INQUA Peribaltic 2015 Working group meeting & International field symposium

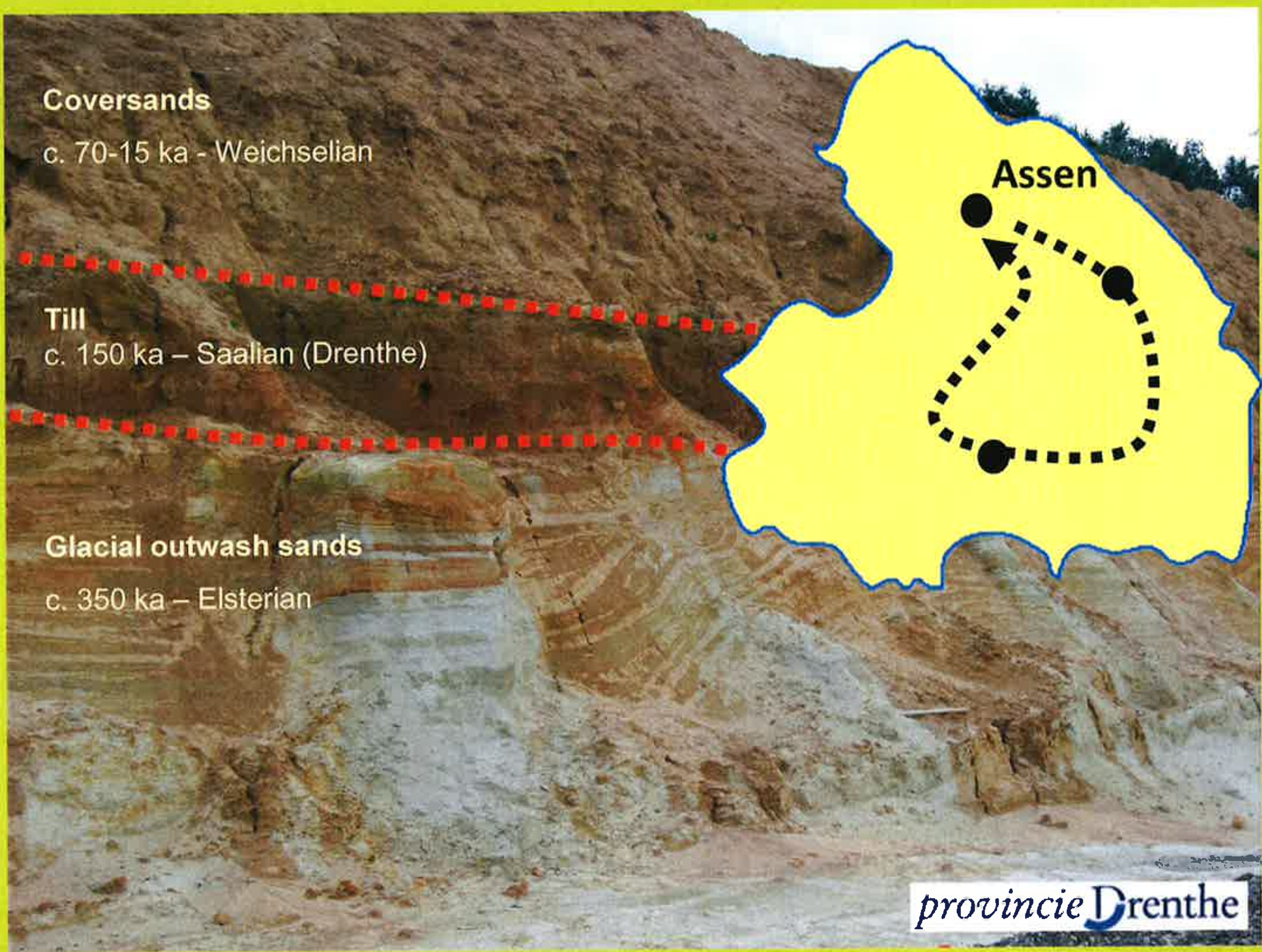
Quaternary Geology and Modern Questions

FIELD GUIDE

Part 2

Assen – GeoPark Hondsrug Wed 4 November

The Netherlands | November 2 – 8, 2015 | Utrecht – Assen - Utrecht



INQUA NETHERLANDS
International Union for Quaternary Research

Dear colleagues,

"From science to practice", this is the theme of the day. You are welcome in the Province of Drenthe. In our organization we started some years ago with a new approach. The core is to work on adaption of geo-heritage and soil-protection and broaden support before official formal planning of actions of communities, Waterboards and Landscape and Nature Protection Organizations. To start with representatives of these organizations we built up a network organization and public on the local and regional level participate in this too. In the frame of this we organize courses, meetings, excursions and every year we reveal one or two Geo-heritage Monuments. Our 5-day courses are visited by 35 persons each year. As a result participants do have new insight and information and they know the way to the Province House. We support them as much as possible, provide maps, and they become our ambassadors when they guide tourists themselves for example.

Today we will visit the pingo-ruine of the Mekelermeer, just opened in October. Hundred and fifty persons were present and local and regional press published articles. Even on Dutch Television we had 2 minutes.......By doing this, every year we pay attention to a Geo-heritage topic. This shows our other role and through our network we inform organizations and public about geo information and our expertise. Geo information you also can find on our websites:

www.provincie.drenthe.nl/bodematlas

www.provincie.drenthe.nl/geoportaal

and all news you can find in our digital newsletter.

All these actions are part of the provincial Policy-plan W(aarde)vol Drenthe. In this program you find our approach, actions and how we protect important areas in different ways. By law we have areas where we have total protection and all what disturbs the geo-heritage value (feature, soil) is not allowed. Furthermore we have areas where we wish to have high and moderate protection. These areas are important for the identity of the Province of Drenthe. All other areas we have in view, but we ask communities to protect them. More than 300 areas are in view and in details you will find descriptions of them on www.provincie.drenthe.nl/bodematlas. Via "Geoportaal" also shape-files of more than 400 maps are available for GIS use.

Features related to deep geology are subject in the Policy-plan for the Deep Underground. This policy-plan regulates waste disposal and how to use potentials for soil-energy. Deposition of nuclear waste-disposal in salt-domes is forbidden.

The base for all these actions is knowledge. And since 2008 we started a program to update our knowledge, by doing research, update maps (for example the soil-map and the geomorphological map of Drenthe) and improve descriptions of areas. The Ph-D study of Enno Bregman is part of this approach. We cooperate with Dutch universities as well as from abroad, and with Applied Universities in North Netherlands. We offer students stages as we will explain today.

Geopark De Hondsrug

To get the status of Geopark initiators have to explain to Unesco/EU Geopark organisation the uniqueness of such an area. The basis for the application is the scientific report Genesis of the Hondsrug - A Saalian megaflute, Drenthe, the Netherlands (Bregman & Smit, 2012: www Geopark De Hondsrug/ EU/Application). A short summary is given in the guide and we will visit a permanent exposition based on our research.

South East Drenthe

Our fieldtrip ends with a visit to an area "the Koppelsluizen" in South East Drenthe. We will show a deep crosscutting of the Saalian Hondsrug and discuss how we made the shift from threat to an opportunity…….and we will show how updated science based information is part of a new situation. Anyhow a lot of people are now informed about the Saalian glaciations, raised bogs and connection with the Baltic…..

We wish you a pleasant and joyful social day and we will close at un unexpected way……

Cathrien Posthumus

Wim Hoek

Michiel Gerding

Enno Bregman

Program

Information:

in this guide

in other guide(s)

Mon 2 November - Arrival in Utrecht *icebreaker*

Tue 3 November - Fieldtrip Utrecht – Texel – Assen

Check-out Utrecht Hotel – Check-in Assen Hotel

Visit NIOZ institute. Coastal Stop at Slufter Texel.

Diner at Workum, halfway between Texel and Assen, before check-in

Wed 4 November - Fieldtrip Assen – Drenthe – Assen

Thu 5 November - Conference day Assen

Fri 6 November - Fieldtrip Assen – IJssel – Utrecht

Check-out Assen Hotel – Check-in Utrecht Hotel

Visit Wageningen Univ., glacial and fluvial stops IJssel + Rhine.

Diner at Utrecht, walking distance of hotel, after check-in

Sat 7 November - Visit TNO Geological Survey NL

Sun 8 November - Departure from Utrecht

Lunch and meals are included for Tuesday 3 to Lunch Saturday 7.
i.e.: evenings of Mon 2-11 and Sat 7-11 you care for yourself

INQUA NETHERLANDS
International Union for Quaternary Research

List of participants from 2 to 8 November 2015

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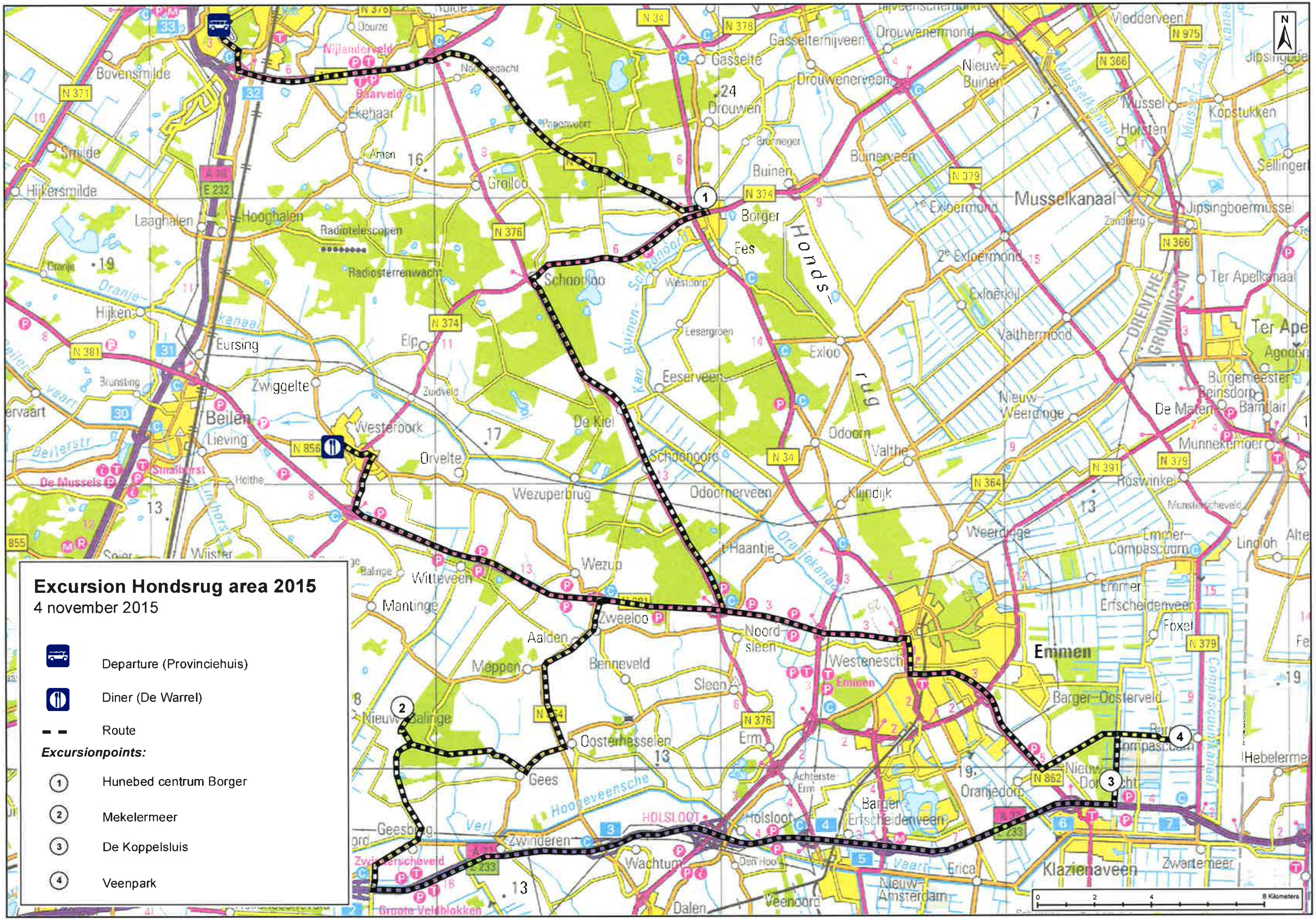
37	Gretha Roelfs	Province of Drenthe	g.roelfs@drenthe.nl

Time	What	Who
9:00	**Departure from Assen (Hotel 'de Bonte Wever')**	
9:30-11:00	**Visit to GeoPark** - Welcome - GeoPark de Hondsrug - Visit to Expedition Poort - Stonegarden/megalith grave	 Hein Klompmaker Cathrien Posthumus Harrie Huisman/Enno Bregman/Harry W
11:50-14:00	**Mekelermeer (Pingo lake in South Drenthe)**	Wim Hoek
14:40 – 15:50	**Koppelsluizen (A sluice-gate in 'de Hondsrug')**	
16:00 – 17:00	**Peat Museum (In the village Barger-Compascuum, South East Drenthe)** - Coffee break - Introduction Peat exposition - Visit Peat exposition	 Michiel Gerding
17:35 – 20:00	**Diner in Westerbork (Village in middle of Drenthe)**	
20:30 – 22:00	**Theatre and drinks in Orvelte (Village in the middle of Drenthe)**	


Excursion Hondsrug area 2015
4 november 2015
Departure (Provinciehuis)
Diner (De Warrel)
Route
Excursionpoints:
1 Hunebed centrum Borger
2 Mekelermeer
3 De Koppelsluis
4 Veenpark
N
Bovensmilde
Smilde
Hijkersmilde
Laaghalen
Hooghalen
Radiotelescopen
Radiosterrenwacht
Hijken
Eursing
Zwiggelte
Beilen
Lieving
Westerbork
Orvelte
Wezuperbrug
Wezup
Witteveen
Mantinge
Zweeloo
Aalden
Meppen
Benneveld
Nieuw-Balinge
Gees
Oosterhesselen
Geesbrug
Zwinderen
Wachtum
Dalen
Veenoord
Holsloot
Nieuw-Amsterdam
Erica
Klazienaveen
Zwartemeer
Oranjedorp
Barger-Erfscheidenveen
Barger-Oosterveld
Emmen
Emmer-Erfscheidenveen
Emmer-Compascuum
Foxol
Weerdinge
Roswinkel
Munnekemoer
Ter Apel
Musselkanaal
Valthermond
Exloërkijl
2e Exloërmond
1e Exloërmond
Nieuw-Weerdinge
Valthe
Odoorn
Exloo
Eeserveen
Schoonoord
De Kiel
Odoornerveen
Klijndijk
Sleen
Noord Sleen
Westenesch
Erm
Schoonloo
Grolloo
Borger
Ees
Buinen
Buinerveen
Drouwen
Gasselte
Gasselternijveen
Drouwenermond
Drouwenerveen
Nieuw-Buinen
Mussel
Kopstukken
Vledderveen
Sellingen
Jipsingboermussel
Ter Apelkanaal
Burgemeester Beinsdorp
Bamflair
De Maten
Lindloh
Hebelermeer
Ekehaar
Amen
Elp
Zuidveld
Nijlanderveld
Baarveld
Hondsrug
Oranjekanaal
Hoogeveensche Vaart
Compascuumkanaal
DRENTHE
GRONINGEN
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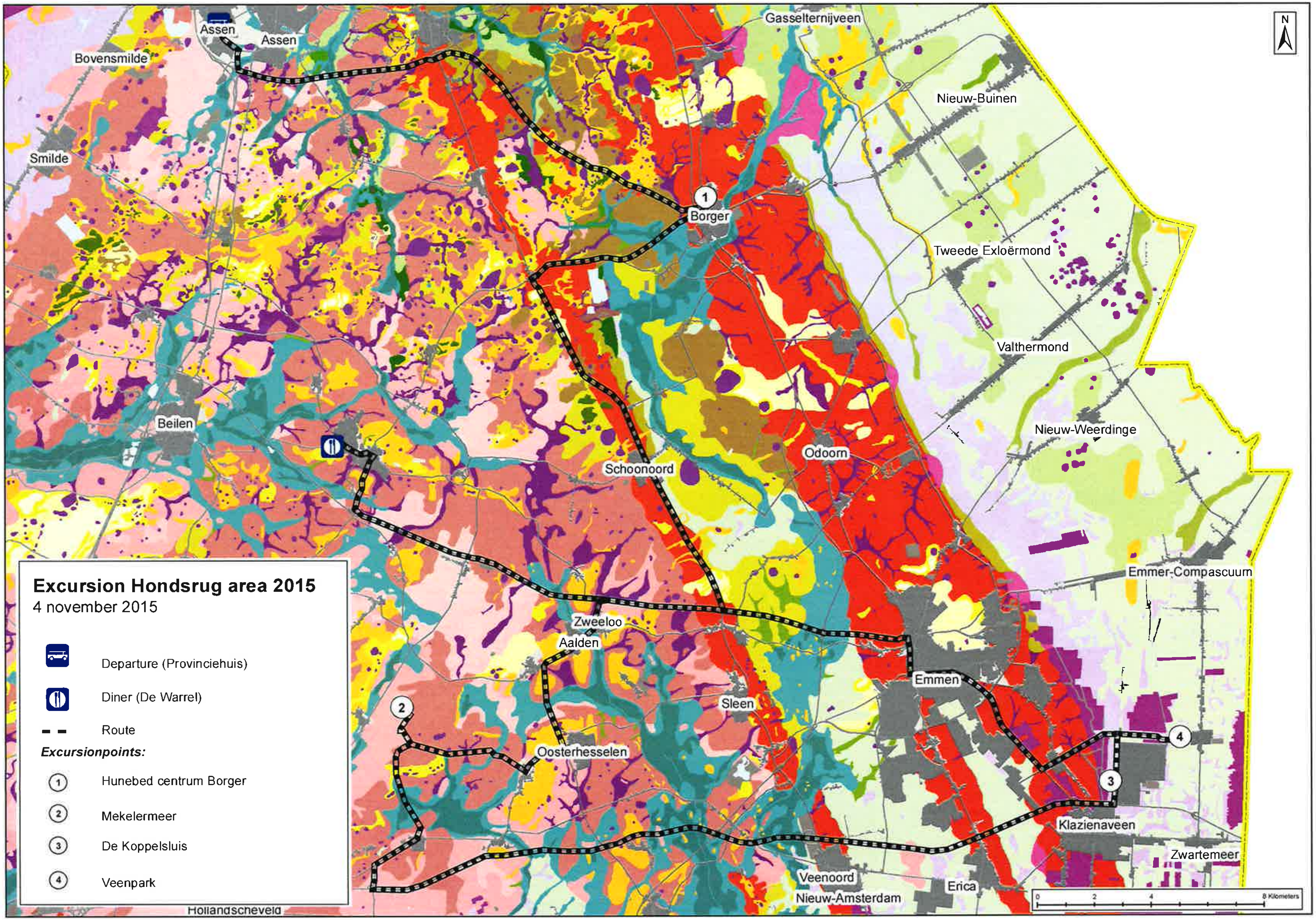
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Odoorn
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Aalden
Emmen
Sleen
Oosterhesselen
Klazienaveen
Zwartemeer
Veenoord
Nieuw-Amsterdam
Erica
Hollandscheveld
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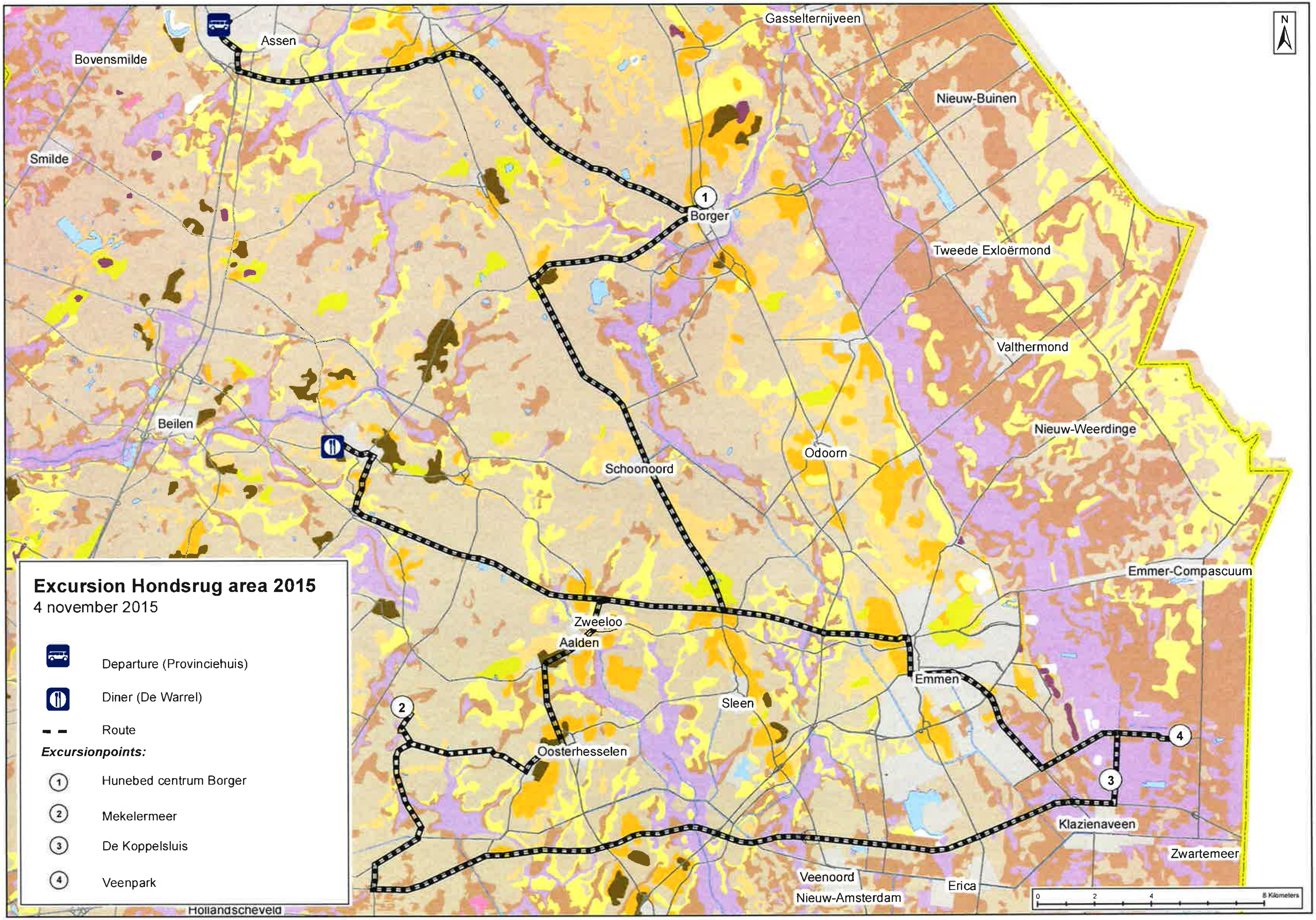
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Zwartemeer
Veenoord
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Nieuw-Amsterdam
Hollandscheveld
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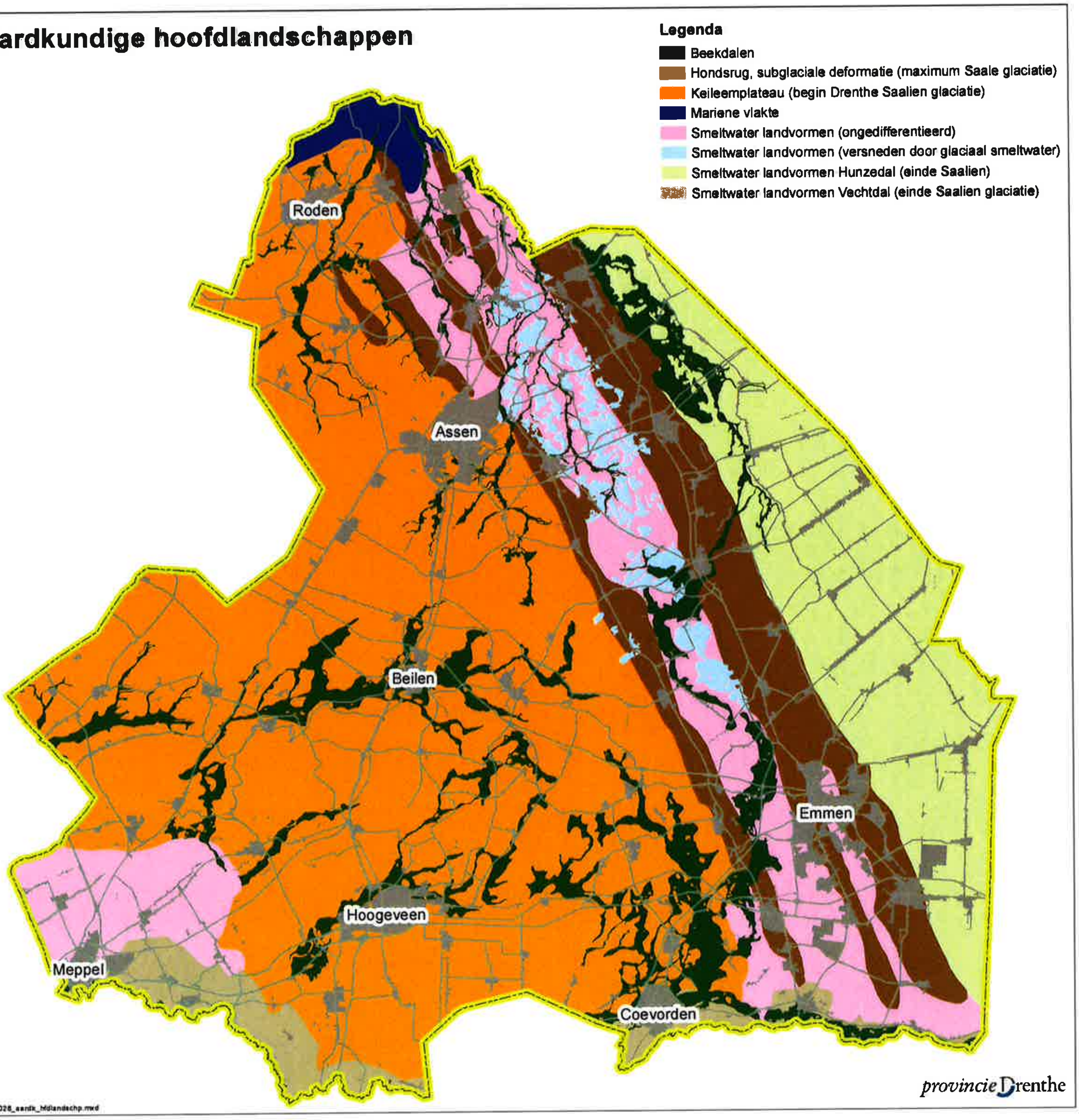
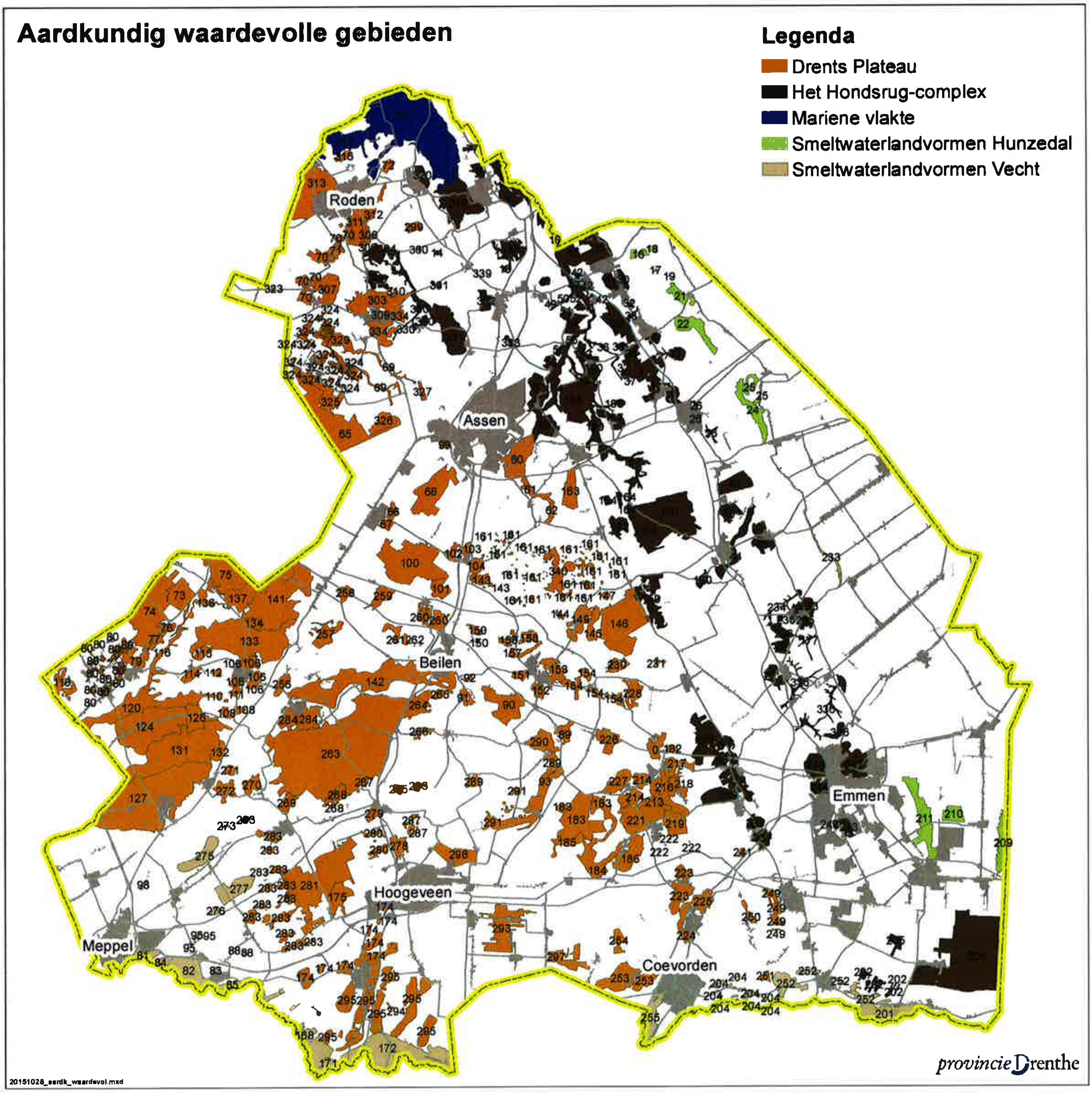
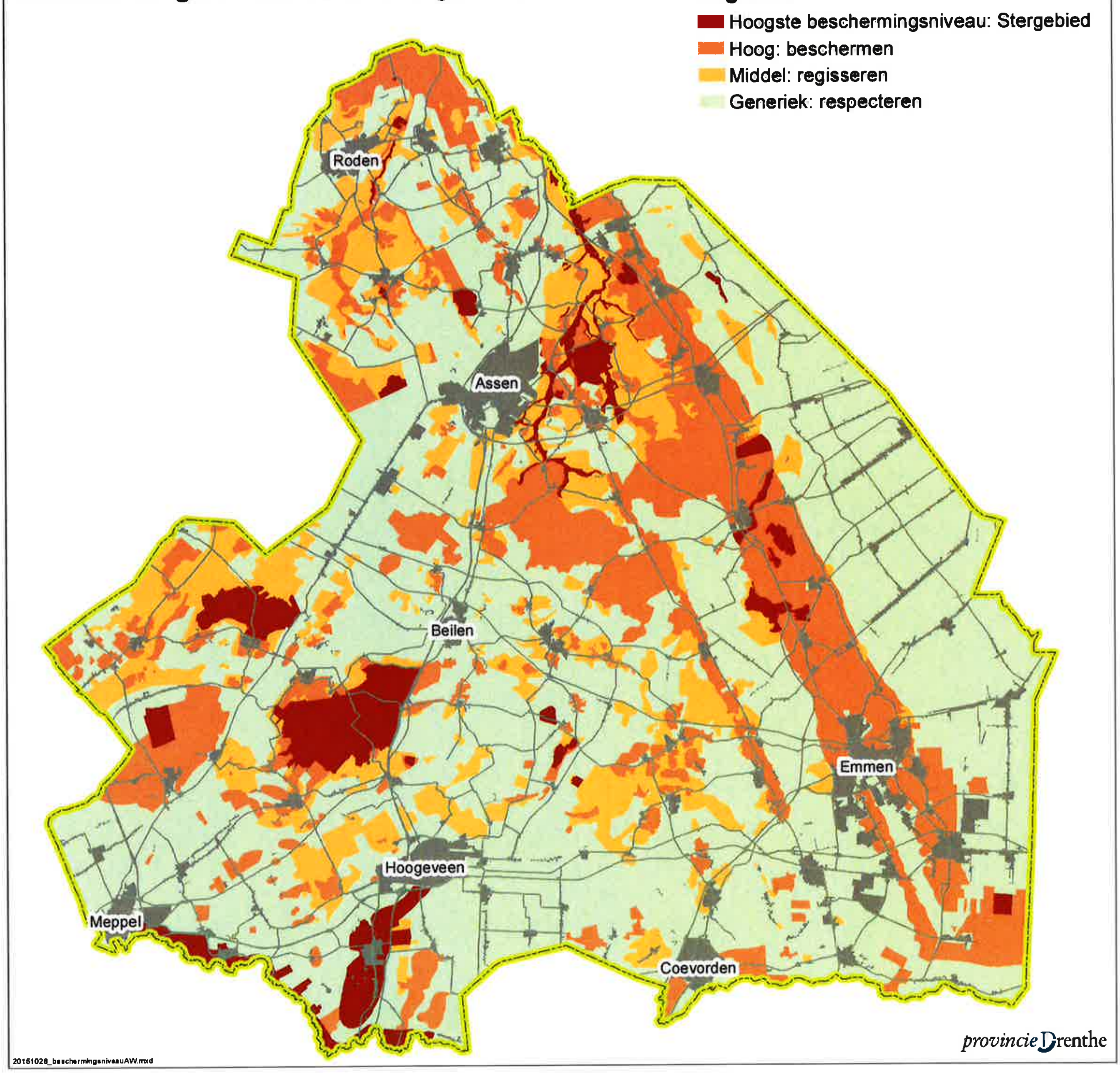
Aardkundige hoofdlandschappen



