GEOLOGICAL SURVEY OF THE HONDSRUG MEGAFLUTE, DRENTHE, THE NETHERLANDS: THE BASE OF A UNIQUE NEW EUROPEAN GEOPARK

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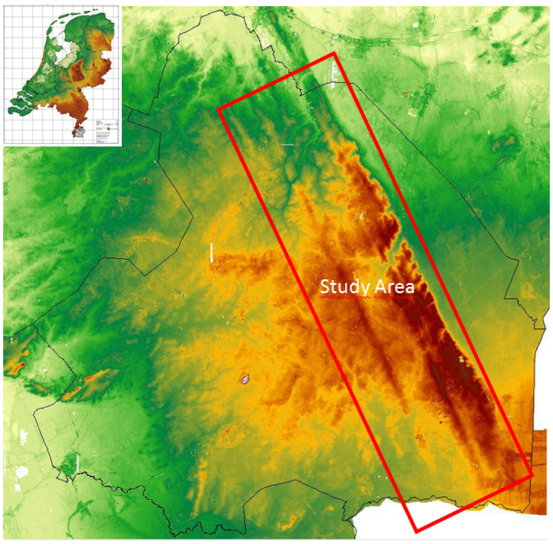
ABSTRACT

Ice streams always reflects an unbalance between accumulation and ablation in ice sheets and along ice sheet margins they are highly variable and dynamic in space and time. Present-day and Last Glacial examples of ice streams demonstrate a behaviour of switching on and off; acceleration and deceleration, migration and change of direction. The situation at the ice margin provides a main control on the mass (in)balance of the ice stream, for example where melting or calving occurs in ice lakes, seas and oceans. The knowledge on controlling factors and process dynamics of present day ice streams has much grown. For paleo-ice-streams, however less studies truly assess process-relations, especially in NW Europe. We have focussed on the Hondsrug – Ice Stream of Saalian age (Drenthe Substage, within MIS 6) in NE Netherlands and NW Germany, glaciated in the penultimate glacial, but not in the last glacial. The best expression is a 60 km long megaflute complex landform, known as 'Hondsrug' (e.g. Rappol, 1984; Van den Berg & Beets, 1987). Because of its unique genesis and preservation, the Province of Drenthe has nominated the Hondsrug to be a UNESCO - GEOPARK.

Results are discussed and related to Winsborrow et al. (2010) hierarchy of controls of ice streams. We have strong reasons that ice streams of the terrestrial ice margins of the former Scandinavian ice sheets of the North Sea, German, Polish and Baltic area are controlled in a different way than e.g. Antarctic actual- and North American palaeo-examples. The ice-streams appear regional initial deglaciation phenomena, affected by substrate and ice-margin control primarily, rather than larger scale expanding ice-cap phenomena. This conclusion opens new approach in understanding the scales and dynamics of ice streaming at the tipping point of maximum glaciation to initial deglaciation, and input for further research between the North Sea and the Baltic.

KEY WORDS: Glaciation model, Saalian Ice Stream, onland, Ice flow, glacial deformation, floting, Drenthe, The Netherlands

INTRODUCTIUON



We report about the scientific study for application of the Hondsrug region (Fig. 1, Drenthe, the Netherlands) to become an UNESCO Geopark.

Fig.1. DEM map showing location of the Hondsrug. Source: Dutch Ministry of Infrastructure.

The genesis of the Hondsrug's peculiar glacial linear ridges is the core topic of our study. Ice-age produced geology and geomorphology controls ecohydrology of the modern landscape, and what relation deeper hydrological and geological elements have with the Hondsrug landscape in past and present are other topics that are addressed. Any contemporary landscape is, of course, the result of a long series of various landscape forming processes, following up each other over time, and interacting through inheritance of substrate and morphology. Imprints of some phases, however, are more dramatic and last to dominate a landscape longer than others. In the case of the northern Netherlands, the penultimate glaciation was the event to last the majorly reorganise the landscape and the landscape of the Hondsrug is exemplary for that. Our study serves to answer the question: Why do we need to protect this unique landscape for future generations, besides for its beauty? Labelling the Hondsrug area a UNESCO GEOPARK status will increase societal awareness for this unique landscape, and aid its protection. The better we understand the properties and history of our landscape related to functions the better society can protect the Hondsrug landscape values without depleting it. Hereto, a brief description is given of how contemporary functions of the Hondsrug landscape are affected by the Hondsrug's genesis, particularly for integrated groundwater management in part agricultural, part nature conservational areas.

