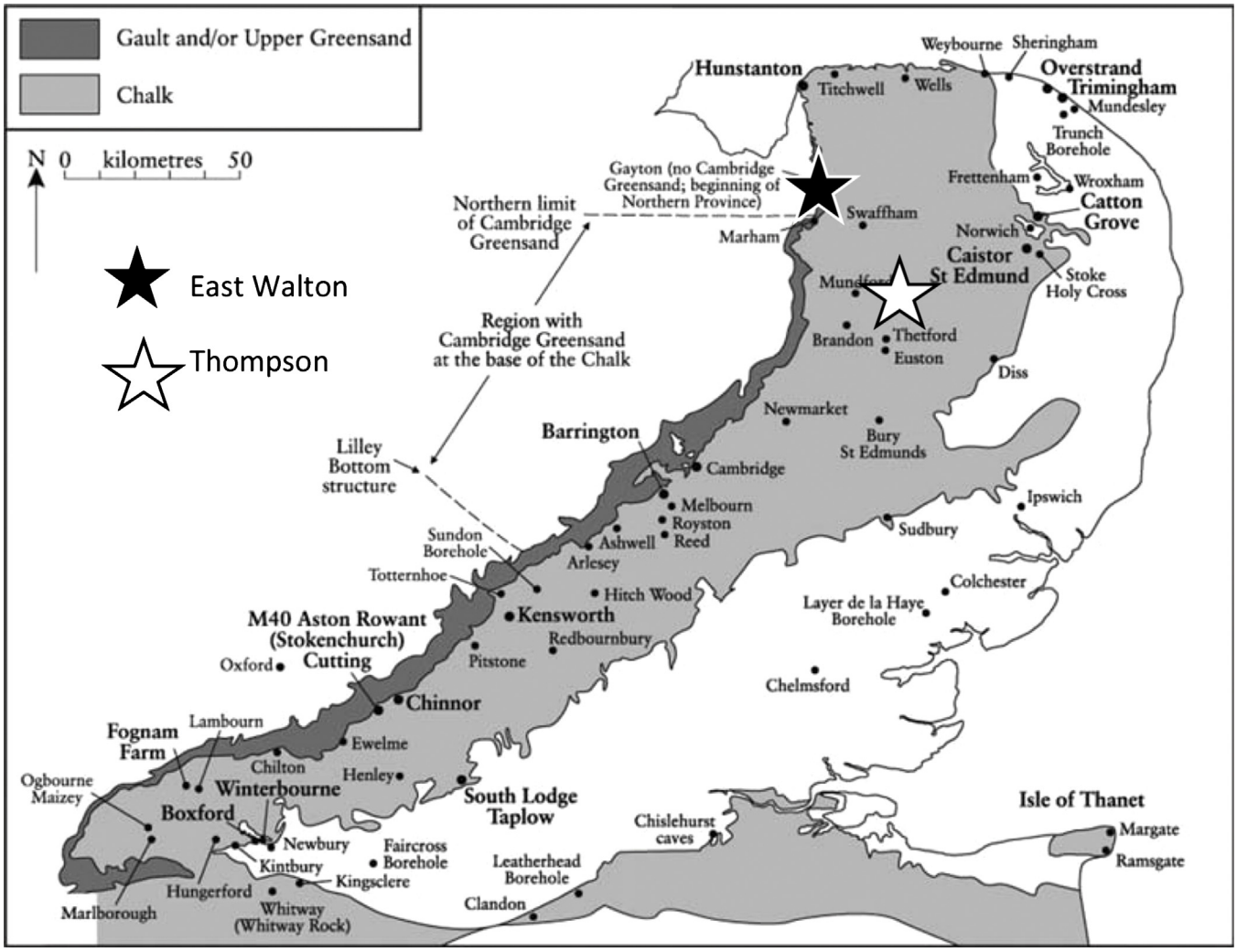

Fig. 1. Shows the solid geology of East Anglia which underlie both study sites (Geological Conservation Review, 2007, p. 2731).