Aardkundig waardevolle gebieden



Beschermingsniveau aardkundige waarde



Stop 1 Visit Geopark De Hondrug

We will go to the Hunebed Centre in Borger. Hunebeds are Megalith graves and related to farmers who lived 5000 years a ago. We will visit the largest hunebed of the Netherlands. The Centre is visited each year by more than 50.000 visitors.

The Hunebed Centre plays an important role in the Geopark, and starting-point of a lot of activities. Cathrien Posthumus will explain more about the background and approach.

Before we will introduce you to De Hondsrug area, one of the sub-glacial formed mega-flutes we have. More in detail we will explain in the bus its geology and of course why it is a Geopark.....

The Hunebed Centre has a lot of outdoor activities. Before departure to our second stop we will visit the Stonegarden. Harry Huisman will explain.

STOP 1 HUNEBED CENTRE BORGER

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

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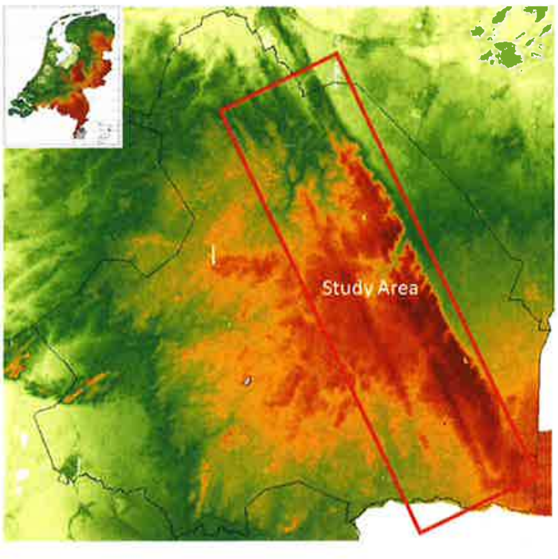
SUMMARY

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 massbalance 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

General

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).

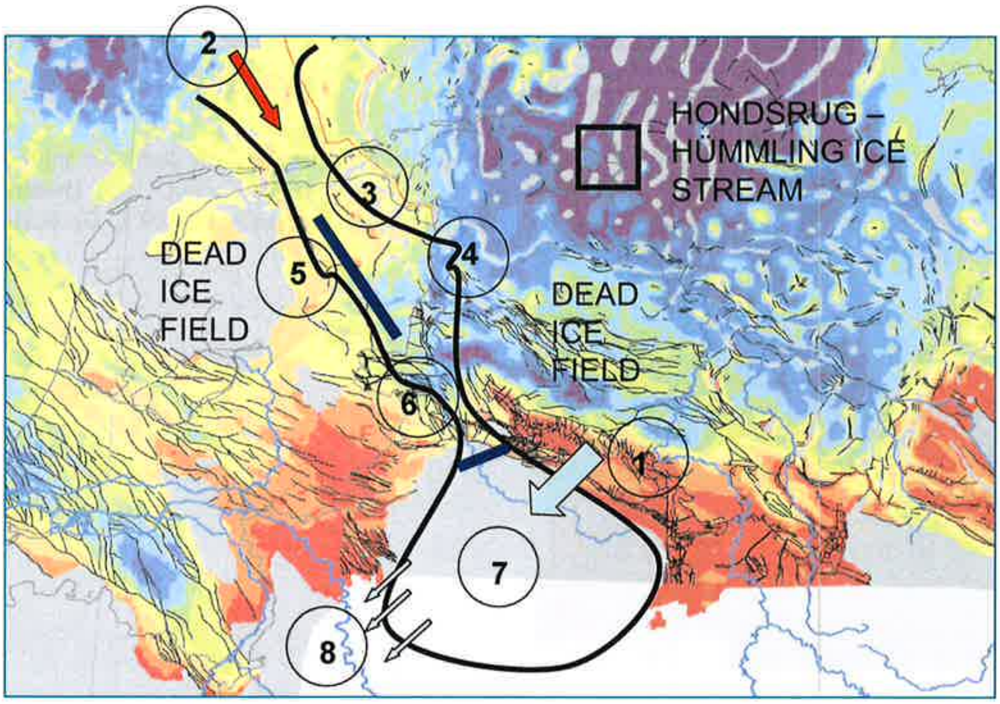


Fig.2. Positioning of the Hondsrug Ice Stream (Saalian, MIS 6; phase 4 in Bregman & Smit, 2012). Dark arrow above: flow direction of the ice stream. Thick line in the north indicates the Hondsrug area; in the south the ice margin (deglaciation phase; indicative). Eight events will be presented in the 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).

Stagnation

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

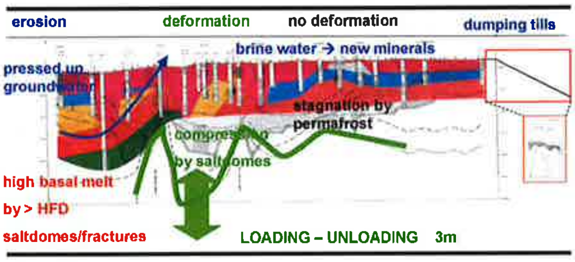


Fig.3. The Hondsrug glacial model.
For explanation: see text.

Processes

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.

Follow up

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.

ACKNOWLEDGEMENT

We thank the Provincial Board of Drenthe to support our study and initiative to nominate the Hondsrug area as a EUROPEAN GEOPARK. This study also should have less results without support and fruitfully discussions with prof. Jan Piotrowski (University of Arhus, Denmark), prof. Seglins (Latvian University, Latvia), dr. J.Ehlers (Geologischers Landesamt, Hamburg, Germany), prof. Jutta Winsemann and Janine Meinsen, Hannover University, Germany), Aleid Bosch, Marco Hoogvliet, Ed Duin, Leslie Kramer (Dutch Geologiscal Survey, Utrecht, The Netherlands) and students F.W.H. Smit; H-J. Pierik; A. van Hoesel; M. Jansen from Utrecht University; A. Klootwijk, M. van Kammen; R. Kleefstra from Hogeschool Van Hall Larenstein at Leeuwarden for data collection and many pleasant moments during fieldwork.
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 Borger.

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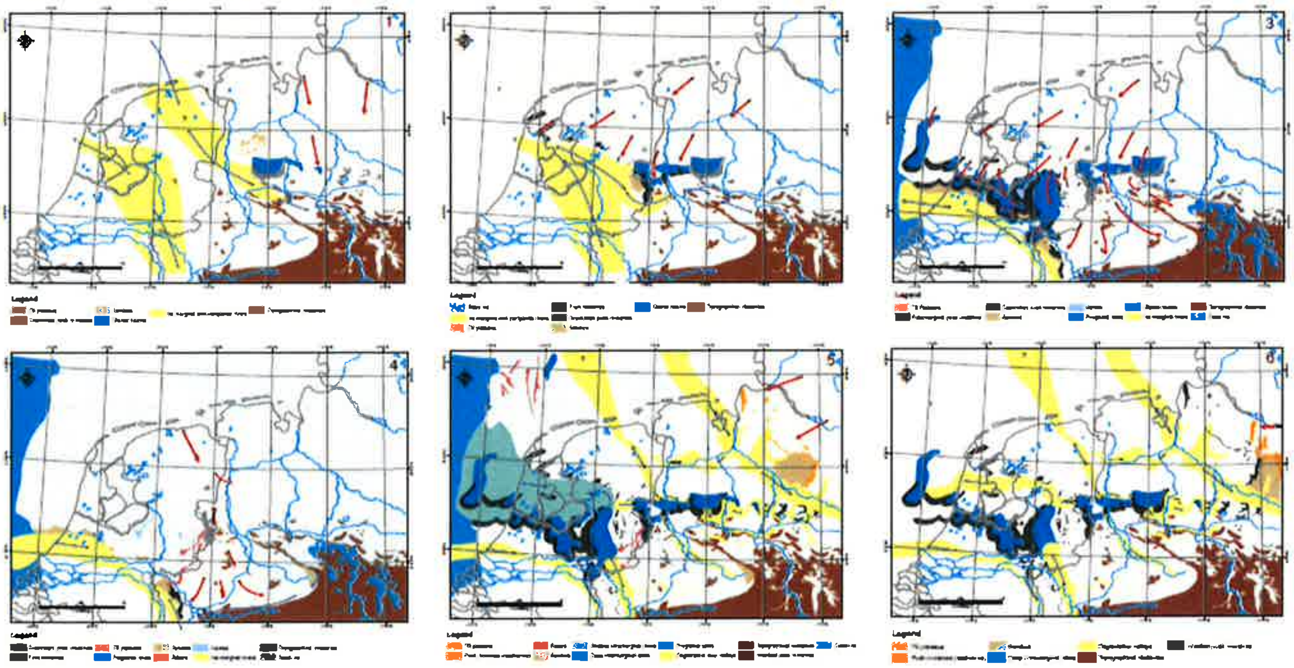
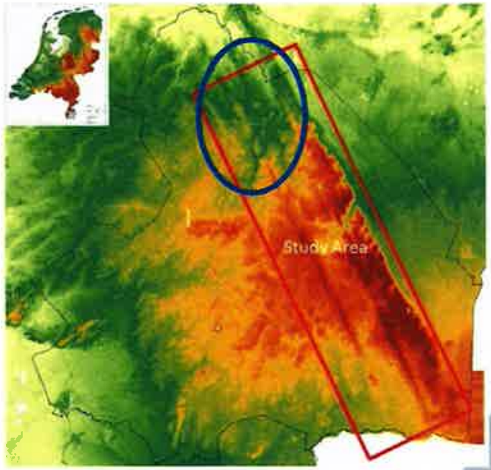
(source article: Proceedings Geopark conference Italy, 2013)

- **Phase 1 and 2**: During the onset of the Saalian glaciation, the ice invaded NW – Europe from towards the South at first, but changed later on towards SE. This might have been the result of a shift in the ice-divide region of Scandinavia. Rivers were deflected towards the west, as a result of large meltwater fluxes from the glacier. The Hunze valley may have been active at the first phase. The end-line of Phase 2 corresponds to the Rehburg line.
- **Phase 3**: During phase three, the maximum ice extent was reached in the Netherlands, where large push moraines where formed at its southern border in Central Netherlands. Moraine failure led to formation of sandurs, and the meltwater could be discharged by the Rhine-Meuse river system towards the North Sea Basin, where a pro-glacial lake formed.
- **Phase 4**.Stagnating ice occurred throughout the Netherlands, but due to an ice-mass increase in the North Sea Basin (NW of Schiermonnikoog) and maybe due to increased geothermal fluxes, the ice could be drained. The ice-stream protruded in between dead ice masses and flowed towards the Münster Basin, creating megaflutings of the Hondsrug-complex.
- **Phase 5**: During deglaciation, large meltwater rivers formed to drain the huge amounts of water from the ice-sheet. Intra-marginal lakes formed in former glacial basins in the Netherlands. The Hunze-river and Vecht-river probably drained part of the meltwater as well, causing erosion of its sediments and deepening of its bed.
- **Phase 6**: As the pro-glacial lake located at the North Sea stopped to exist, sea level dropped significantly, leading to a much lower erosion level for the rivers. This led to deep incision into pre-existing meltwater valleys.

The proposed new phase model

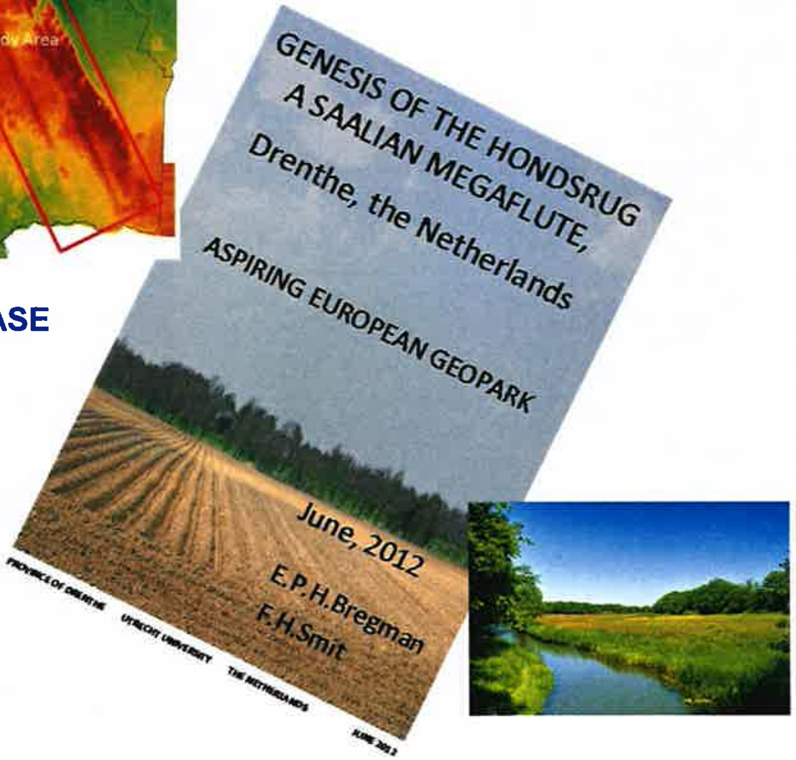


THE HONDSRUG GEOPARK, *inclusive The Drentsche Aa area*



GEOLOGISCHE BASE TO BECOME A GEOPARK

MAIN QUESTION: WHY UNIQUE AREA?

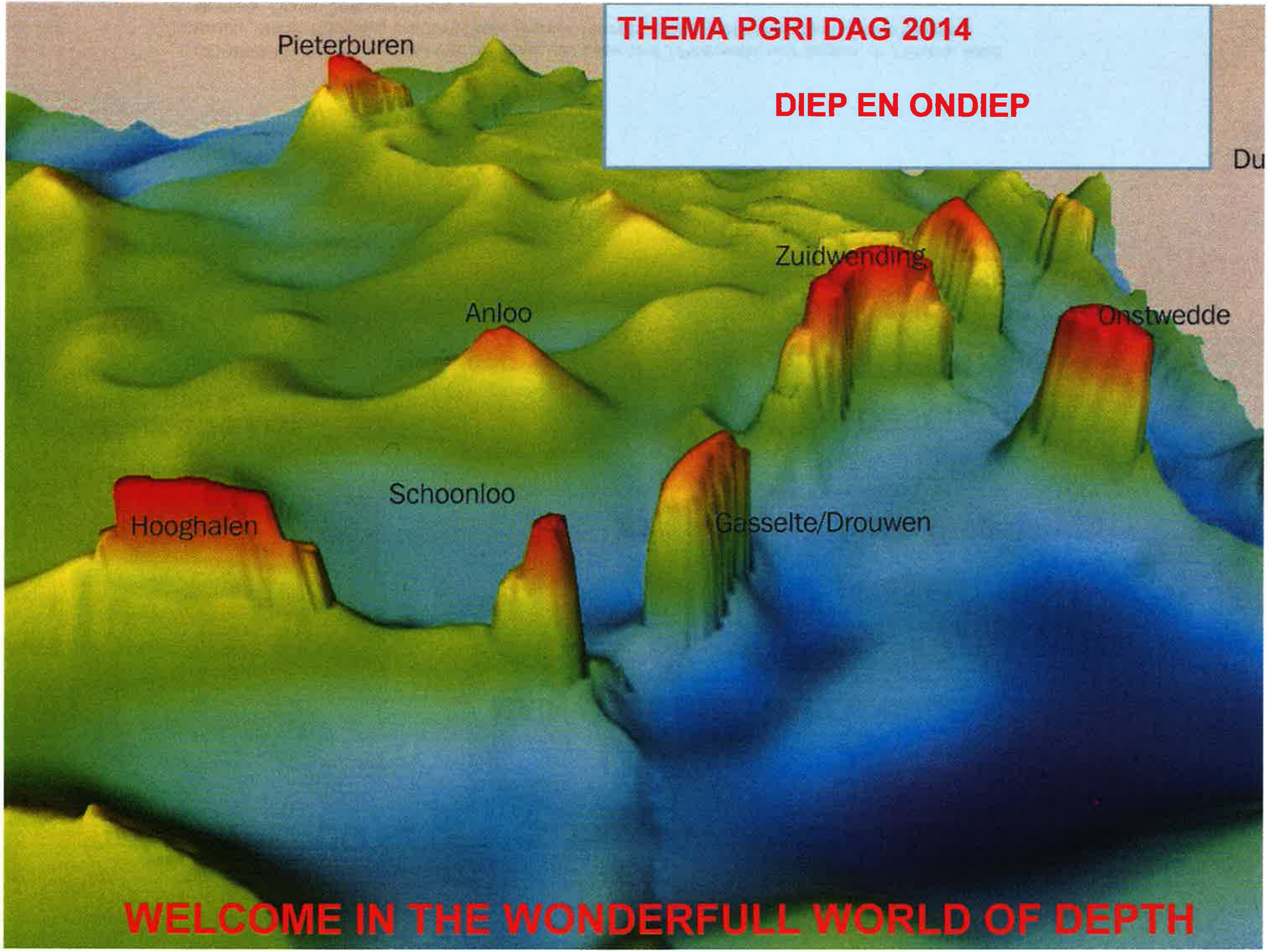


PRESENTATION

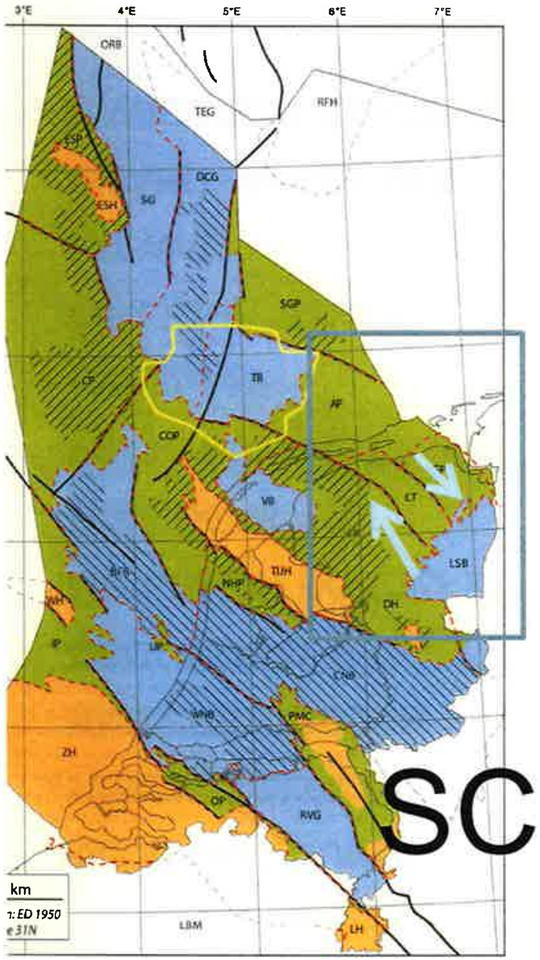
Enno Bregman

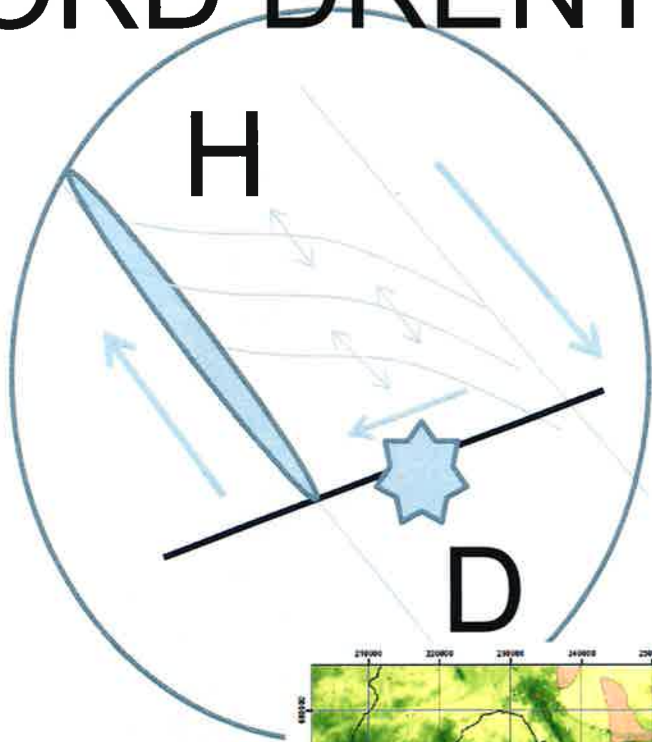
- DESCRIPTION
- POSITIONING
- STUDY AREA
- ICE STREAM

COOPERATION: dr Kim Cohen, dr M.Bakker, dr I Lüse, prof J.Piotrowski, prof Seglins, dr J Ehlers, Aleid Bosch , Marco Hoogvliet, Ed Duin, Leslie Kramer, Harry Huisman, prof Winsemann, Janine Meinsen, students: Florian Smit and others

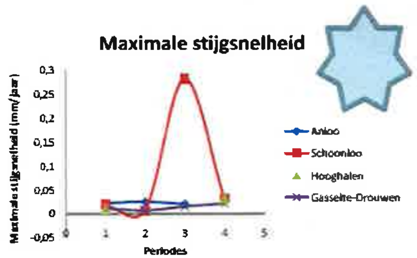

THEMA PGRI DAG 2014
DIEP EN ONDIEP
Pieterburen
Du
Zuidwending
Anloo
Onstwedde
Schoonloo
Hooghalen
Gasselte/Drouwen
WELCOME IN THE WONDERFULL WORLD OF DEPTH

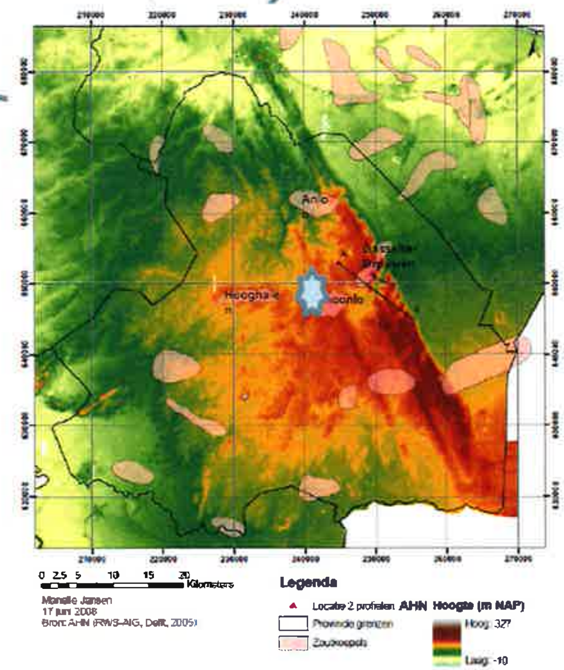
NOORD DRENTHE





SCHOONLO





NU:

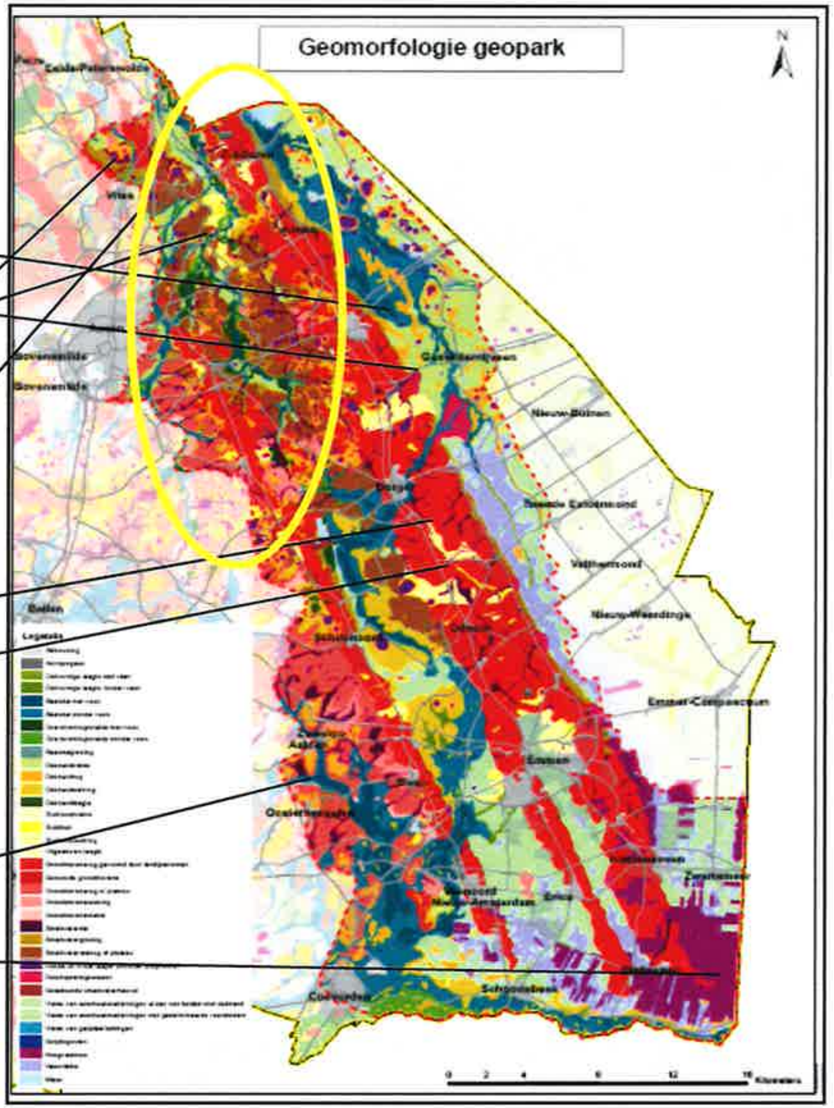
→ 25% OPEN BREUKEN

→ SLENK: EPICENTRUM GR.