METHODS

We have importantly updated the reconstruction of phases of the glaciation for the wider region on base of a GIS data base and have collected new data on the paleo-ice stream using road-cut outcrops, boreholes, seismics and ground penetrating radar and "new" till-characterisation techniques (XRPD analyses of clay minerals).

RESULTS

Based upon previous studies and newly acquired data, we suggest a new glacial model of the Hondsrug area: a complex of megaflutes as a result of a Late Saalian ice stream with a NNW – SSE flow direction. The Hondsrug is formed by an ice stream, the Hondsrug Ice Stream, with the onset zone NNW of the province of Groningen in the present North Sea and was triggered by a breach of subglacial Lake Weser into Lake Münster, which pulled the ice masse to flow. Because of this, we propose to call this kind of ice stream a push – pull ice stream. With reference to Stokes and Clark (2005), this kind of terrestrial ice stream is the second known in the world and as we know the best studied one (Fig. 2).

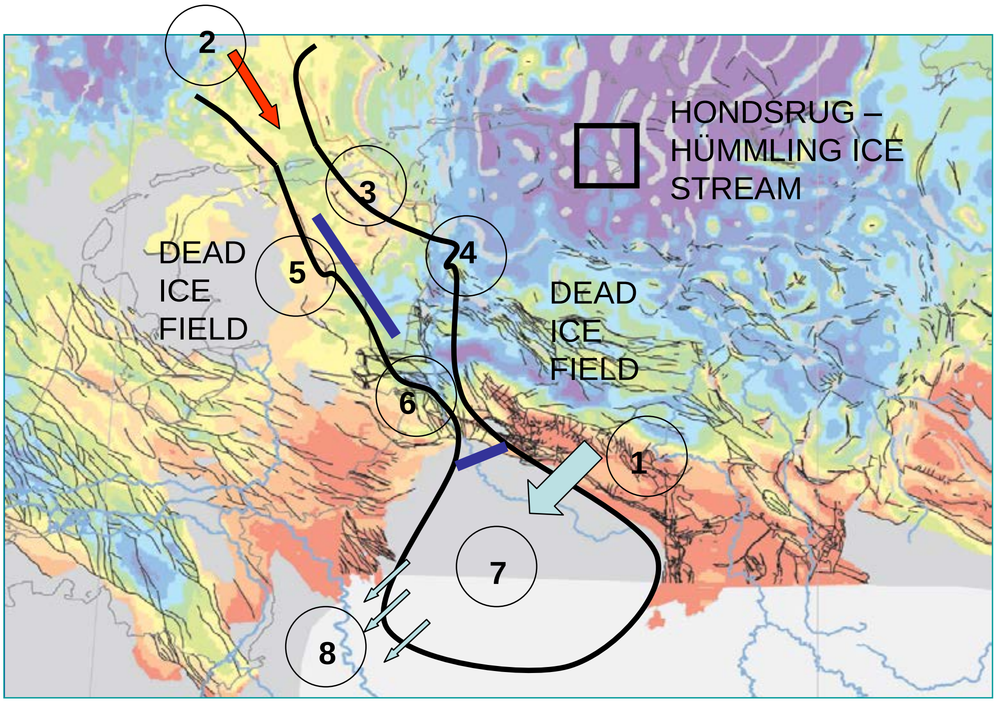


Fig.2. Positioning of the Hondsrug Ice Stream (Saalian, MIS 6; phase 4 in Bregman & Smit, 2012). Dark arrow above: flow direction of the ice stream. Thick line in the north indicates the Hondsrug area; in the south the ice margin (deglaciation phase; indicative). Eight events will be presented in the presentation and show unique character of recent well studied onland ice stream where positioning as well as flow characteristics are strongly related with deeper geological structures.Background map: Lower Trias (Doornenbal & Stevenson eds. 2010: South Permian Basin Atlas, SPBA) indicating also tectonic structures (black lines).