→ DISCUSSIE: DEFINITIE NEOTECTONIEK

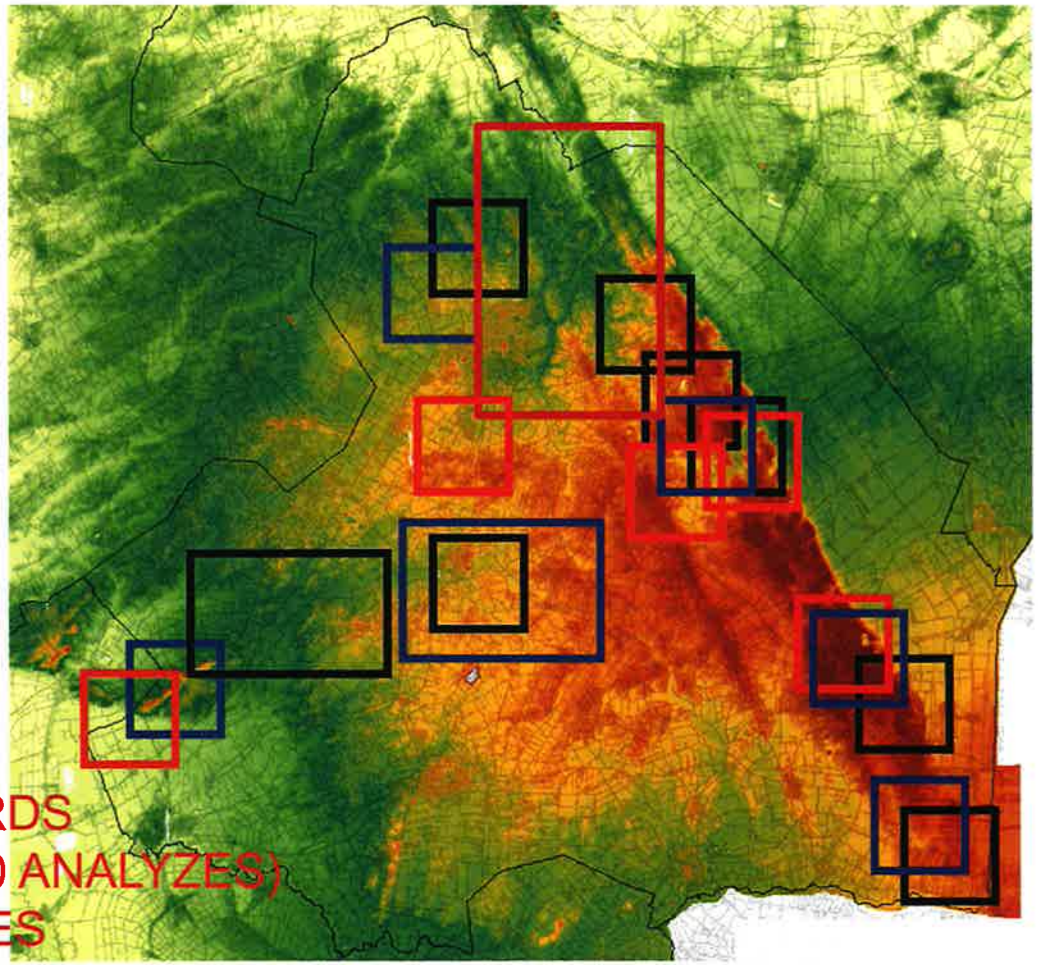
FOCUS ON GENESIS MEGAFLUTE
NOT ON PRESENT GEOMORPHOLOGY/ POST GLACIAL PROCESSES

- PARABOLIC DUNES
- HUNZE VALLEY
- KNIPHORSTBOSCH
- GEOLOGICAL MONUMENT DONDEREN
- BOULDERS
- PINGO REMNANT
- CREVASSE INFILLING “ESKER” LEEWAL
- INLAND SANDDUNES
- RAISED BOG BARGERVEEN



ONDERZOEK DRENTHE 2008-2013

NIEUW GLACIATIE MODEL



Profiles/ transects

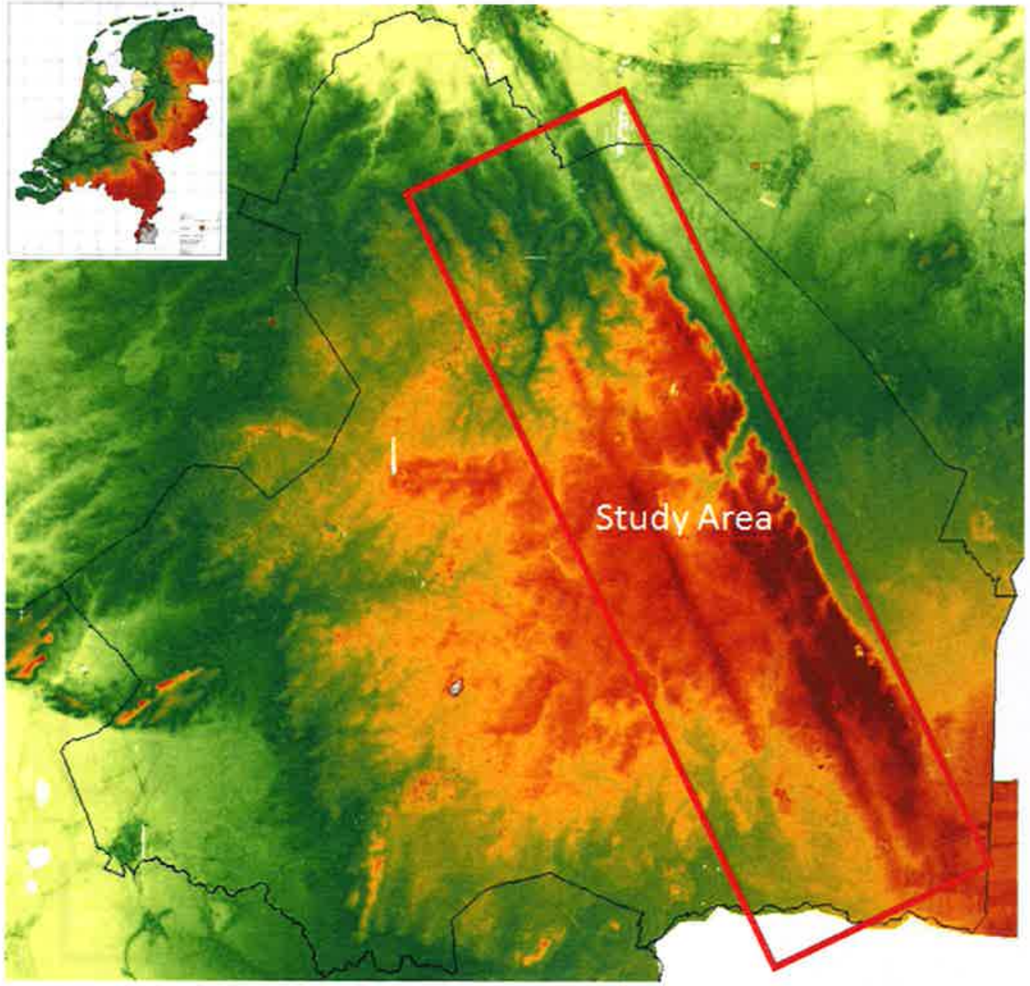
GPR

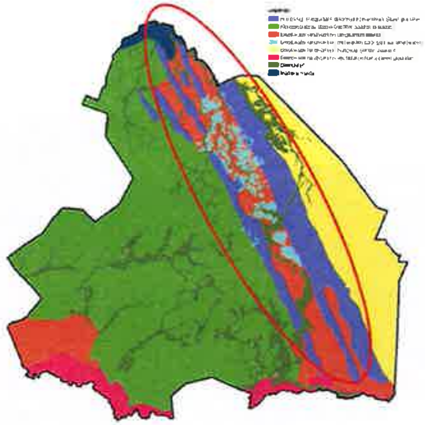
XRPD

MODELLING GW

- 6 LOCATIONS: PROFILES
- TRANSSECTS: ROADCUTS
- SEDIMENTOLOGICAL RECORDS
- XRPD: 8 LOCATIONS (+ 6; 400 ANALYZES)
- GPR: 5 LOCATION; 6 PROFILES
- BORINGS (HANDAUGER/ “DINO”)
- PREVIOUS STUDIES (o.a. Rappol, 1983; Haldorson, 1989)

I DESCRIPTION





- 60 KM
- COMPLEX > RIDGES
- HEITH 6 m – 28 m
- NNW- SSE ↔ NE - SW
- Elsterian surfacing
- Late Saalian (MIS 6)

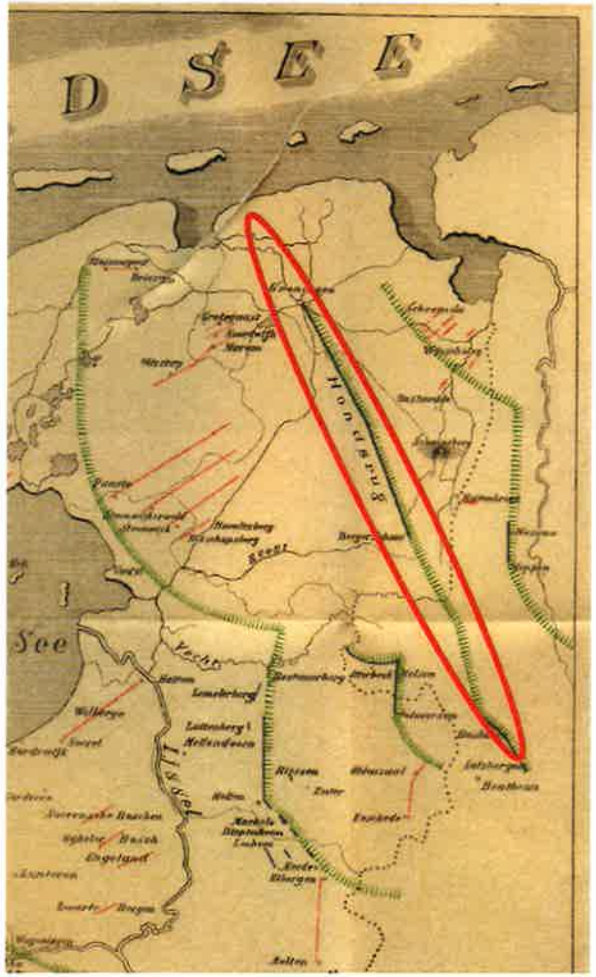
POSITIONING……

- **REMARCABLE FEATURE….**

Gerard Mercator,
1585

- **ON THE FIRST " MODERN"**

  GLACIAL MAP OF THE NETHERLANDS



Dr J.Martin,
Oldenburg 1893

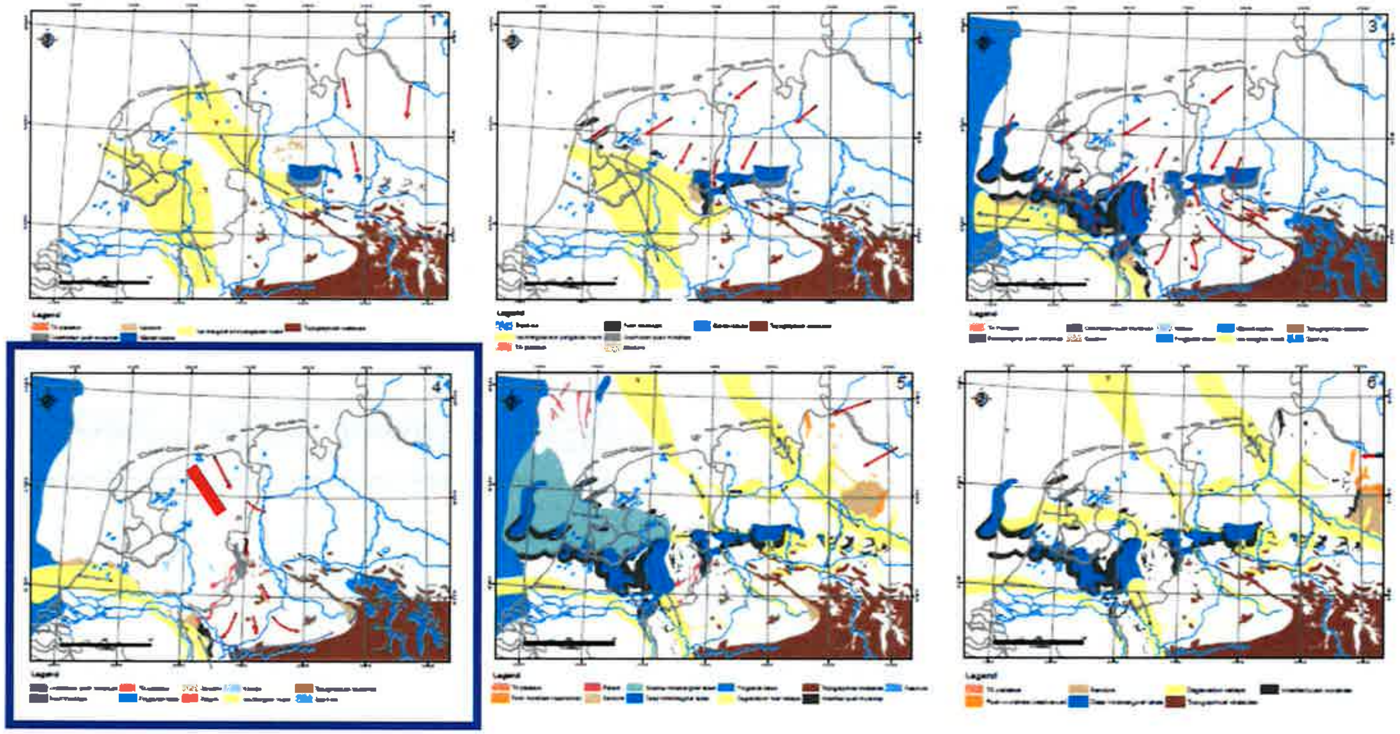
HISTORY HONDSRUG STUDIES

- A LOT OF MODELS AND DISCUSSIONS

Du Bois(1902); Jonker, (1907)	British – Scand. ice contact
Ter Wee(1989); Zonneveld (1975)	retreat – advance - tectonic
Van den Berg & Beets (1987)	dead ice – ice stream
Busschers ea, 2008	British – Scand. ice contact

- HOW FORMED?

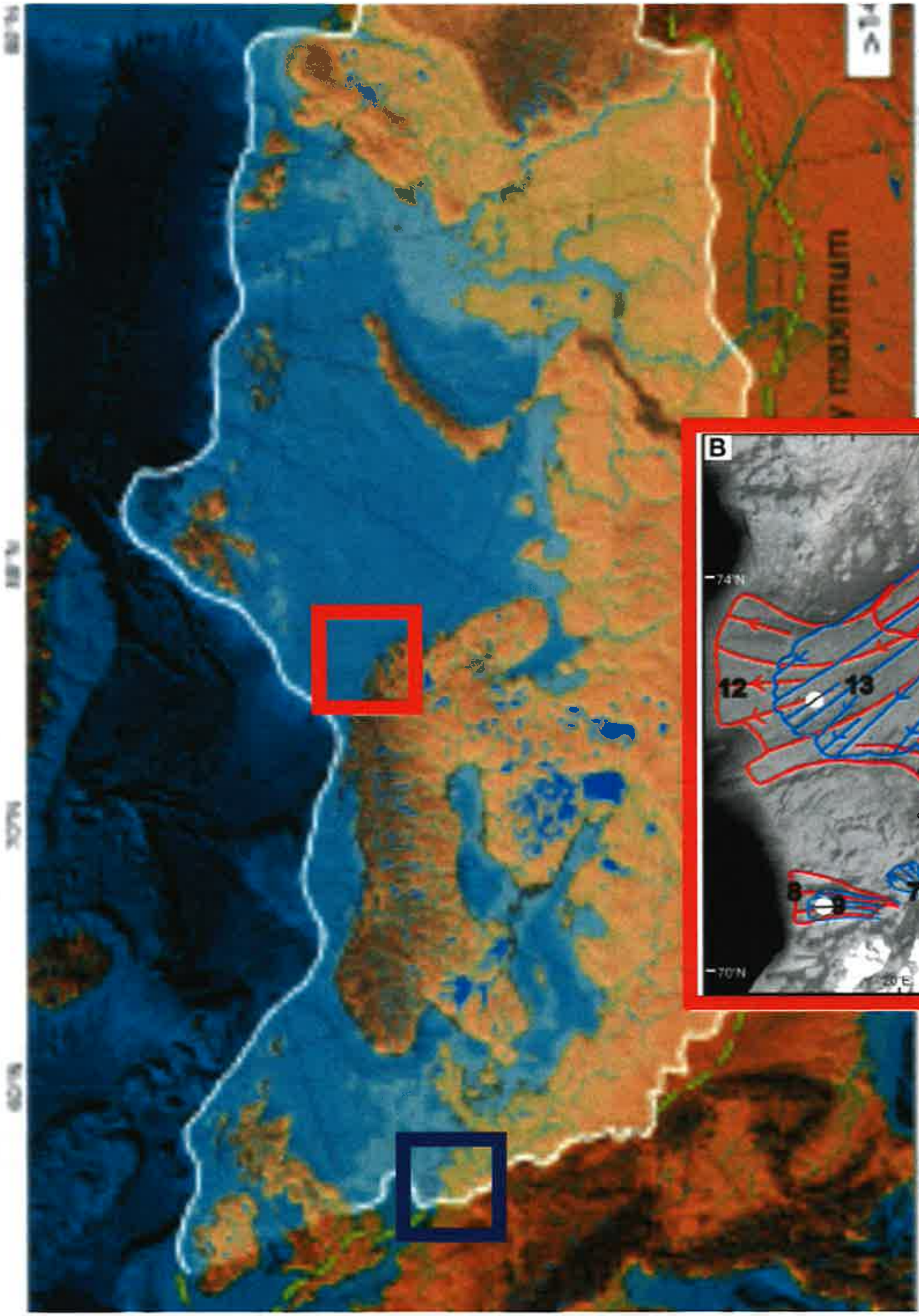
- **NEW MODEL: GIS DATABASE, DEM, PREV. STUDIES**
- **APPROACH: Boulton, 2002; Kleman, 2006 e.o.**
- **6 PHASES: GLACIATION AND DEGLACIATION**



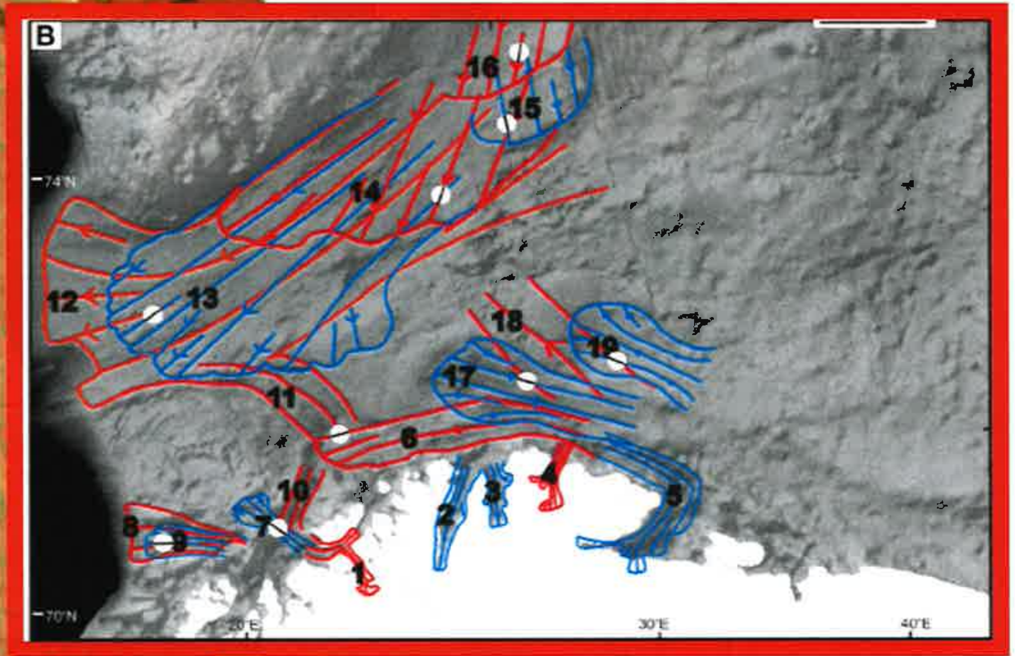
Bregman, Pierik & Cohen, 2012

→ HONDSRUG: PHASE 4, LATE SAALIAN (MIS 6)

→ DEGRADATION OF ICE FIELD, AFTER MAX EXTENSION



EXAMPLE PLEISTOCENE MAXIMUM MARINE ICE STREAMS: RECENT STUDIES



HONDSRUG, SAALE

→ ONLAND

Svendsen, 205

Winsborrow, 2010

POSITIONING IN THE IML:

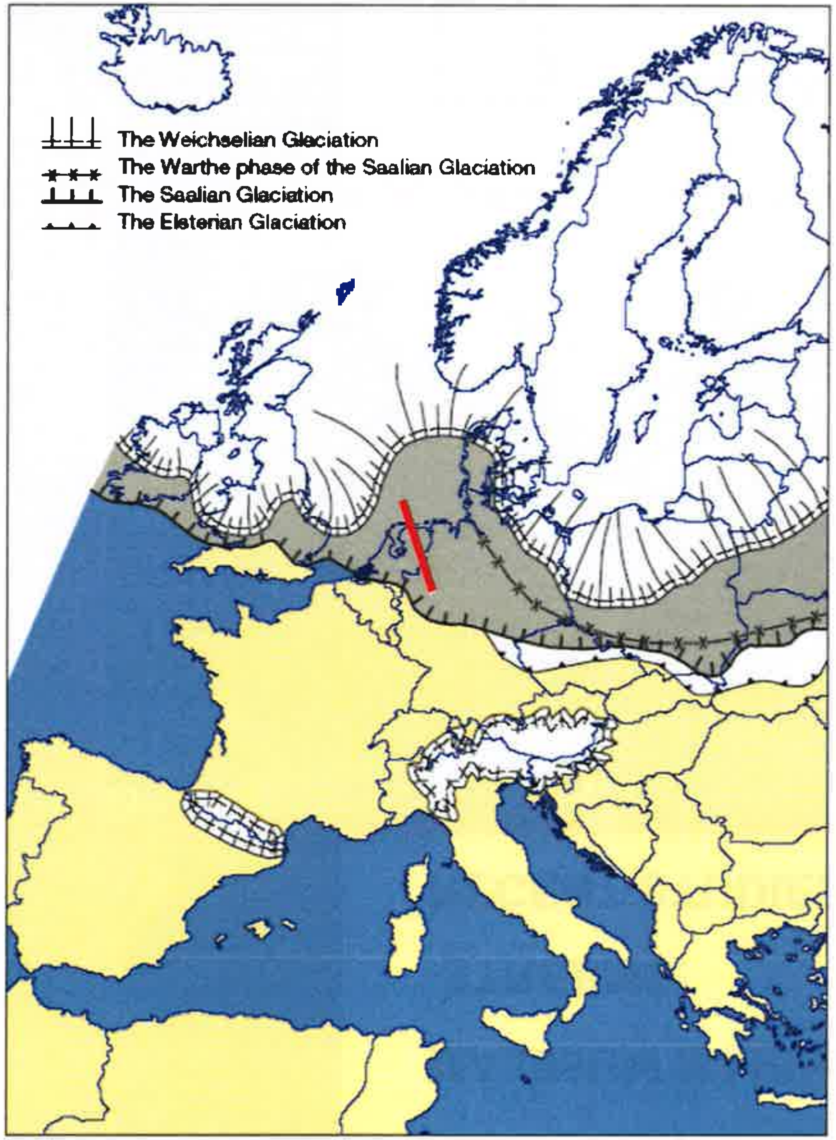
→ **NOT DEFORMED OR ERODED IN WEICHSEL**

→ **LATE SAALIAN**

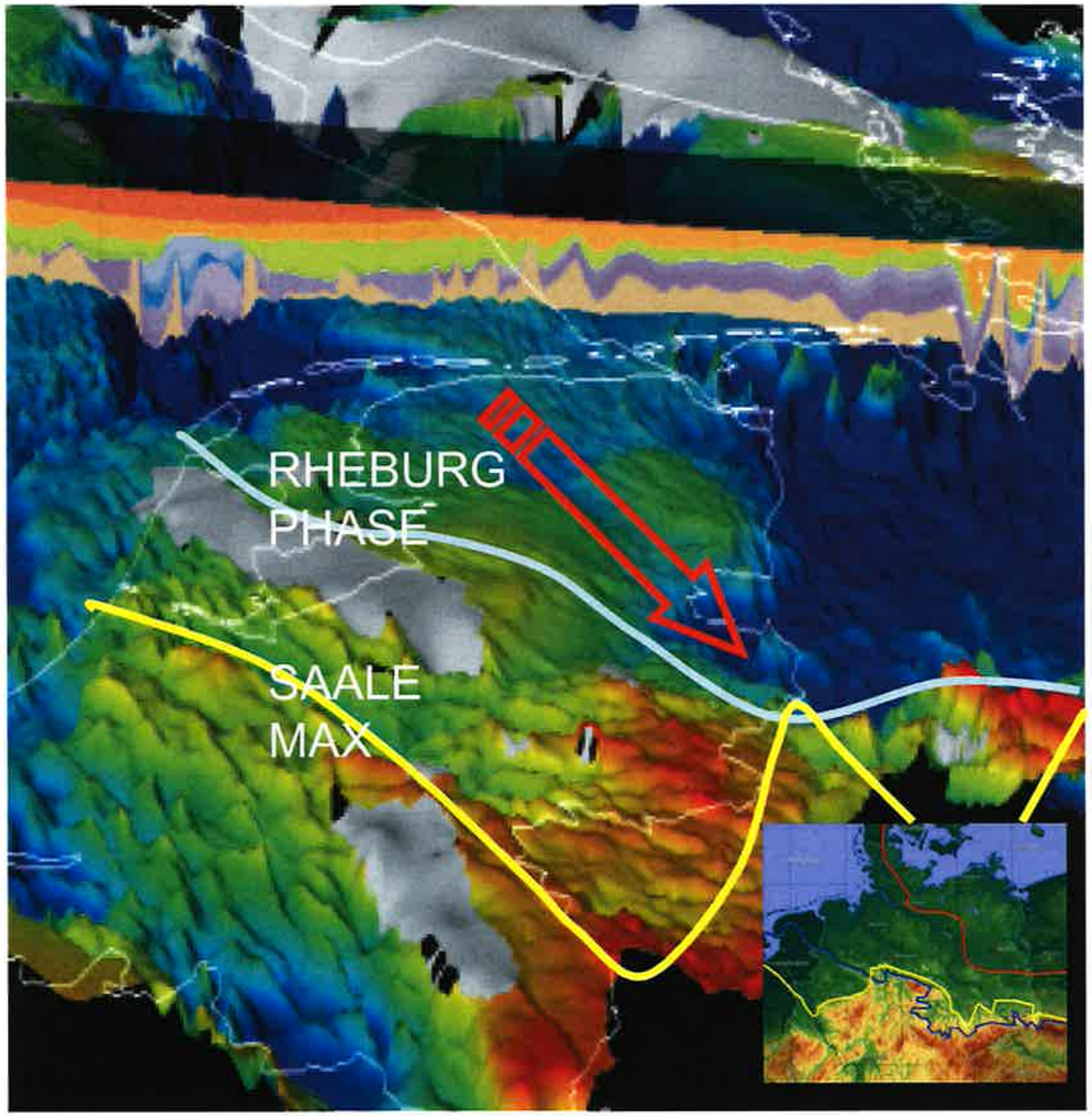
↓

A UNIQUE GLACIAL LANDSCAPE

KEY AREA GLACIAL STUDY

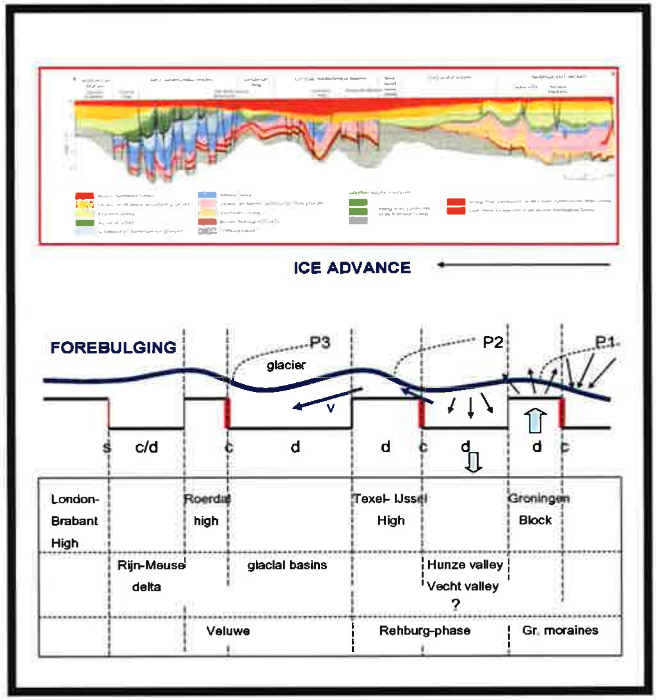


WITH ATTENTION ON DEEP GEOLOGY

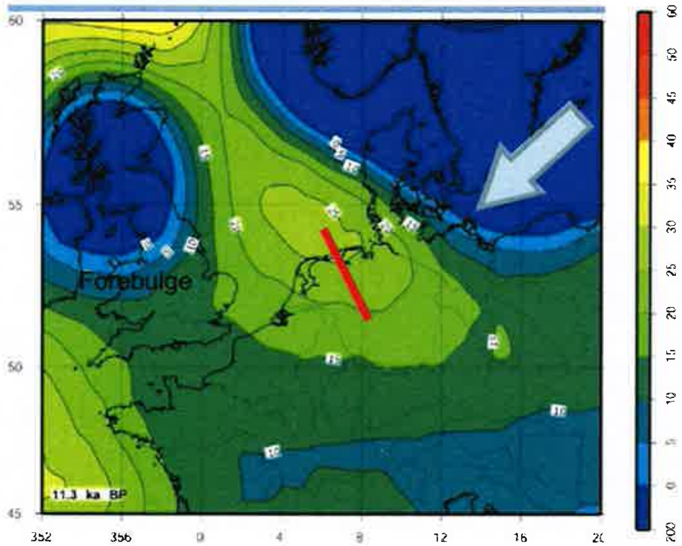


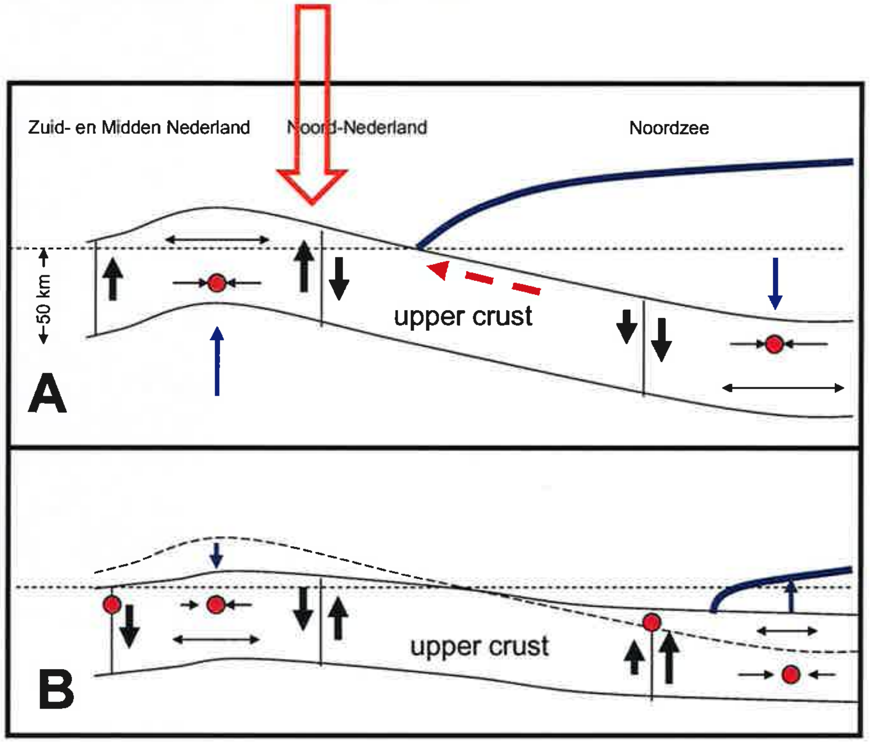
→ REFLECTS ICESTREAM BEHAVIOUR

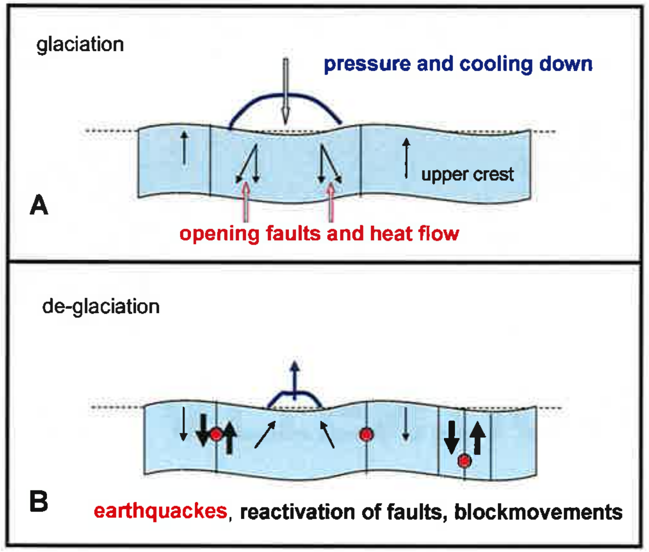
→ STAGNATION - SLIDING



→ POSITION ON FOREBULGE







→ **IMPACT ON EARTHCRUST**

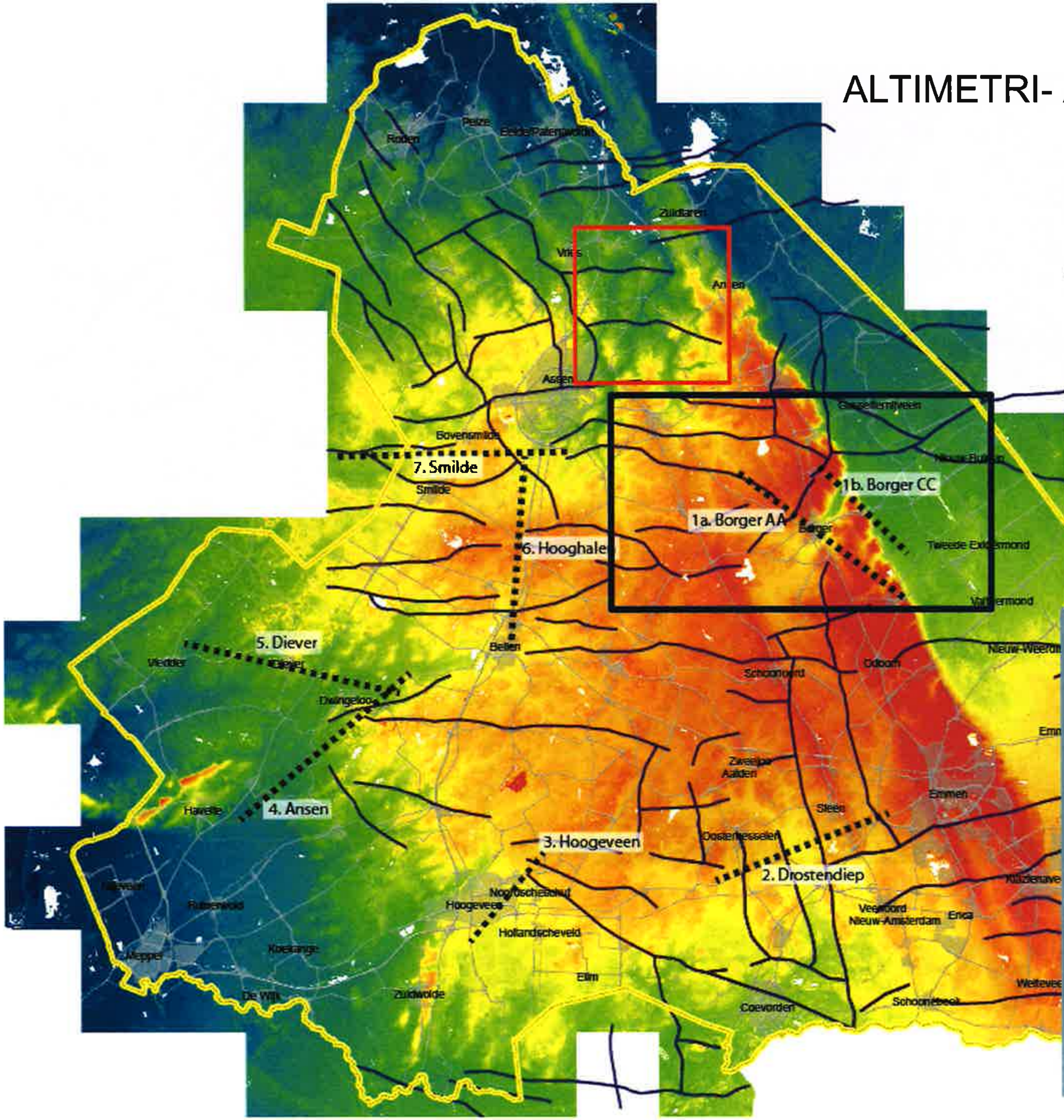
→ **ICEFLOW DIRECTION ~ GEOLOGY**

→ **TILL THICKNESS**

DIFFERENTIAL LOADING AND UNLOADING

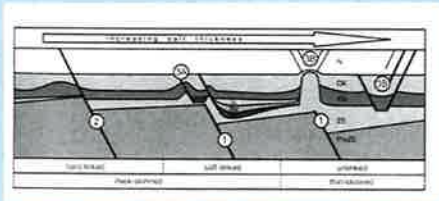
ALTIMETRI- AND SEISMIC DATA

provincie Drenthe

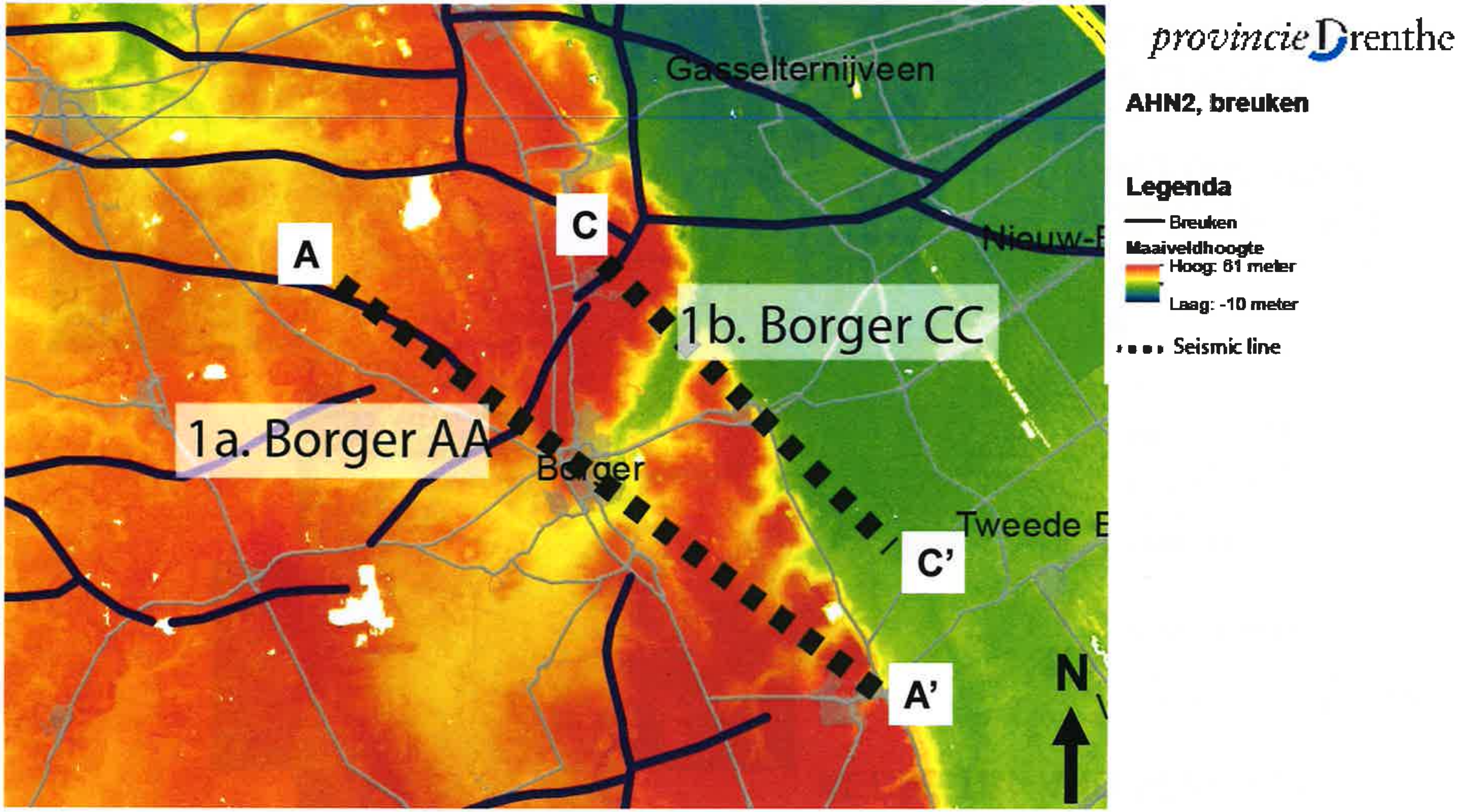


RELATION DEEP AND UNDEEP?

INFLUENCE GLACIATIONS?

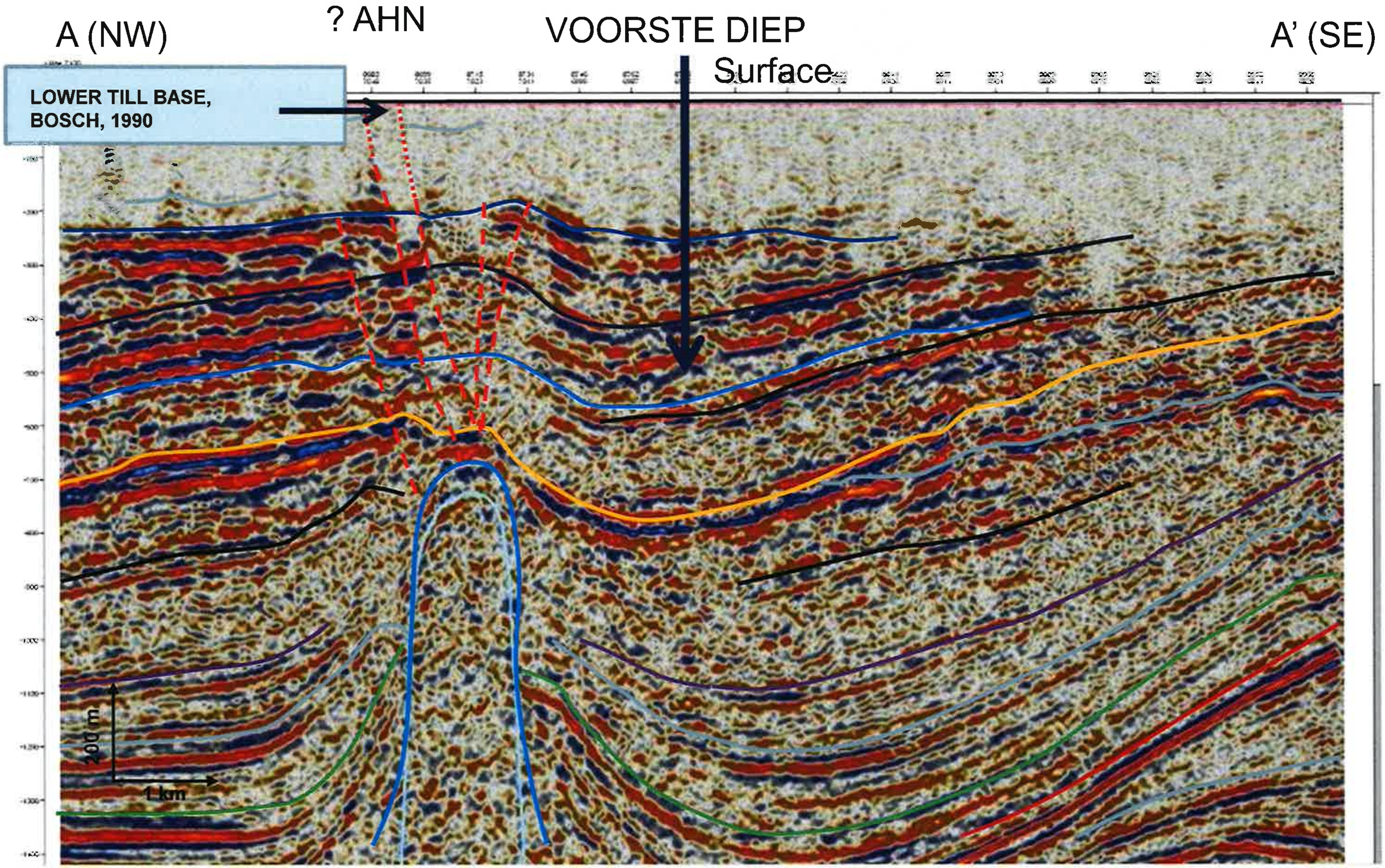


1a. Borger AA



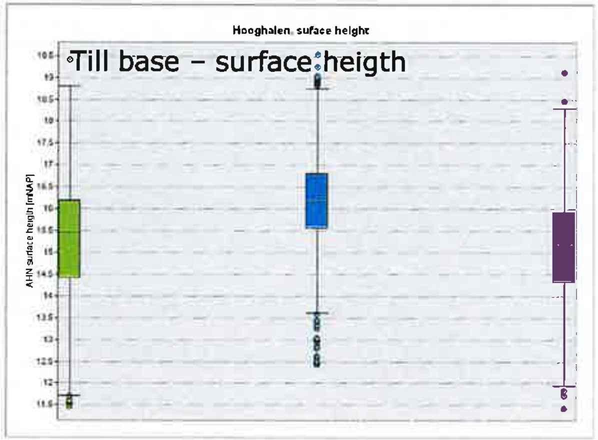
Gasselternijveen
Nieuw-
C
A
1b. Borger CC
1a. Borger AA
Borger
Tweede E
C'
A'
N
provincie Drenthe
AHN2, breuken
Legenda
Breuken
Maaiveldhoogte
Hoog: 61 meter
Laag: -10 meter
Seismic line

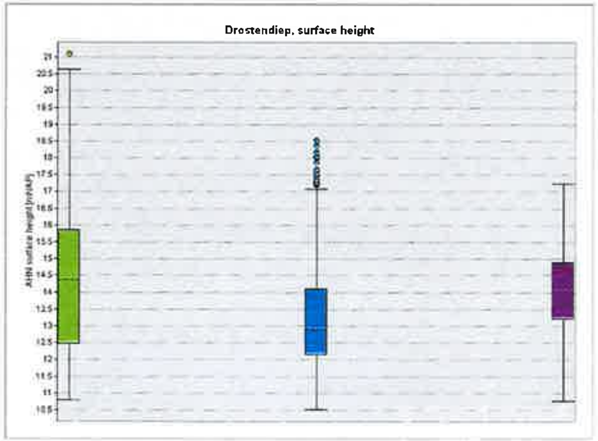
1a. Borger AA



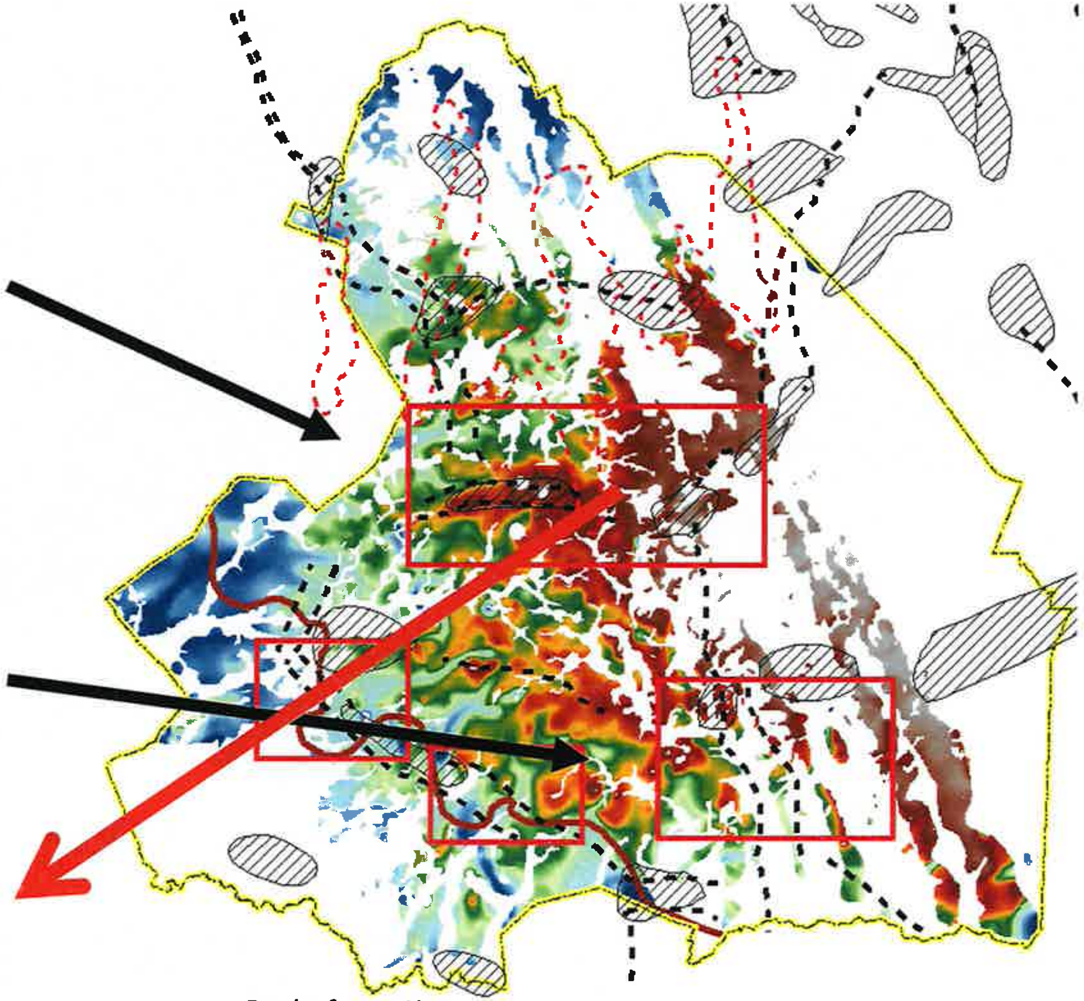
A (NW)
? AHN
VOORSTE DIEP
A' (SE)
Surface
LOWER TILL BASE,
BOSCH, 1990
200 m
1 km

SAALE:TILL BASEMENT





POSTGLACIAL UPLIFT : 2.5 M



Peelo formation (southern limit)

pradolina

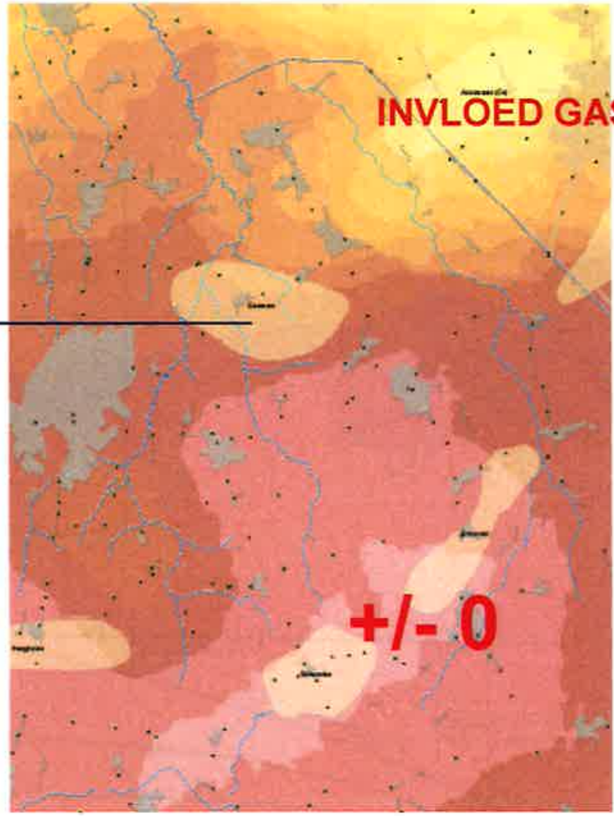
Tertiary fault

saltdomes

Bregman/prov Dr/ TNO, (in prep.)