In the study area (Fig.3), stagnation related to deeper geological structures led to deposition of thick tills in the most northern part of the Hondsrug at a height of 6 m above sea level. In this part of the area older sediments of Elsterian age are surfacing because of a high amount of melt water that resulted in large scale erosion of tills that were deposited, which was caused by basal melting due to high geothermal heat fluxes.
In the middle of the Hondsrug area strong subglacial deformation occurs, caused by brine groundwater that were pressed up towards the surface, and stagnation of the ice flow due to the occurrence of shallow salt diapirs.

HONDSRUG – GLACIAL MODEL

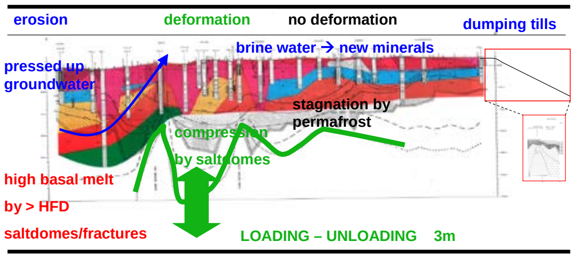


Fig.3. The Hondsrug glacial model.
For explanation: see text.

Near salt diapirs of stagnation groundwater rised groundwaterpressure and forced discharge of groundwater by subglacial channels and piping. In the southern part of the Hondsrug area no deformation of deposits of an older NE – SW ice flow occurs by the Hondsrug – Ice stream. No deformation of older tills and sediments occurred (only a thin ice stream till cover) indicate the occurrence of permafrost and fast ice flow due to flotation of the ice stream in this part of the Hondsrug.

By lateral selection and building up of glacial sediments and tills, the megaflute reaches its maximum height of 28 m above mean sea level. The ridges, which are classified as mega-scale glacial lineations, formed in a similar way as smaller scale counterparts (flutings). The glacial lineations make up an alternation of ridges and lows and this implicates a difference in pressure between the ridges and lows. The ice thickness is smallest at the highest point of the ridges, and largest at the bottom of the lows, thus the pressure of the ice is largest in the lows and lowest at the ridges. This will push sediment from the higher pressure zones in the lows, towards the lower pressure zones located at the ridges.
Downstream, tills are dumped in the Itterbeck Basin, where the ice stream changed its flow direction, through a tectonic lower area into the Münster Basin, where most glacial debris was dumped in the proglacial Lake Münster (Bregman, 2008; Winsemann, et al., 2011).

Results of our study are comparable with flotation model for ice streams, developed by Jørgensen and Piotrowski (2003), although different in chronology. Instead of the Late Weichselian Funen Island ice stream with different glacial features, the megaflute of the Hondsrug is a Late Saalian feature and not deformed by the last glaciation. That makes the Hondsrug a unique (Saalian) glacial feature. In most parts of Europe, the Weichselian ice advance overprinted and eroded Saalian features (mostly) completely.

The Hondsrug as well as the Hondsrug Ice Stream are formed after the maximum Saalian ice advance in a degrading marginal ice field. We described the controlling parameters and compared these with a hierarchy of controlling parameters given by Winsborrow et al. 2010.

Sub glacial geology processes (reactivation of faults; shifting mantle flow/Heat Flow Density, HFD) influenced by forebulging plays an important role in the onset zone and in combination with ice margin calving. Both these parameters are the main reasons to start the flow of the terrestrial ice stream.

In future, the newly model of the Hondsrug and Hondsrug Ice stream model needs testing and improvement as well, as the onset zone as the terminal zone needs much more attention in future. In that case, both studies will be totally different in approach. In the onset zone, seismic data and the interpretation of deep well logs are very important for palaeo reconstruct-tion, whereas in the terminal zone much more attention must be given to lithostratigraphy with attention to fluvioglacial deposits (e.g. Herget, 2008), impact of dumping of the Hondsrug Ice stream of debris and implications of the breach of Lake Weser in the former Lake Münster with possible implications for the formation of the Untere Mittelterasse 3 (UM3; Klostermann, 1992) in the Rhine valley.