RECENTE BODEMBEWEGING Noord Drenthe

zoutkoepel



Spherical Kriging

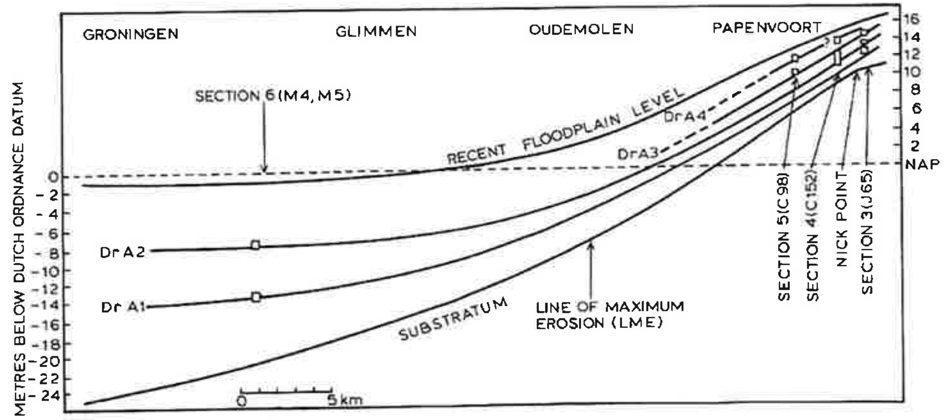
minimum tot 1960 versus maximum vanaf 2000

eenheid: m

- -0,180389062 - -0,18
- -0,18 - -0,17
- -0,17 - -0,16
- -0,16 - -0,15
- -0,15 - -0,14
- -0,14 - -0,13
- -0,13 - -0,12
- -0,12 - -0,11
- -0,11 - -0,1
- -0,1 - -0,09
- -0,09 - -0,08
- -0,08 - -0,07
- -0,07 - -0,06
- -0,06 - -0,05
- -0,05 - -0,04
- -0,04 - -0,03
- -0,03 - -0,02
- -0,02 - -0,01
- -0,01 - 0
- 0 - 0,01
- 0,01 - 0,02
- 0,02 - 0,03

RESULTS UPLIFT/ UNLOADING

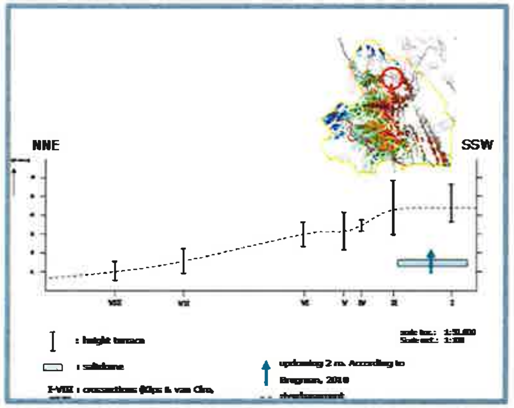
- CHANGE EROSION SURFACE



- SHIFT WATERDIVIDE: 800 M TO NORTH

- DRYER (FOSSIL) VALLEYS UPSTREAM

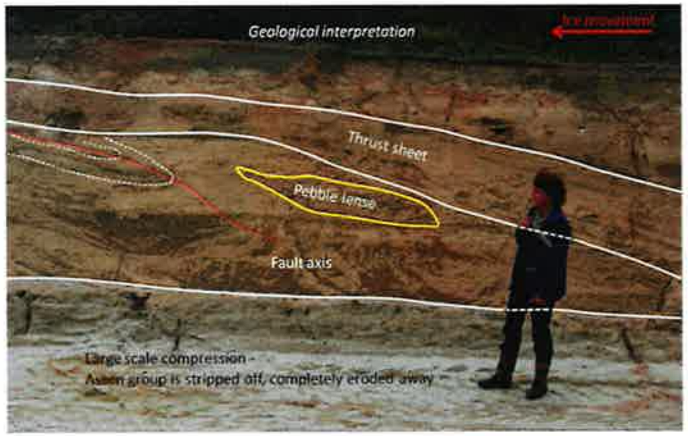
- TERRACES



- DIFFERENTIAL REBOUND

OTHER RESULTS

- ERRATICS
- TILLS
- GPR
- GLACIAL STRUCTURES



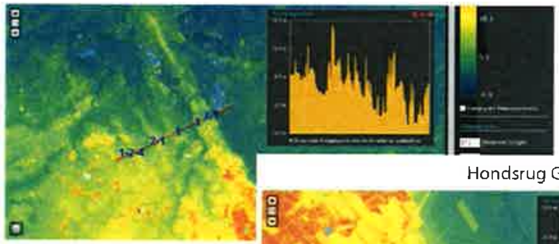
Borger, North of the viaduct, East face

RESULTS

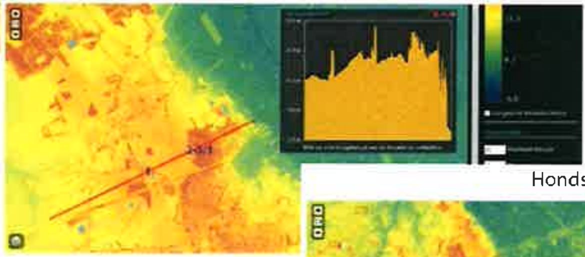
Hondsrug: complex of different ridges and erratic-types

Hondsrug Ridges from AHN

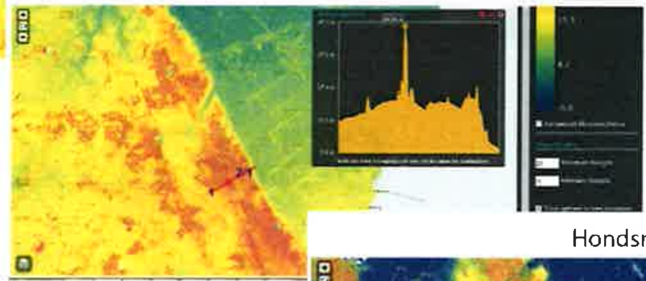
Northern Drenthe Hondsrug complex



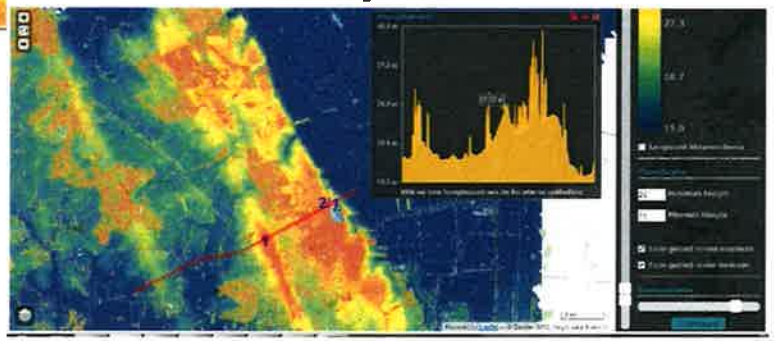
Hondsrug Gieten

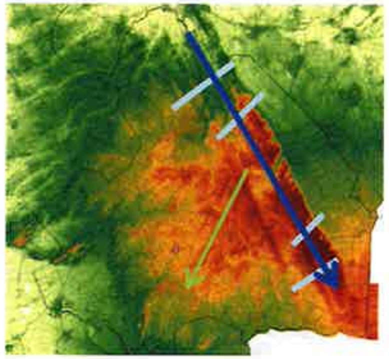


Hondsrug Valthe



Hondsrug Emmen





Group	Type	Dir	Calc	Glaciation stage / Hesemann nr.	Characteristics in field	Occurence on Hondsrug
Heerenveen	Heerenveen 4		–	West-Baltic phase 2350,2260	1. Sandy till 2. Flint-rich 3. Boulder configuration: South Sweden 4. Boulders often homogenized with Assen type of till	- Western part Rolder Ridge - Has been found in Eext
Emmen	Nieuweschoot		+	Second East-Baltic 10000, 9001	1. Absence of flint 2. [illegible] 3. Limestones are rounded, contain striae 4. Crushed and kitted together as breccias	-North of Noordlaren -On Noordlaren type normally
	Emmen 2		–	Second East-Baltic 10000, 9001	NO FLINT > ERR	-South of Noordlaren -[illegible]
Assen	[illegible]		+	Second East-Baltic 7020, 6110	1. [illegible] 2. [illegible] 3. [illegible] 4. [illegible]	-North of Noordlaren Overlain by Nieuweschoot
	Assen 1		–	Second East-Baltic 7120, 6220	FLINT < ERR 4. Distinguish with Emmen: high flint content (10-20%)	[illegible] Noordlaren [illegible] by Emmen-type
Voorst	Voorst 3		+	First East-Baltic phase	LIMESTONE > 4. Low boulder content (polished and striae do occur)	Exclusively on northern part of HC
	Oudemirdum		–	First East-Baltic phase	Does not occur at HC	Does not occur at HC

www.geodan.nl/ source erratic types:
h.huisman, 2013 , zandstra, rappol, 1987

CONCLUSIONS: TILLS

ERRATICS

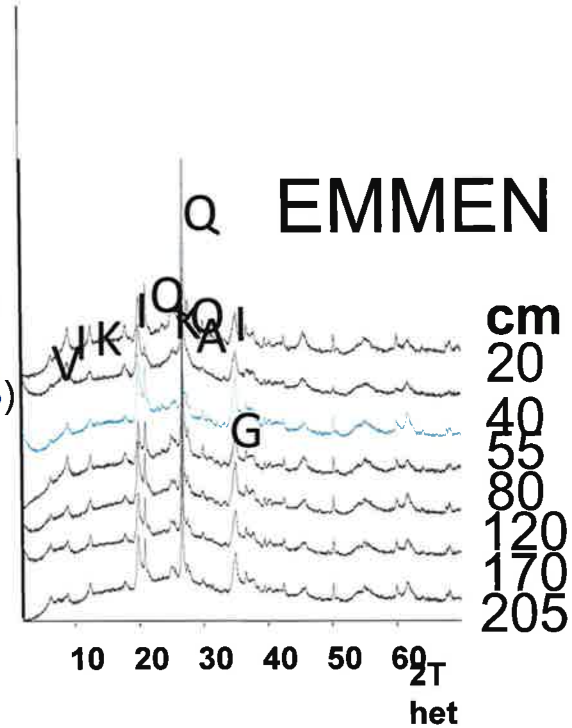
- HONDSRUG ICESTREAM (NNW – SSE) **OVERPRINTED** OLDER ICEFLOW DIRECTION (NE-SW)

- CONFIRMED BY

→ CLAY MINERALS ANALYSES

(TYPE, DE- and NEW FORMED, UNBASAL REFLECTIONS)

→ GPR



XRP

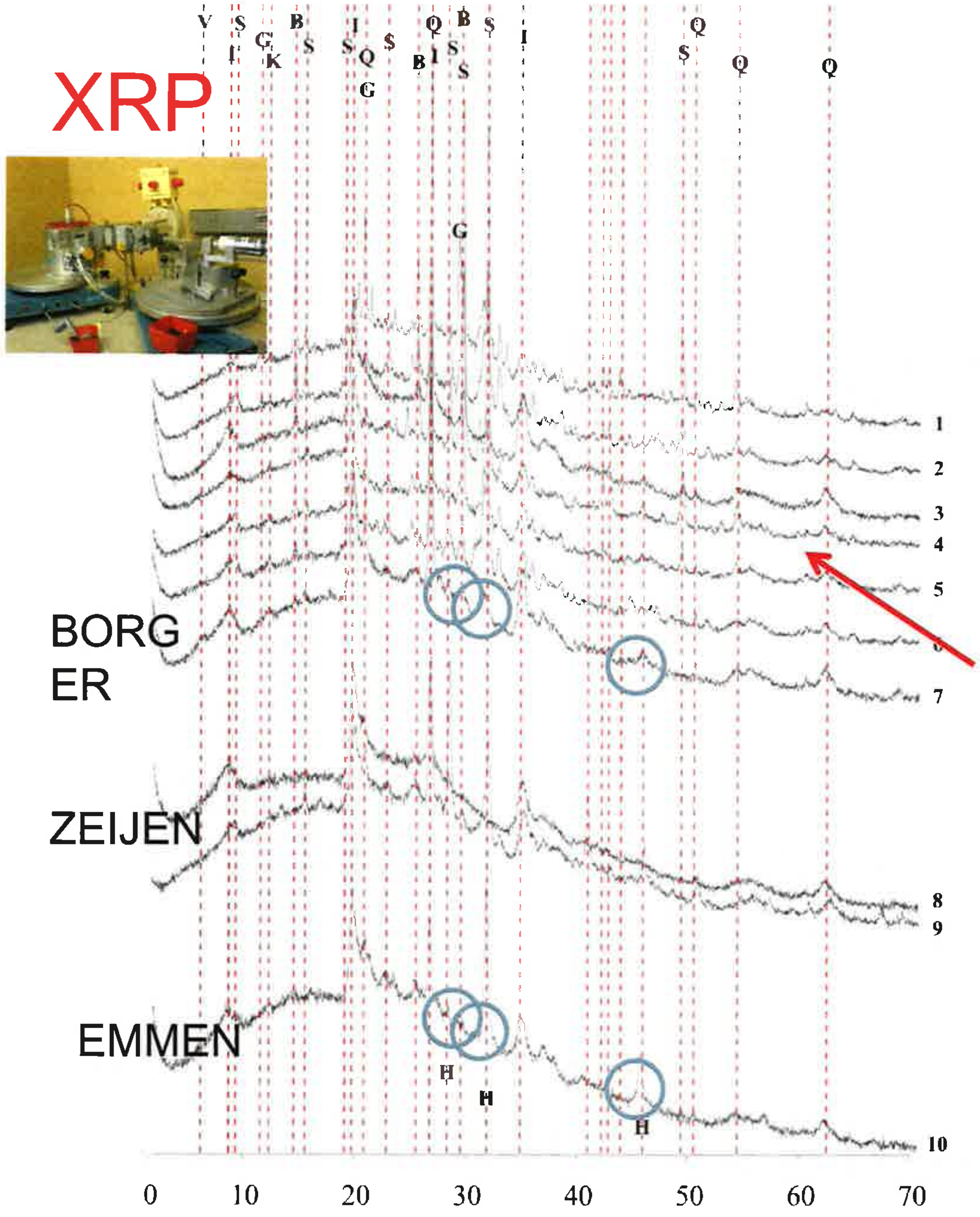


Figure 9. Full XRD pattern of random powder preparations of samples from **Emmen** outcrop: Samples depths: **1**- 20 cm; **2**- 40 cm; **4**- 55 cm; **5**- 80 cm; **6**- 120 cm; **7**- 205 cm, **Zeijen** outcrop: Samples depths: **8**- 100 cm; **9**- 140 cm; **10**- **Borger** outcrop- 120 cm;

Symbols: ***V****-vermiculite;* ***I****-illite;* ***G****-gypsum;* ***K****-kaolinite;* ***K****-kaolinite;* ***B****-bassanite;* ***S****-syngenite;* ***Q****-quartz;* ***H****- halite;*

→ Polytypes indicates conditions of forming (kaolinite!)

→Halite, syngenite and bassinite brine water influence (lowest tills)

→55 cm –s.l.: no basal reflections indicate shearing plane

EMMEN – BORGER - ZEIJEN

DRENTHE SAMPLE AREA – RESULTS

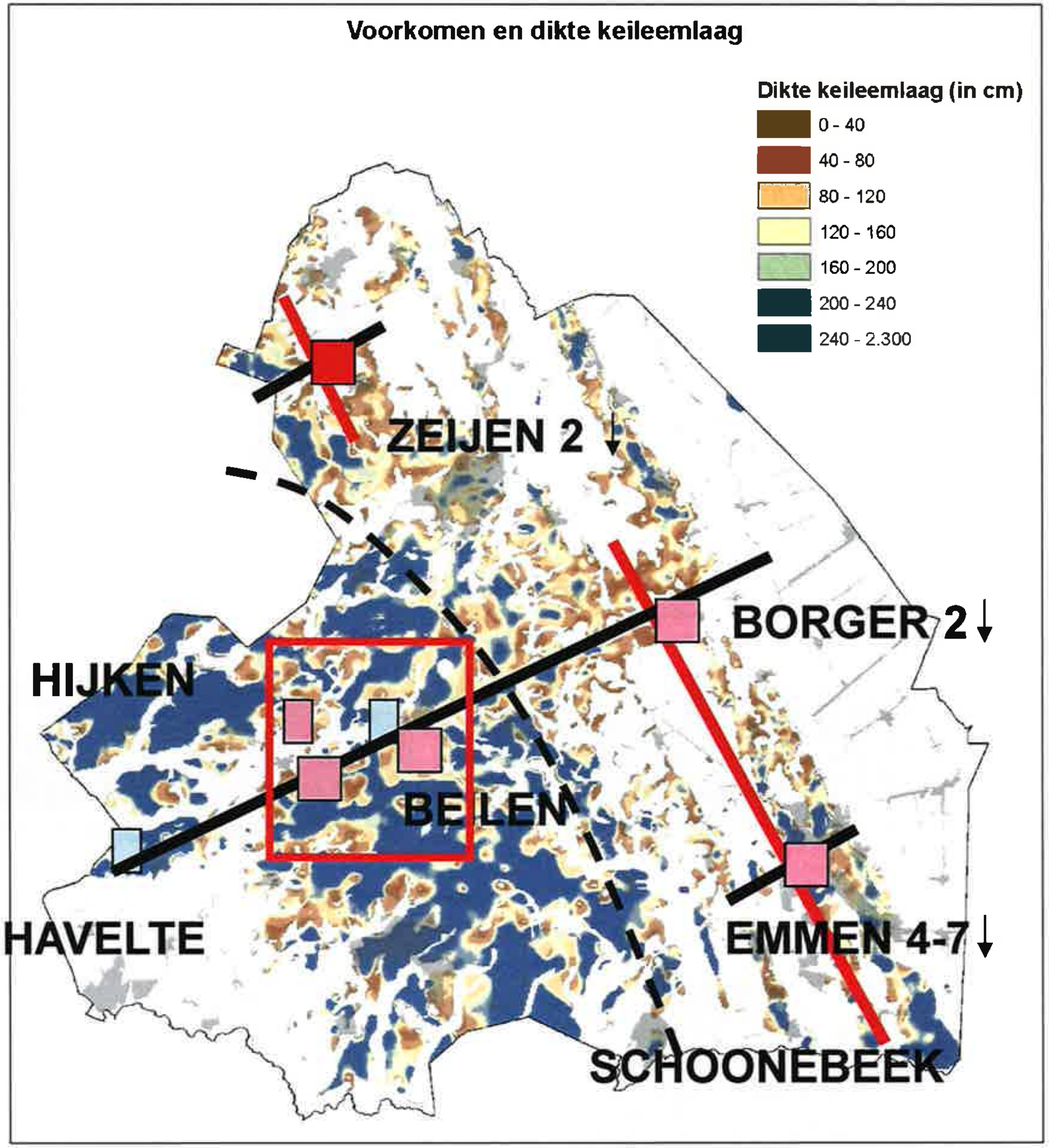
LOWER TILL T.S.I.

0. 70 – 0.90

0.50 – 0.70

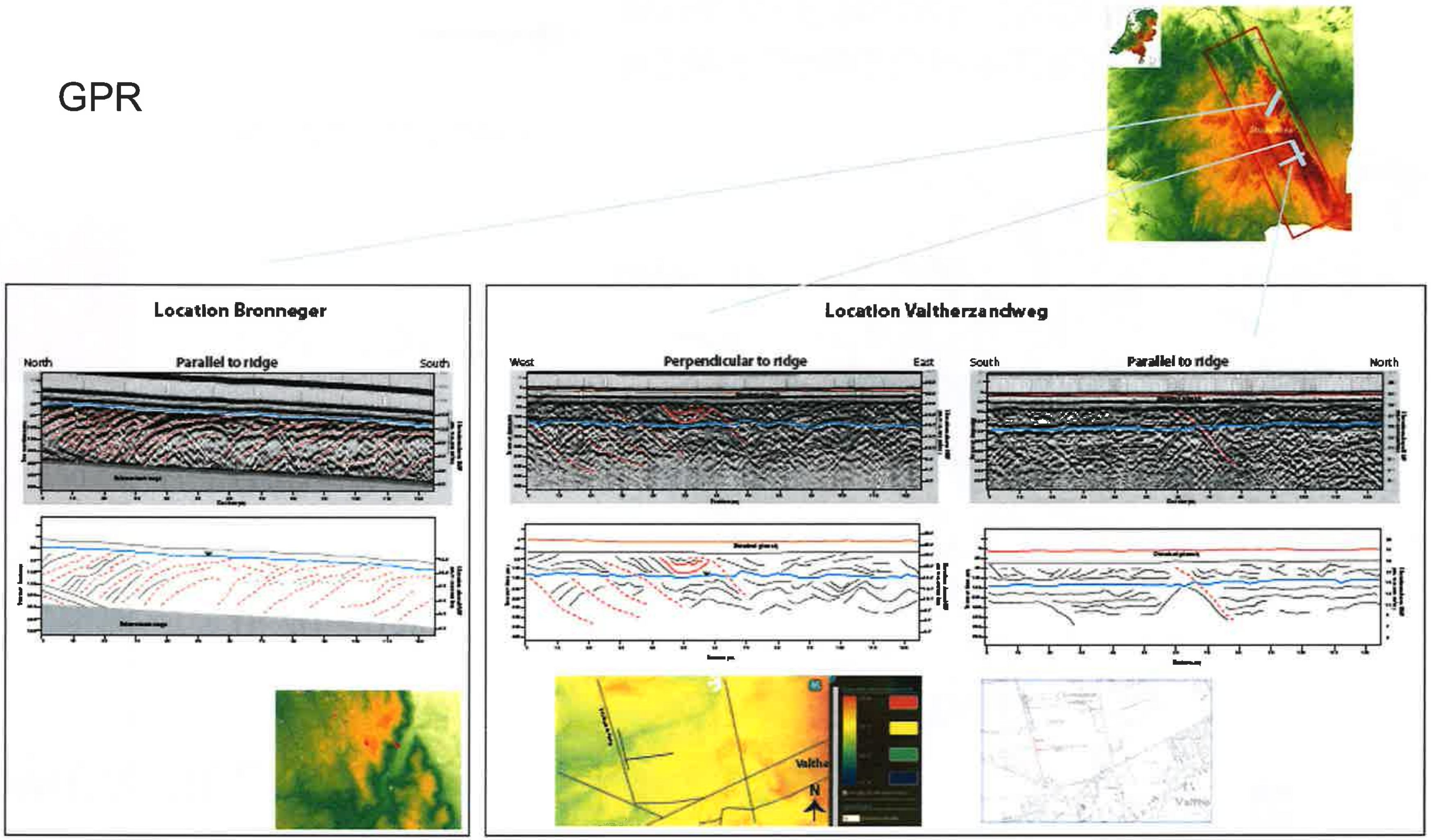
0.30 – 0.50

INTERLAYERING



→ **NEW FORMED MINERALS INDICATE BRINE GROUNDWATER**

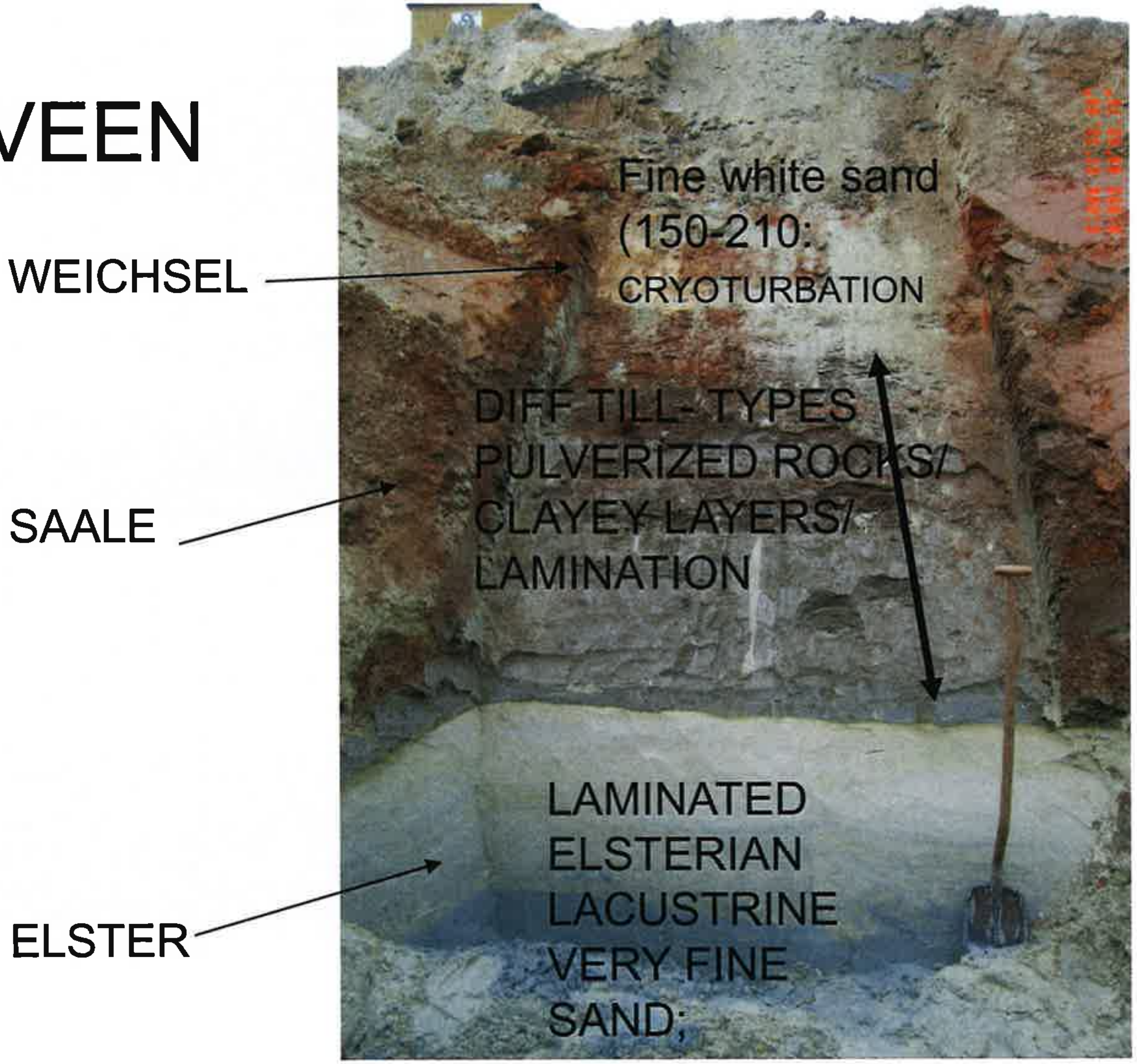
GPR



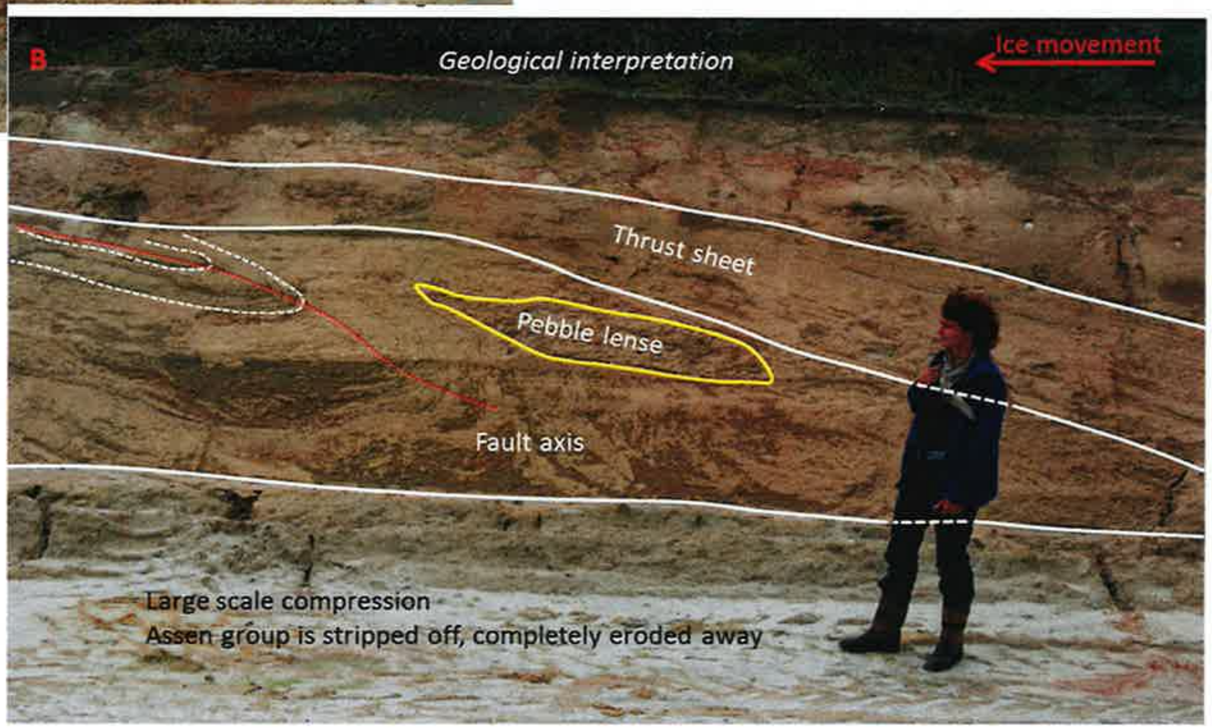
Location Bronneger
North
Parallel to ridge
South
Location Valtherzandweg
West
Perpendicular to ridge
East
South
Parallel to ridge
North
N

GLACIOLOGICAL FEATURES

- KLAZINAVEEN

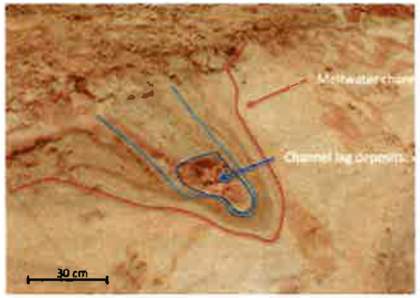


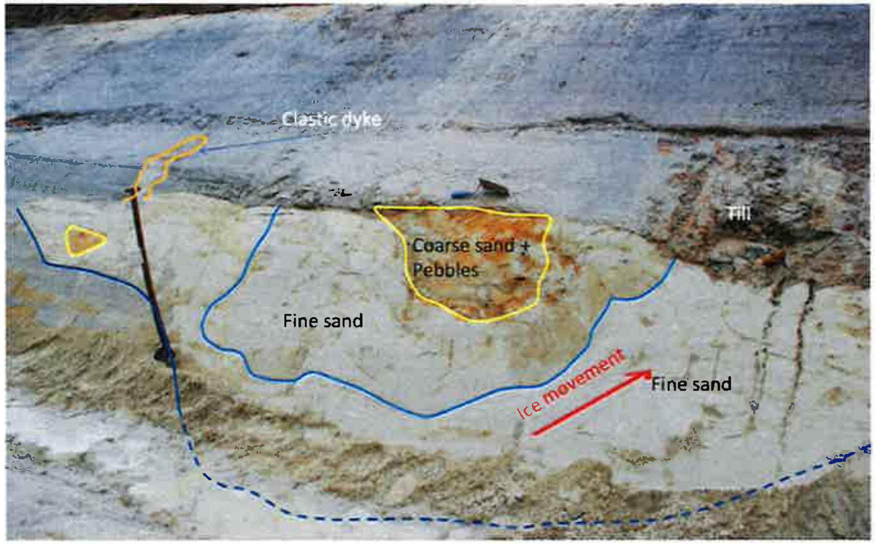
BORGER N34

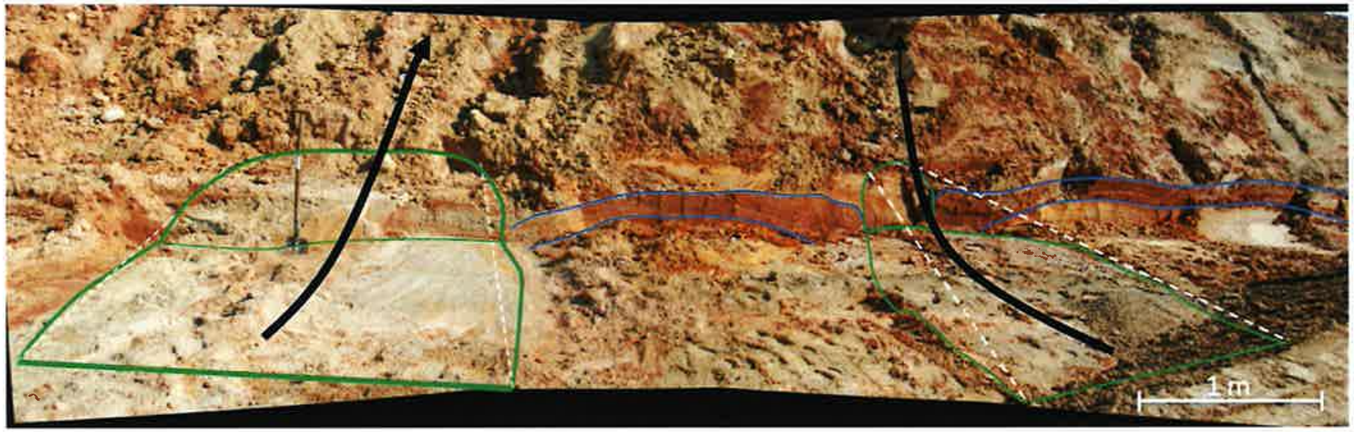

B
Geological interpretation
Ice movement
Thrust sheet
Pebble lense
Fault axis
Large scale compression
Assen group is stripped off, completely eroded away

GLACIOLOGICAL FEATURES

- GIETEN





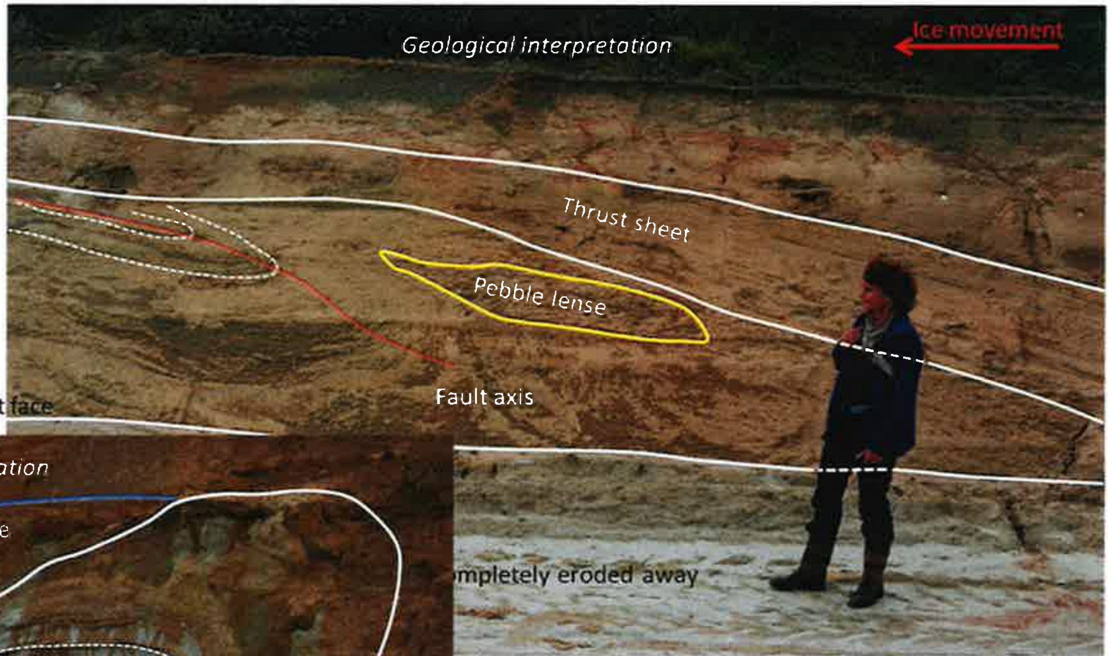


PIPING

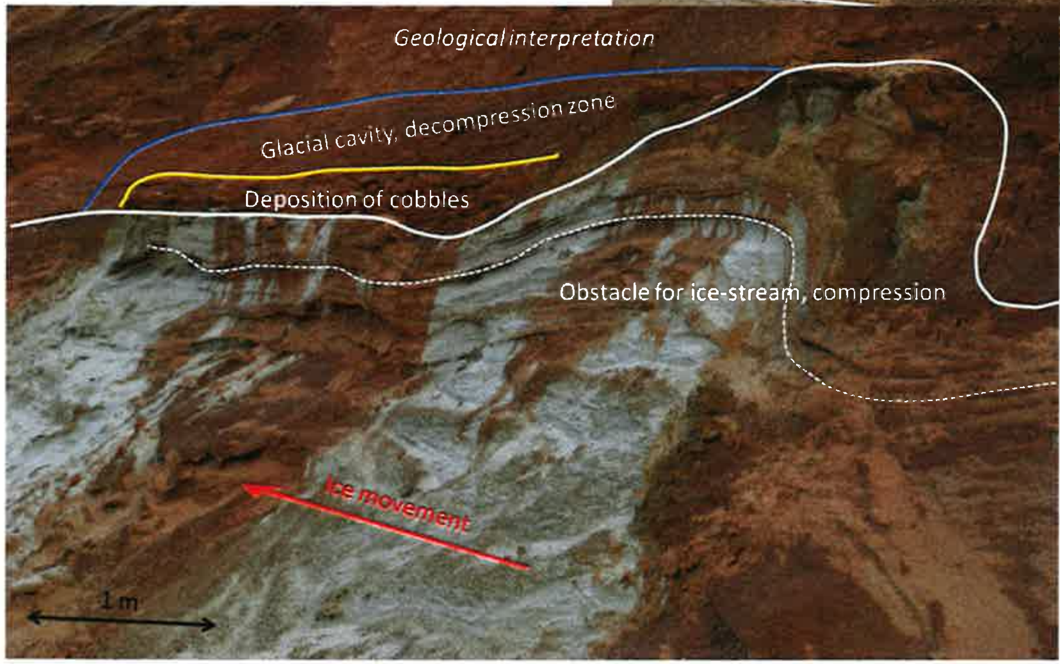
GLACIOLOGICAL FEATURES

- BORGER

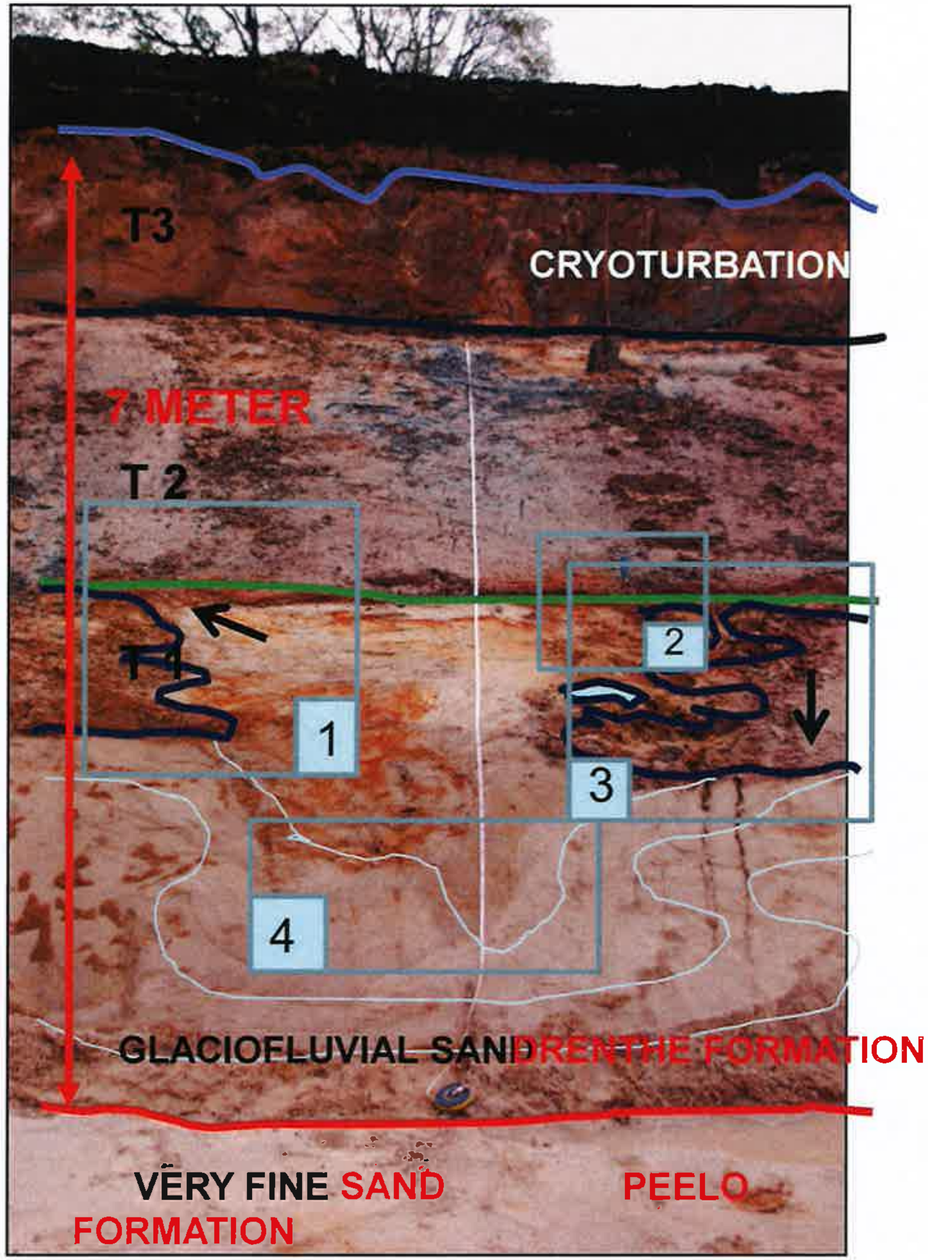
Borger, North of the viaduct, East face



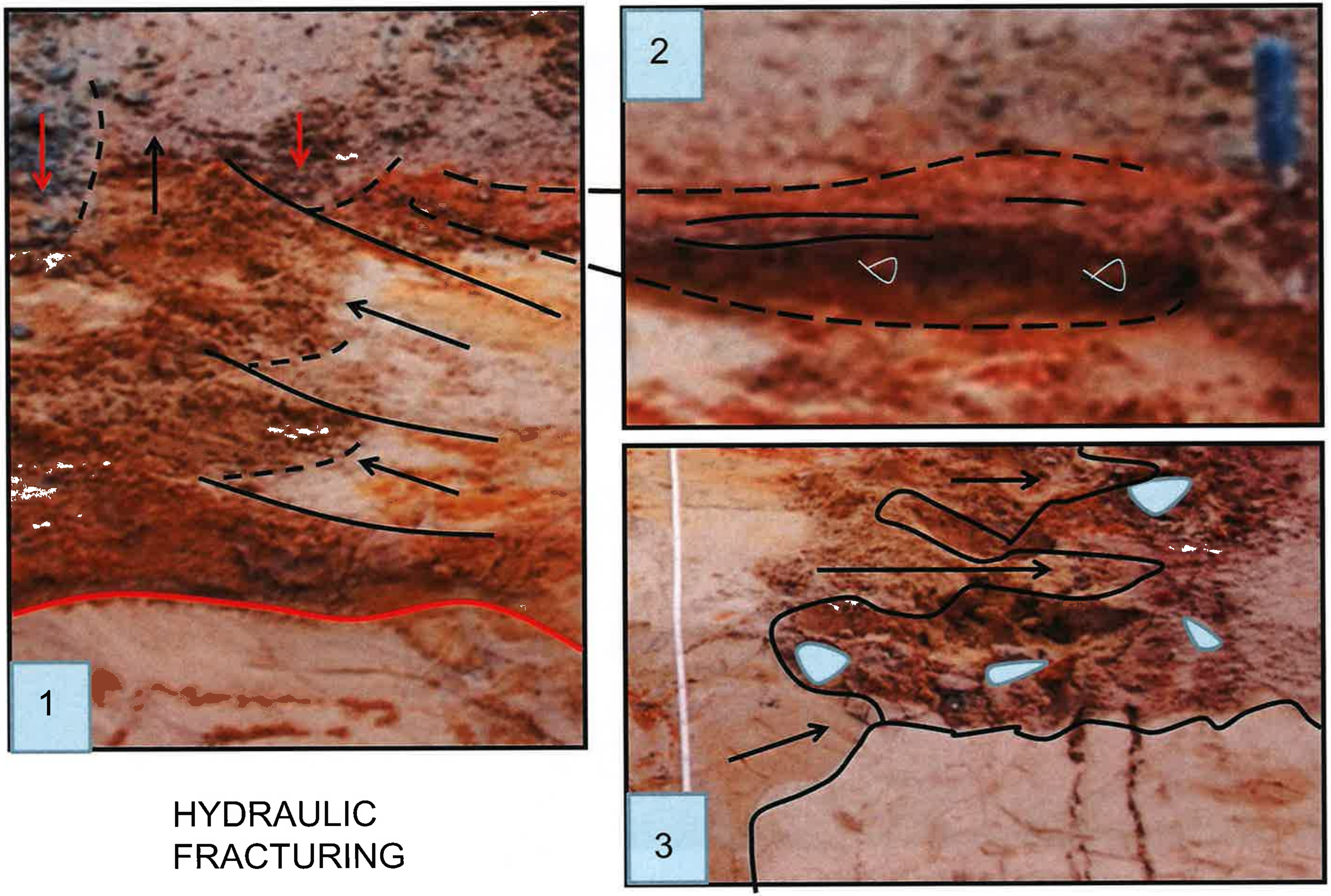
North of viaduct, east face



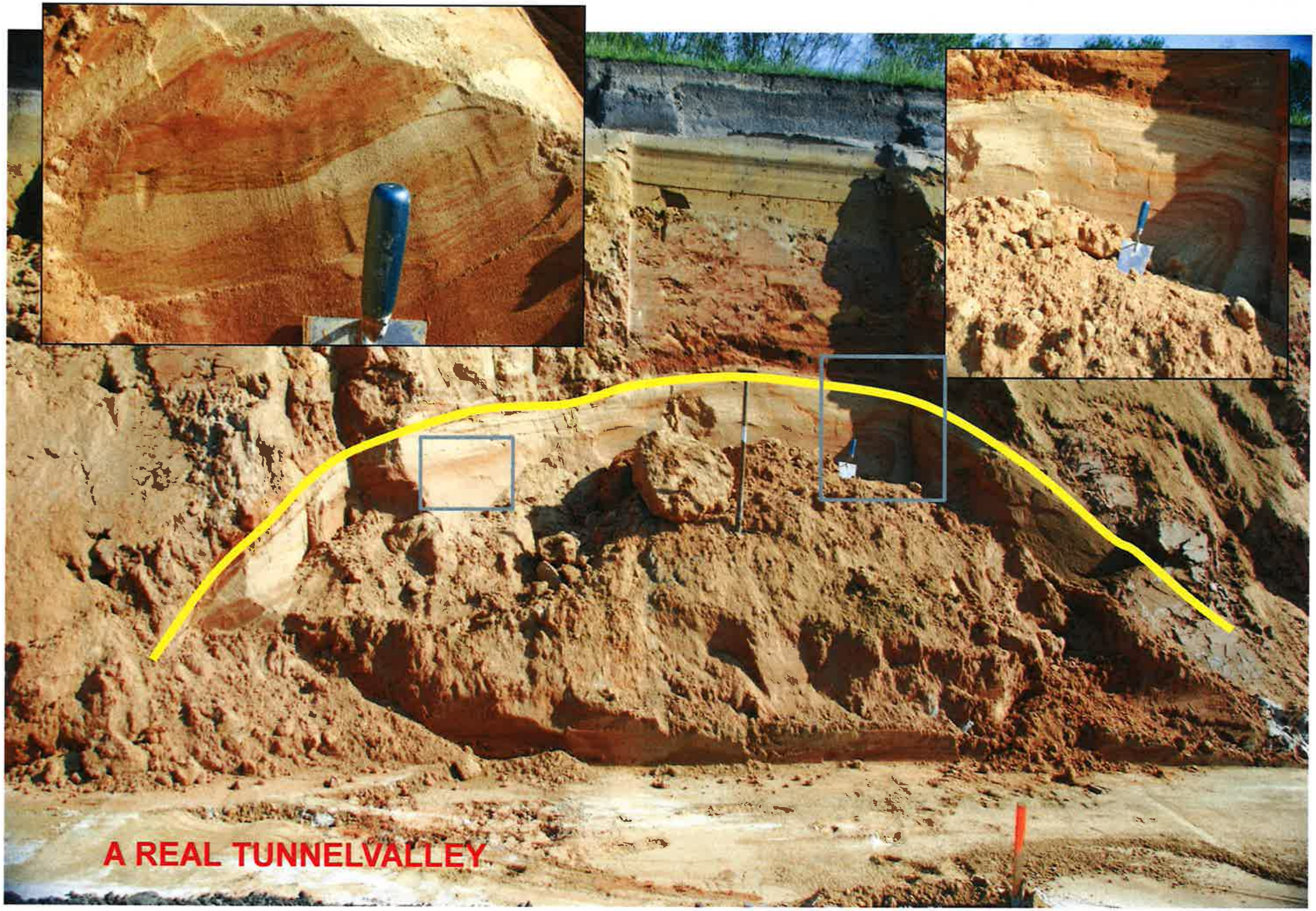

GIETEN N33

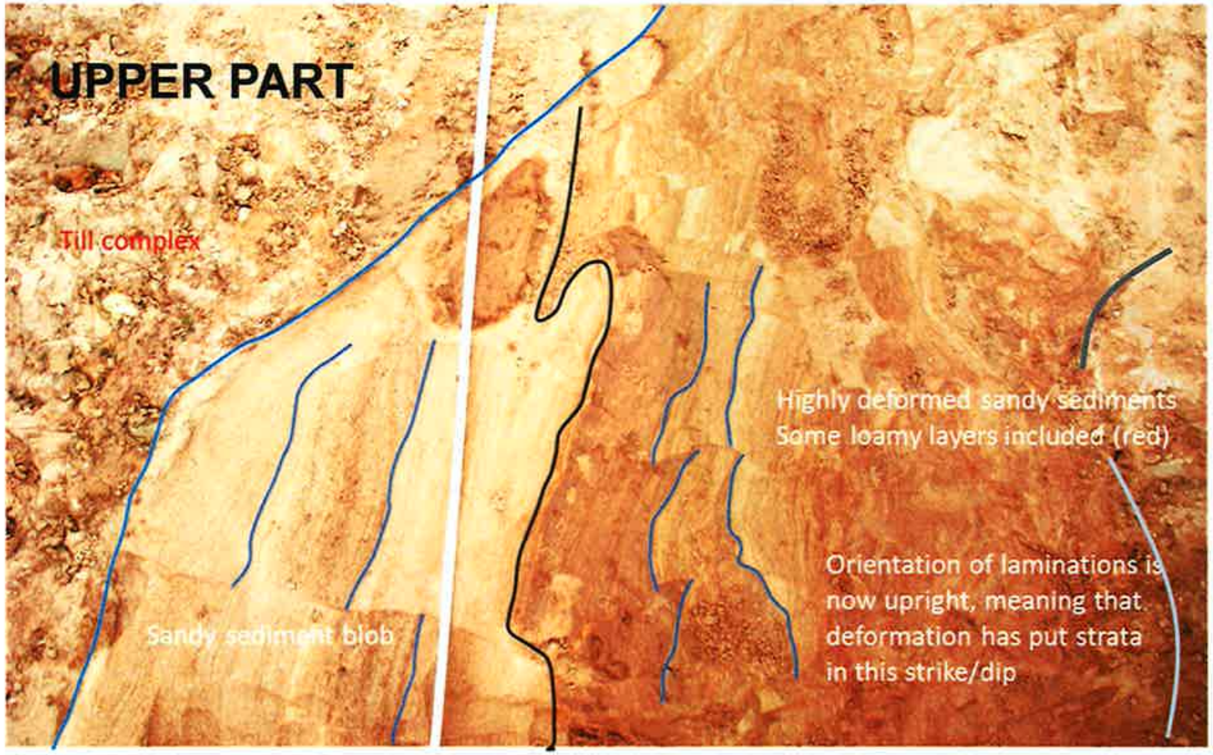


T3
CRYOTURBATION
7 METER
T 2
T1
1
2
3
4
GLACIOFLUVIAL SAND
DRENTHE FORMATION
VERY FINE SAND
PEELO
FORMATION



HYDRAULIC
FRACTURING


A REAL TUNNELVALLEY



RESULT OF PIPING
GIETEN N33

COLLAPSED WATER-RELEASE STRUCTURES

GLACIOLOGICAL FEATURES

- NORTH DRENTHE

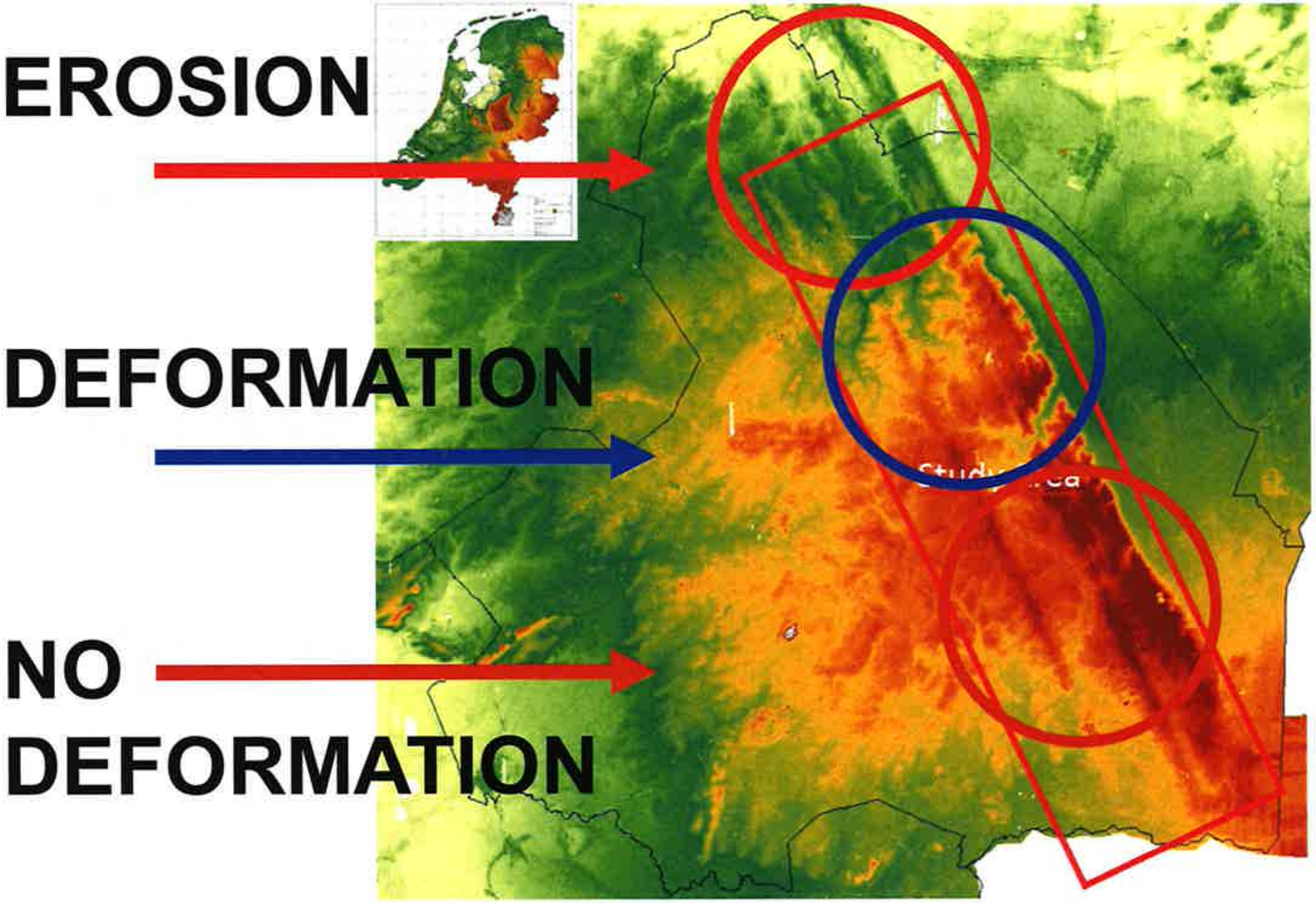
EROSION

BOULDER PAVEMENT

CONCLUSIONS GPR + XRPD + ERRATICS

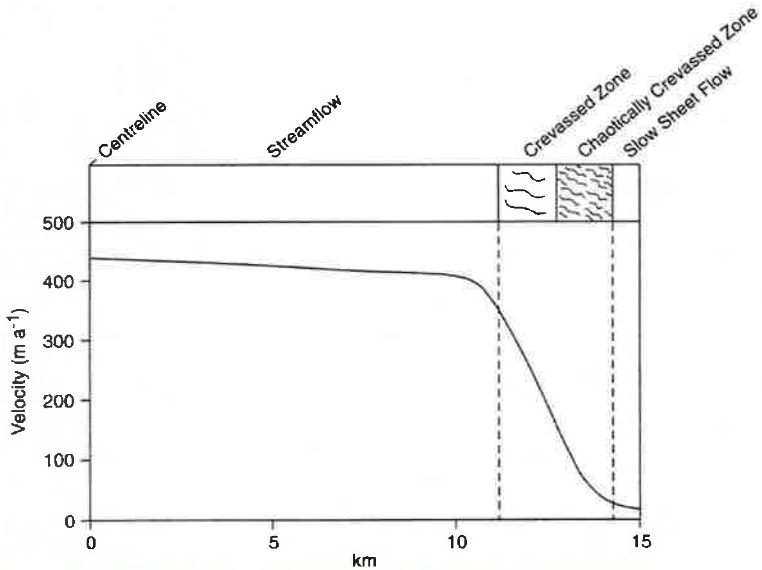
→STRONG SPATIAL DIFFERENTIATION

→ HONDSRUG = MARGINAL FEATURE



WHY FLUTINGS?