We defined as a main point of discussion the link between HFD and a higher basal melting rate, which could be an important key question for testing our Hondsrug model in combination with reversed groundwater flow, subglacial pathway and permafrost. Another point of attention should be the correlation between stagnation and basal melt (and combination) which results in dumping of (melt out) tills. We have strong indications that in the Hondsrug area thick tills correlates with stagnation due to the occurrence of deeper geological structures. But, our approach is a very rough one and the proposed link between 'deep' geology and surface processes needs more attention with modern insight based upon glaciological interpretations of glacial deposits and detailed analysis of these sediments with new techniques like GPR and XRPD.

Finally we conclude that the glaciation and the deglaciation phase are very dynamic and need more attention in the future and could be seen as a new paradigm (Bitinas, 2008). To our opinion, we have to pay more attention to the dynamics and variation during the formation of ice streams, for example in local patchy zones with differences of ice thickness, precipitation and windshield conditions (e.g. van den Berg, et al. 2007).

The impact of local stagnation of ice flow (e.g. Pierik, Bregman & Cohen, in prep.) deserves too more attention with a variation in the amount of accumulation of ice in the IML. We conclude that these variations have impact on regional and local variations of events in the deglaciation phase, which leads to a-synchronic developments in time and space. The resulting differences in dynamics in the deglaciation phase need more attention. Glacial landscape studies need to include glaciation as well as deglaciation phases, including dynamic pro-, sub, and post glacial processes. Glacial dynamics however, including deglaciation, must be studied on the "level of the playing field". That means, in other words, that local and regional glacial studies always must be related to the context of different geographical spatial and time scales. These kind of researches need an integrated approach and can only be successful based upon interdisciplinary cooperation of different fields of studies of Earth sciences due to its high complexity.

GEOLOGICAL REASONS TO BE A EUROPEAN GEOPARK

1.

In most parts of the Ice Marginal Landscaes (IMLs) in Europe, the Weicselian ice advance overprinted and eroded Saalian features almost completely. The Hondsrug megaflute is a late Saalian feature not eroded and deformed by the last glaciation. This makes the Hondsrug a unique (Saalian) glacial feature.

2.

With respect to the forming processes the Hondsrug is formed by an icstream triggered by pushing in the onset zone and the breach of Lake Weser in the northern part of the Múnster Embayment (Winsemann, et al, 2010) acted as a pulling force. These kind of pull-induced ice streams are also been described by Stokes and Clark (2005) in relation to the Dubawnt Lake ice stream in Northern Keewatin, Canada and are as far as we know the only in the world known two inland terrestrial ice streams induced by calving of the terminal zone in a lake.

3.

The unique Saalian glacial feature of the Hondsrug is of great interest for fundamental further scientific study to understand ice stream behaviour and impact of glaciations on landscape forming processes, inclusive impact of loading and postglacial unloading on deep and shallow geological structures like salt diapirs and differential rebound of the Earth crust. Differential rebound formed river terraces, a shift of the watershed, the river pattern and still have influence on deep surfacing groundwater flow.

4.

The Hondrug area is a key area for further research with focus on geo-hydrological and geo-physical modelling of the presented concepts related to the origin of the Hondsrug which contributes to better paleao re-constructions of terrestrial ice streams and glacial features, to understand geoheritage values and glacial impact on sub- and postglacial morphology, soilformation and natural values. This is worth full knowledge for protection of glacial landscapes in the IML.

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Finally during research we shared knowledge about the unique landscape of the Hondsrug presented in this article with the ice-age museum in the area (Hunebed Centre, Borger). This is precisely in the spirit of EUROPEAN GEOPARKS, sharing knowledge of the geoheritage of the region to a broader public, local inhabitants, tourists and other visitors, young and old, from The Netherlands and abroad. For this reason we are thankful that Hein Klompmaker and Harrie Wolters made it possible to realize an exposition about Ice Ages in the Hunebed Centre.

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