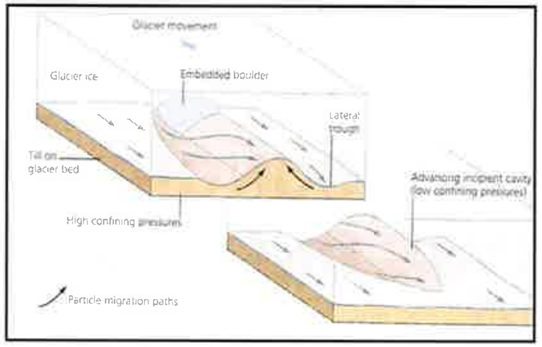
→ MARGINAL AREA



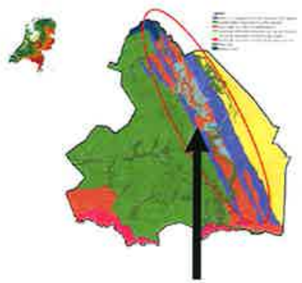
→ DRUMLINAZATION

→ PRESSURED SUBGLACIAL MELTWATER

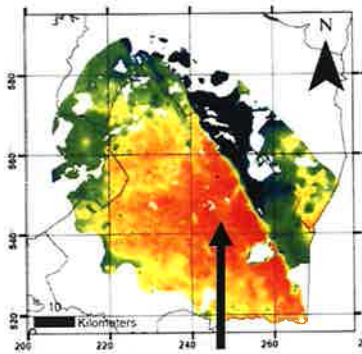
→ EROSION - SEDIMENTATION



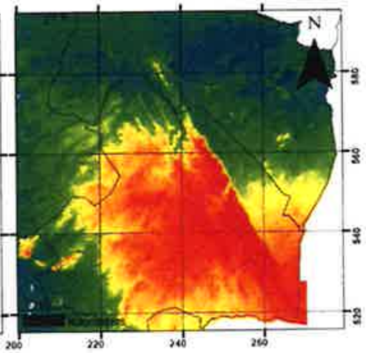
EVANS & BENN, 2007



ELSTERIAN SURFACING

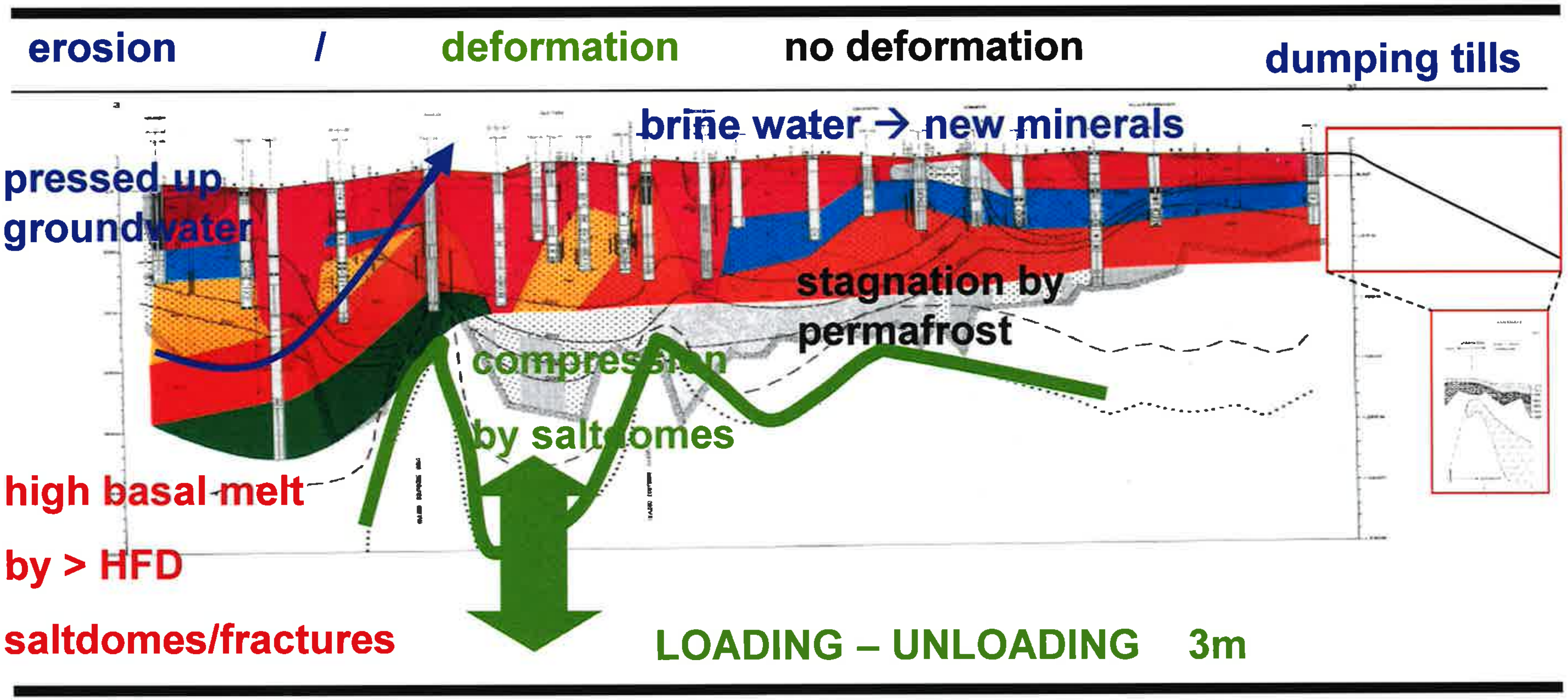


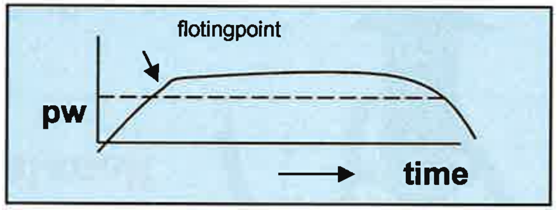
TOP ELSTER



AHN Dino, TNO

HONDSRUG – GLACIAL MODEL





GLACIAL MODEL

deformation pattern implicates alternation of:

erosion – basal sliding and – floting of the Hondsrug- Ice stream

→ **1 REFERENCE KNOWN: FÜNEN IN DENMARK, BUT LESS DETAILS ALTHOUGH YOUNGER (WEICHSELIAN)**

e.g. Jorgensen & Piotrowski, 2003

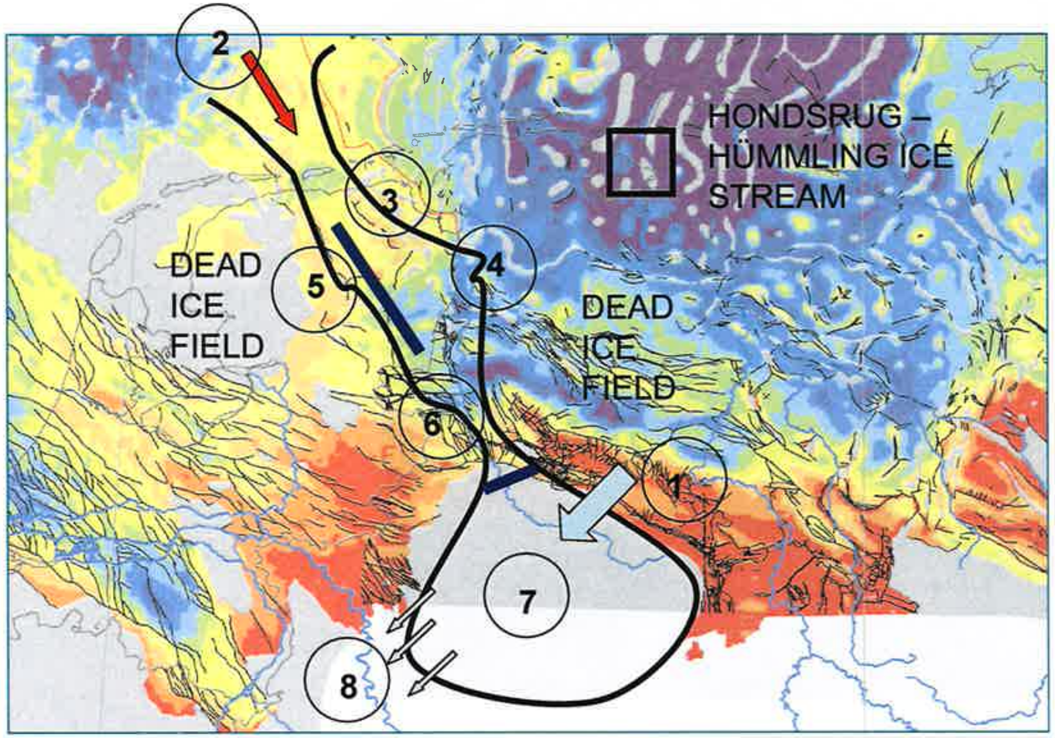
III

THE HONDSRUG – HÜMMLING ICE STREAM

- **HONDSRUG MODEL INDICATED HFD,**

  DEEP GROUNDWATERFLOW, ETC. HOW TO EXPLAIN?

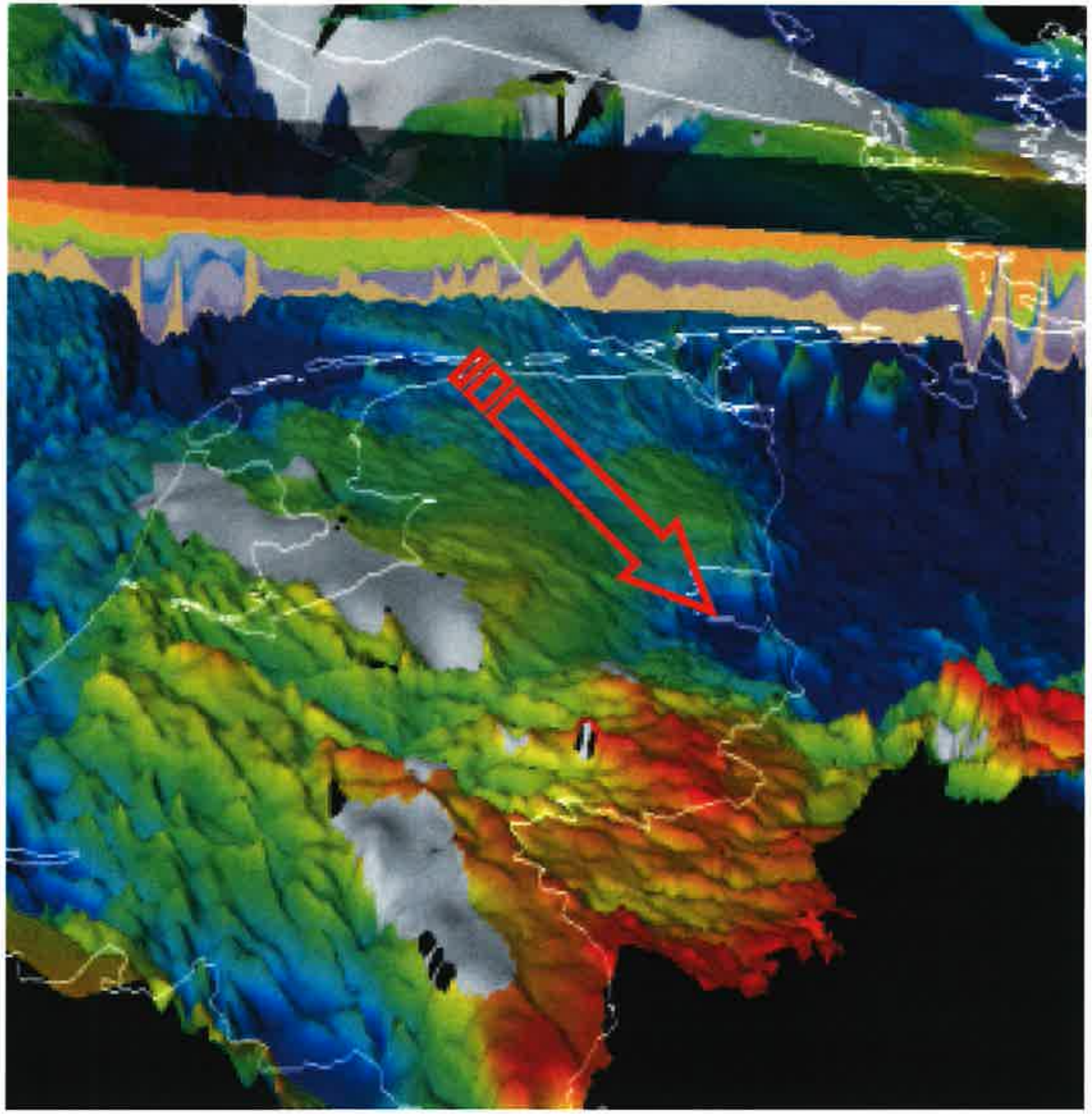
- **POSITIONING – AND START ?**



BACKLGROUND

PBA, 2011

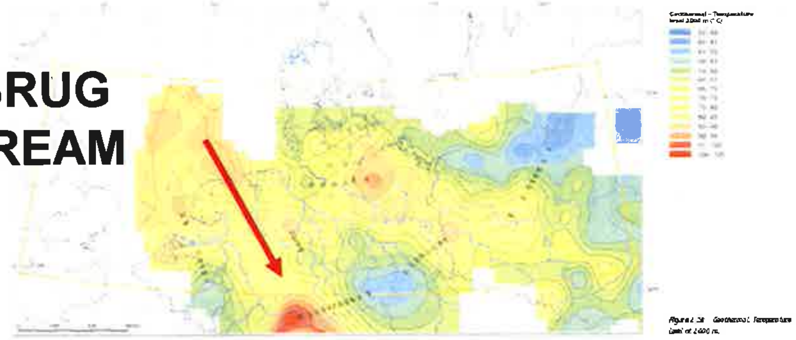
BACK TO DEEP GEOLOGY

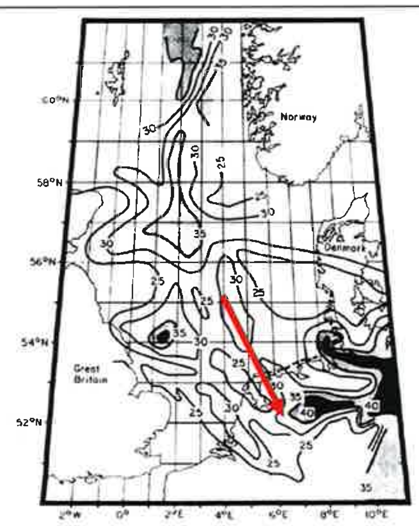


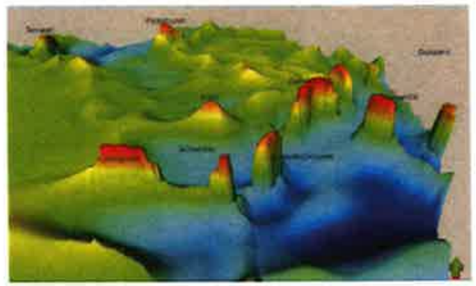
BACKLGROUND
PBA, 2011

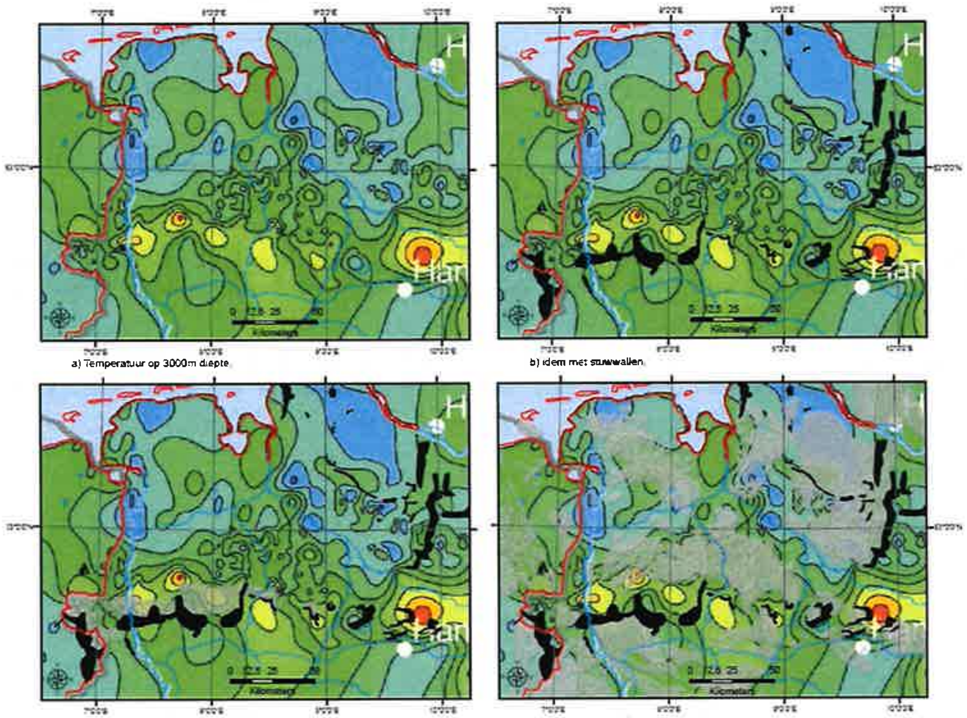
CORRELATION GLACIAL FEATURES-GEOTHERMAL HOTSPOTS

HONDSRUG ICE STREAM









a) Temperatuur op 3000m diepte

b) idem met stuwwallen

c) idem met stuwwallen en glaciale bekkens

d) idem met stuwwallen en keileemplateaus

NW EUROPE

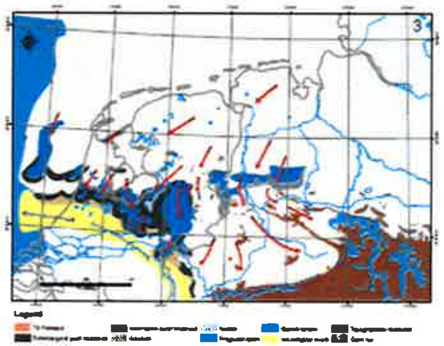
THE SAME

↓

NEW INSIGHT

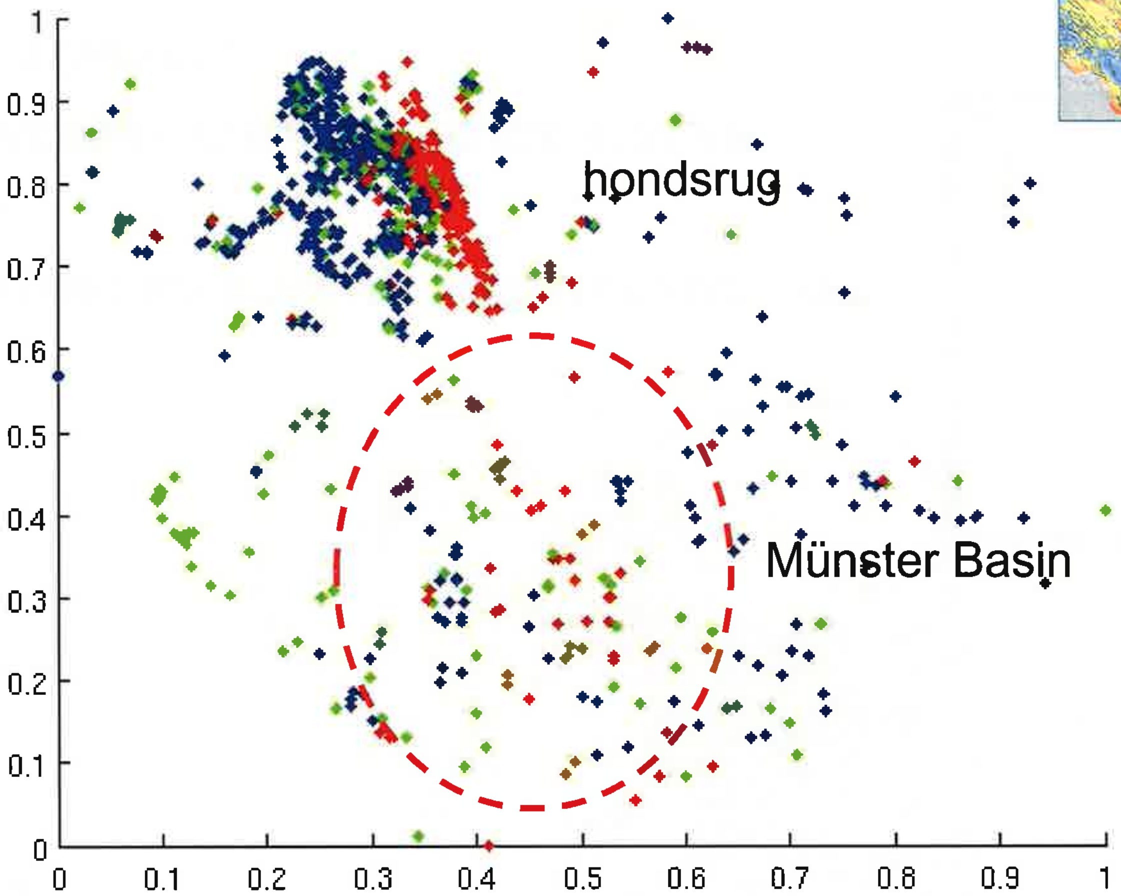
POSITIONING

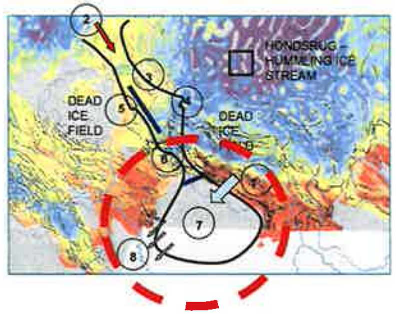
- IN BETWEEN DEAD ICE FIELDS “COLD BASE”
- SOUTH-WESTERN ICEFLOW STOPPED



- MELTWATER PRESSURE: HOTSPOT “WARM BASE”
- PATHWAY MELTWATER: GRABEN-SYSTEMS →NNW
- TRICKERED ICE FLOW

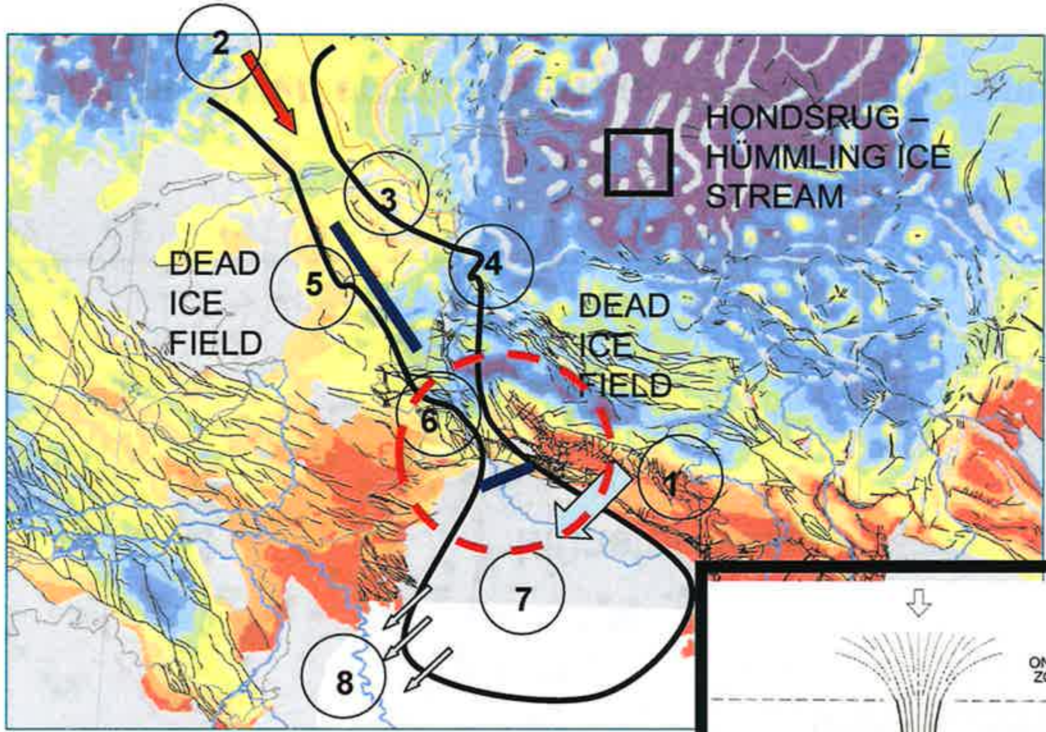
7

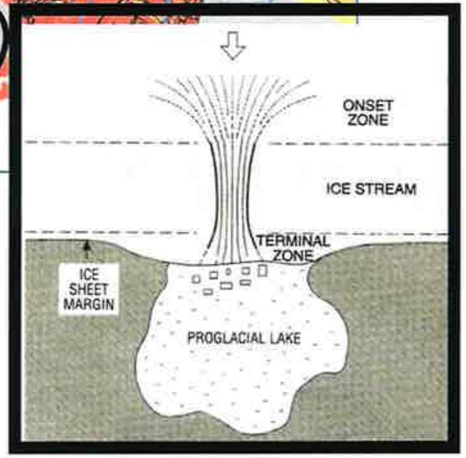




Positioning of East Baltic erratics (red) at the Hondsrug and in the Münster Basin (Van Balen, UNPUBLISHED)

4/6





CLARK & STOKES, 2005

→ **HONDSRUG ICE STREAM: LONGITUDINAL TYPE**

→ **TERRESTRIAL TERMINATING ICE STREAM, INLAND CALVING**

→ **1 SIMILAR ICE STREAM TYPE KNOWN: DUBAWNT ICE STREAM**

WHAT CONTROLLED THE HONDSRUG – ICE STREAM ?

STRONG

↓

WEAK

Winsborrow *et al*, 2010	Our study
Topographic trough	Subglacial geology
	- blocks, faults, saltdomes
	- geothermal heatflux (HFD)
Calvin margin	Inland ice margin
	Topography
	- proglacial valleys
Soft bed	Abundant meltwater
	- waterpressure
Abundant meltwater	Soft bed
Smooth bed	Smooth bed
Geothermal heatflux	Controlled pathway
Topographic step	- obstacles

MAIN GEOLOGICAL REASONS TO BE EUROPEAN GEOPARK

- IN EUROPE UNIQUE PRESERVED SAALIAN FEATURE
- FORMED BY SUBGLACIAL MELTWATER
- WELL STUDIED: KEY AREA FOR SCIENCE
- WORLDWIDE 2.KNOWN ONLAND ICE STREAM

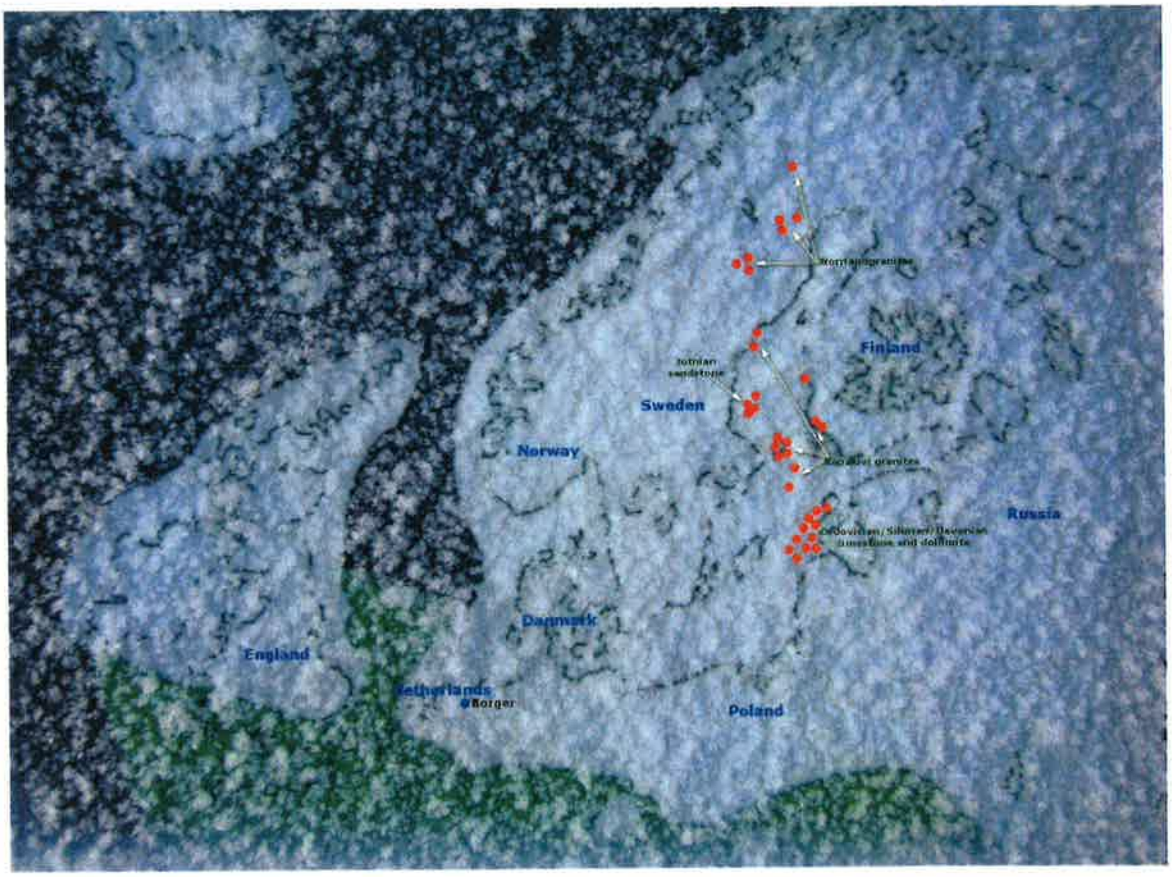


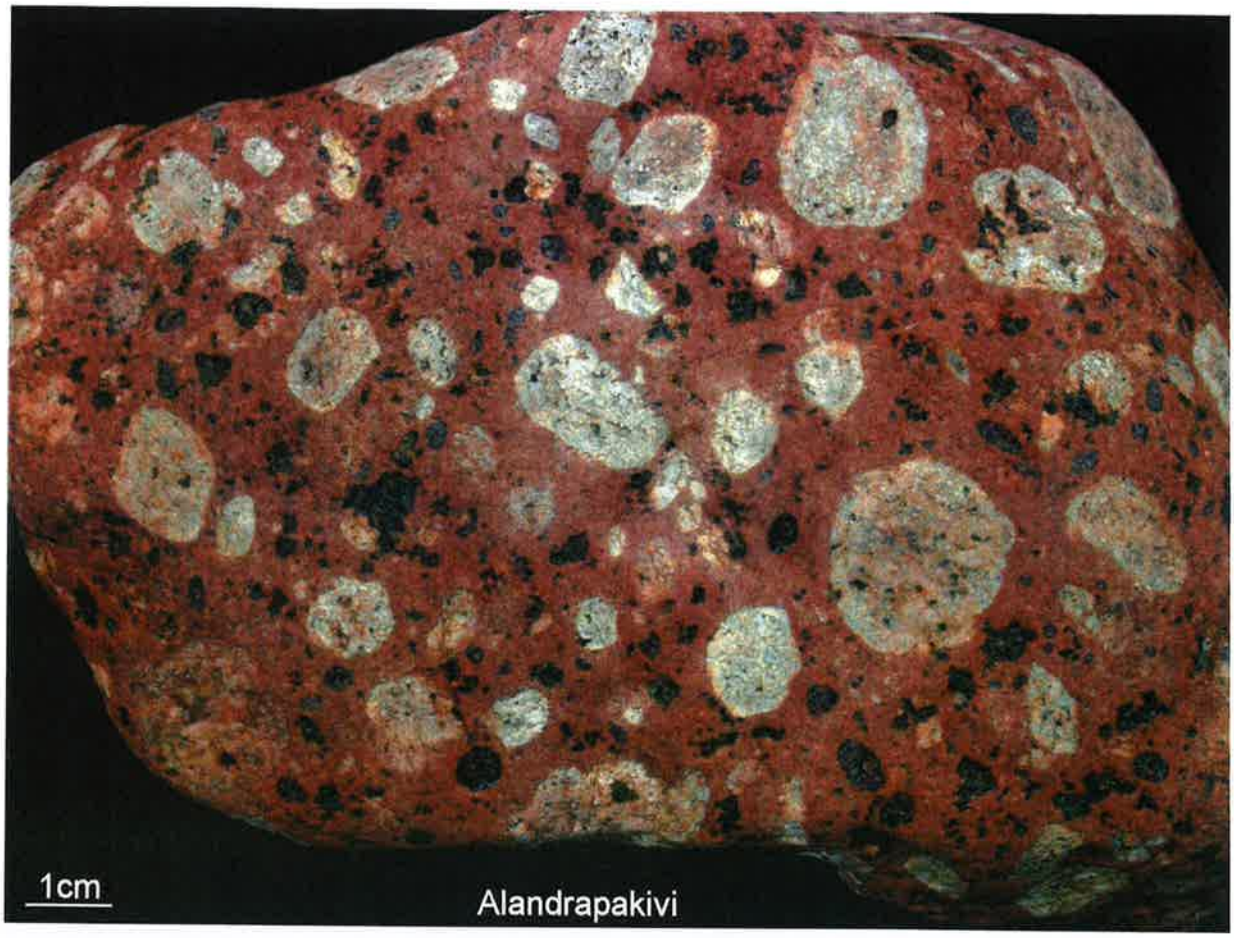
The Saalian boulder garden (H.Huisman)

Just outside the Hunebedmuseum in Borger you will find a large terrain completely covered by thousands of boulders. Among them there are many big ones, but most of the boulders are quite smaller. All of these boulders have been brought together almost by one person, to build the biggest glacial boulder garden in the Netherlands.

During the Saalian ice age, some 150.000 years ago, Scandinavian inland ice covered almost half of the Netherlands. In the very last phase of the Saalian glaciation an icestream moves from the North Sea Basin southeastward over the eastern part of the province of Drenthe. After melting away the ice leave thick layers of till and an enormous amount of erratics. Most of the erratics come al the way from the northeastern part of Scandinavia, e.g. Finland, Botnian Gulf and Northern Sweden.

Some of the erratics are so called indicator boulders. Investigations have shown us the area of origin in Scandinavia from which these boulders are derived. In the Hondsrug area we can find a hugh amount of red rapakivigranites, which come from the Aland Isles in southwest Finland, some 1500 kilometers away. You will find many of them in our boulder garden.




1cm
Alandrapakivi

Stop 2 Mekelermeer

We visit the newest Geoheritage Monument in the Province of Drenthe and will explain our aim and approach.

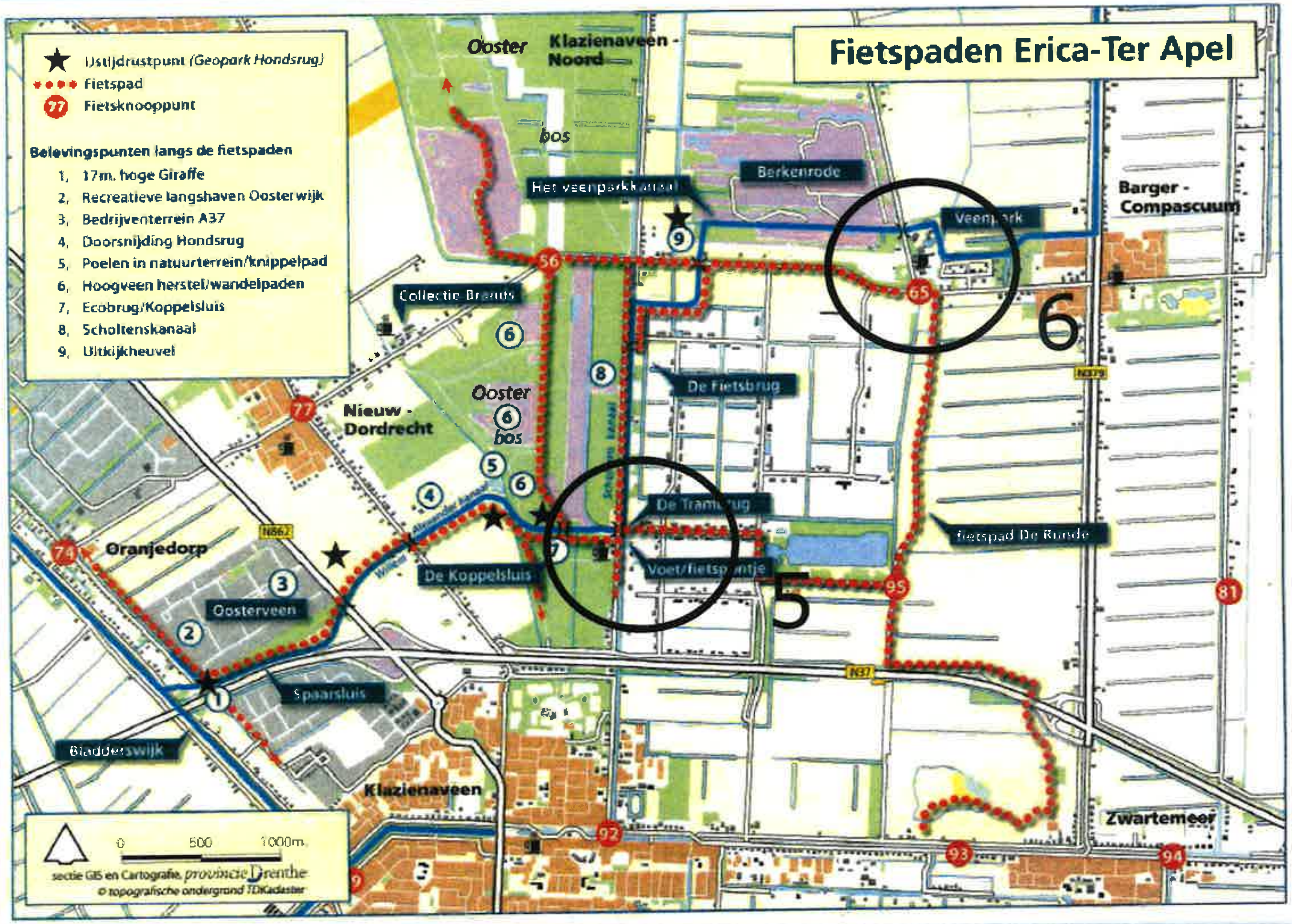
Results of scientific research will be presented by dr. Wim Hoek, who also had the floor in the presentations yesterday.

Let us discuss also our approach of the Pingo Program as presented by Anja Verbers. What are the possibilities for international cooperation?

Stop 3 South East Drenthe; Koppelsluizen

We will visit the new Koning Willem Alexander canal with locks (sluices). The canal connects waterways for The Netherlands to Germany and transverse De Hondsrug. Although from geoheritage point of view not ideal, we found opportunaties to integrate different functions and to expose geoheritage much more than before..........

provincie Drenthe

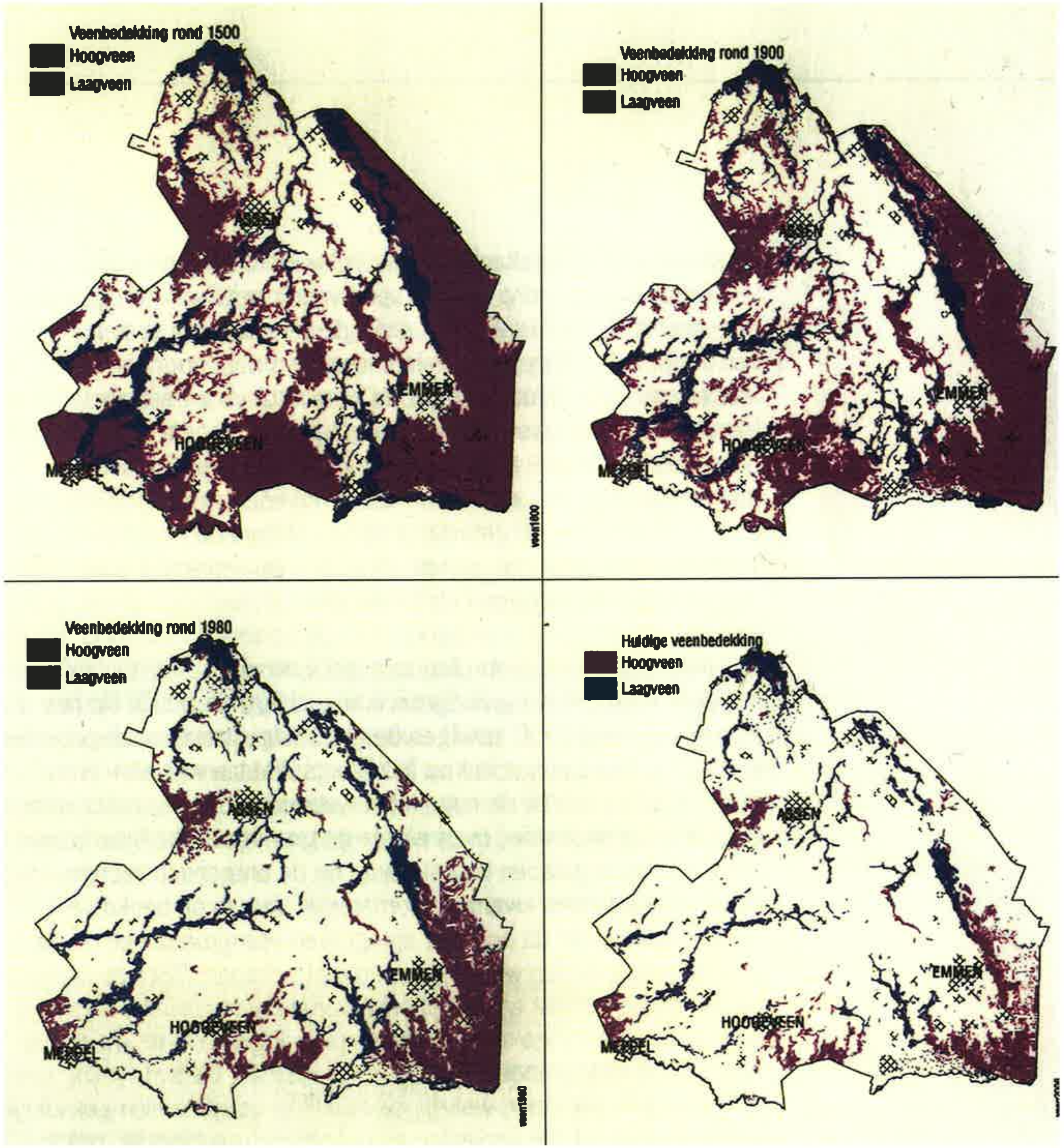


Stop 4 Veenpark (Moorpark)

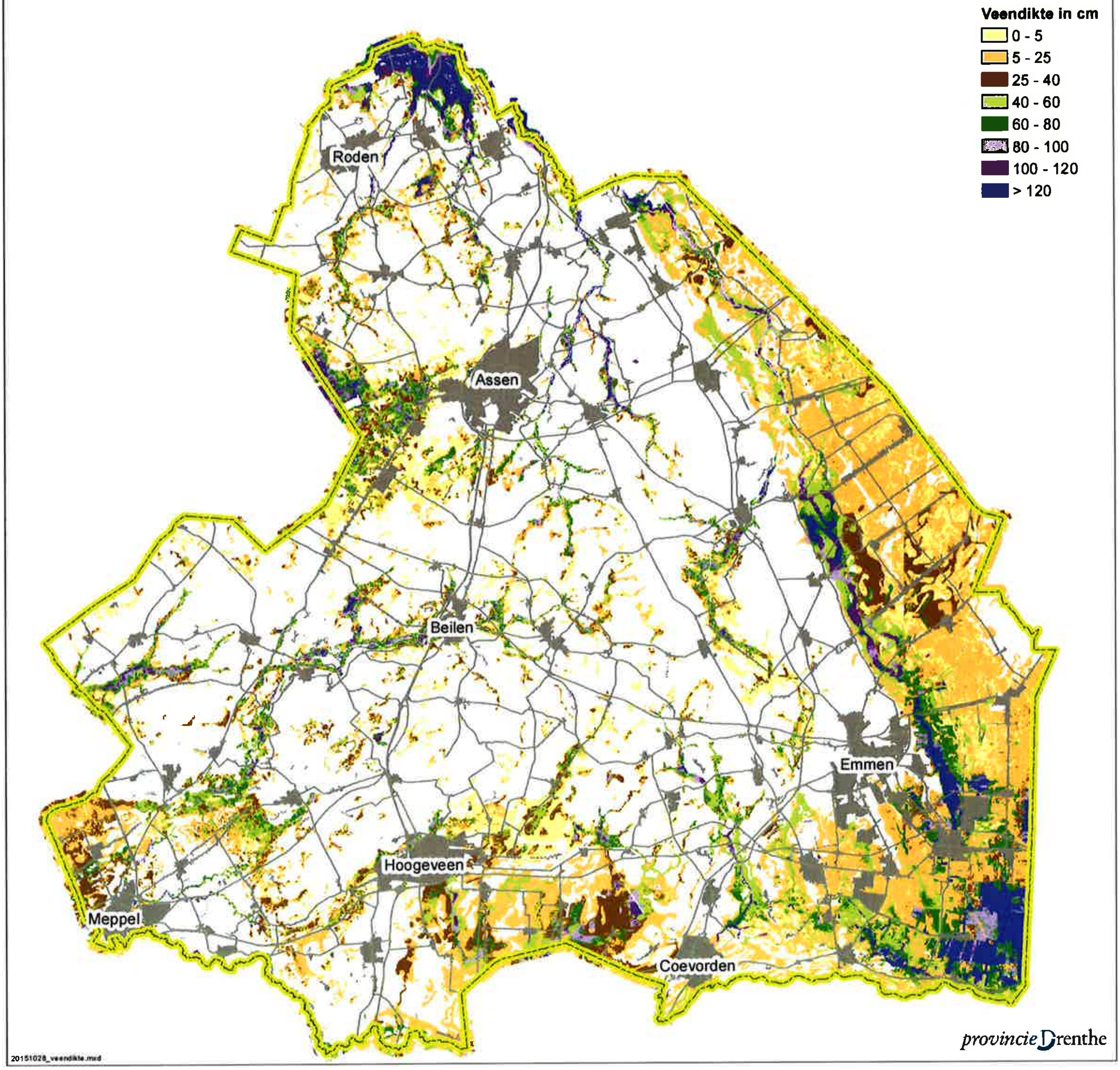
In the park all is related to peat: how raised bogs formed, how digged and used for fuel, the people and how new landscapes are formed. On our road to the park - before – we see canals to drain the raised bogs and to transport peat to mainly the western part of the Netherland.

The history of peat will be introduced by dr. Michiel Gerding, who also explains more about the peat exposition.

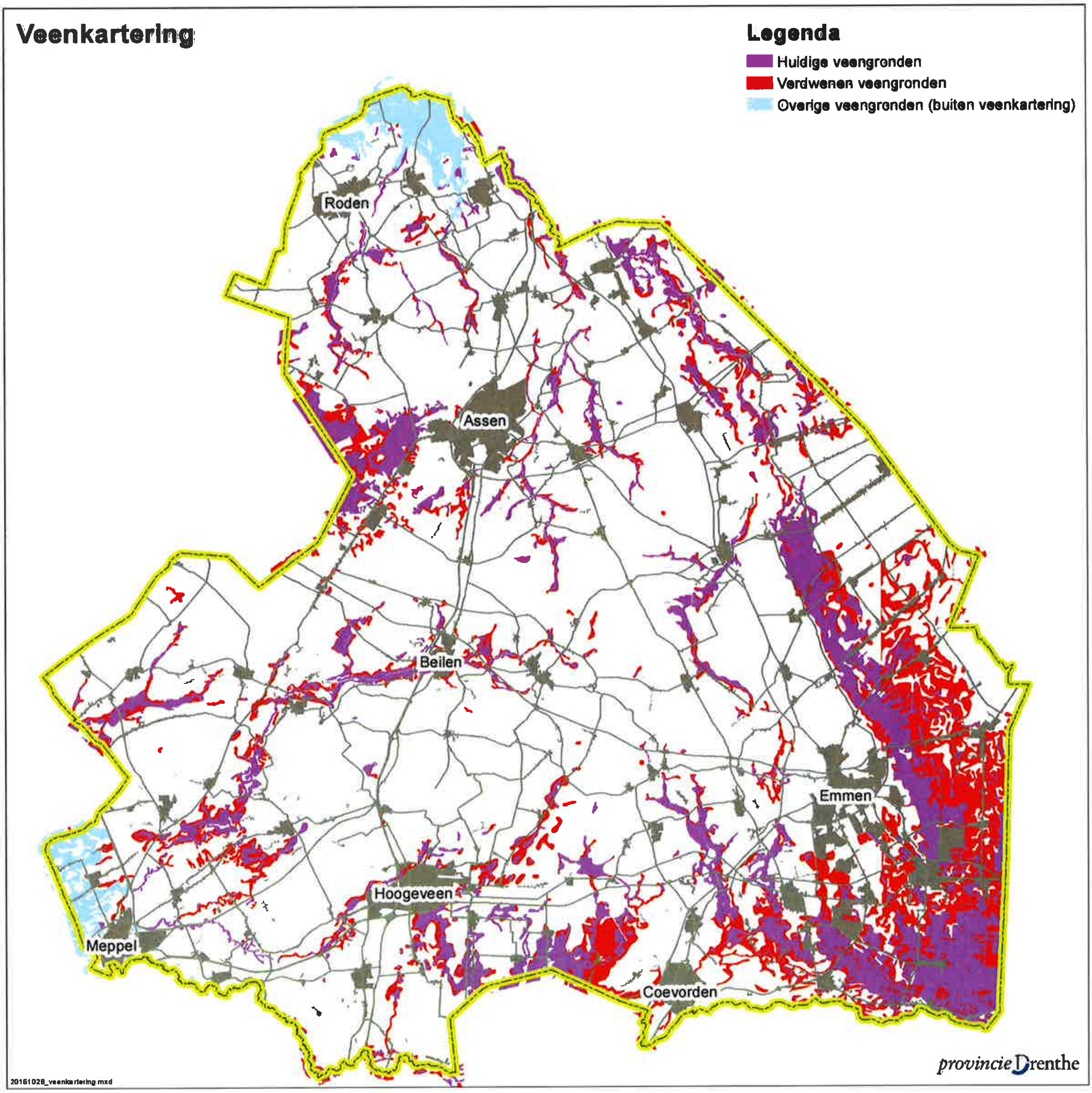
PEAT DEGRADATION



Veendikte

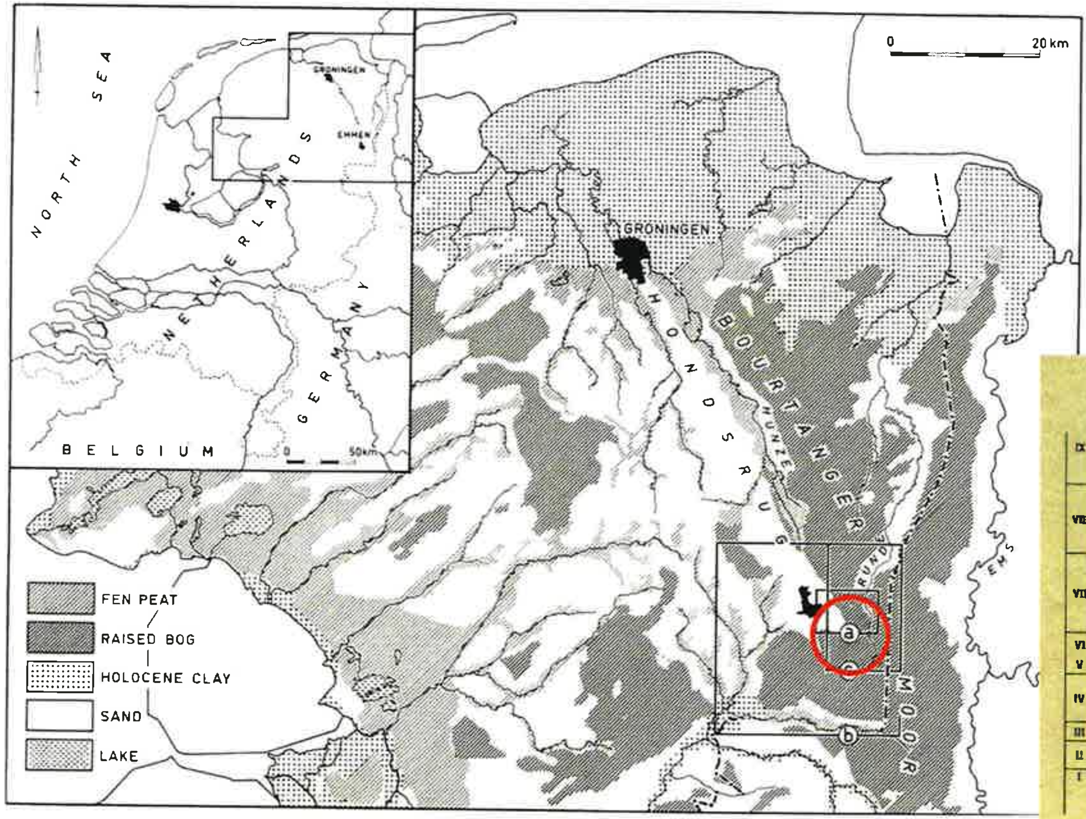


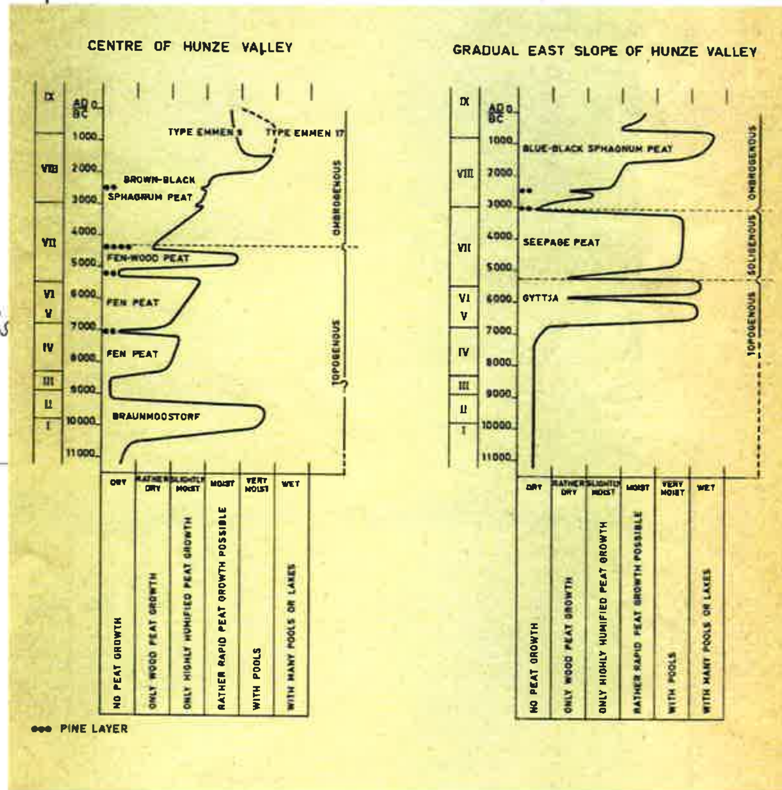
Legenda
Veendikte in cm
0 - 5
5 - 25
25 - 40
40 - 60
60 - 80
80 - 100
100 - 120
> 120
Roden
Assen
Beilen
Emmen
Hoogeveen
Meppel
Coevorden
provincie Drenthe
20151028_veendikte.mxd



Veenkartering
Legenda
Huidige veengronden
Verdwenen veengronden
Overige veengronden (buiten veenkartering)
Roden
Assen
Beilen
Emmen
Hoogeveen
Meppel
Coevorden
provincie Drenthe
20151028_veenkartering.mxd

RAISED BOG BOURTANGER MOOR





OVERGROW THE HONDSRUG RIDGES IN 2000 YEARS....

Canals and energy. The relationships between canals and the extraction of peat in the Netherlands 1500-1950.

Dr. Michiel A.W. Gerding
Historian of the province of Drenthe
P.O. Box 117
9400 AC Assen
Netherlands
m.gerding@drentsplateau.nl

Defintions:

-**peat**: the geological formation
-**turf**: the material noun for the dried substance
-**a turf**: a block of dried peat, predominantly used for fuel
-**black turf**: peat used for fuel
-**peatlands**: fens and bogs (moors) from which peat (turf) is extracted
-**dagwerk:** the amount of turf dug by a team of workers in one day. By average 10.000 blocks.

INTRODUCTION

Fens and bogs, peatlands, are in the words of Julius Caesar "land that can not be walked upon and water that can not be sailed on". That it can be used for fuel is first recorded by Plnuius the Elder, who in his *Naturalis Historia* (77 A.D.) mentions people who dug lumps of earth which they dried in wind and sunshine and then set fire to in order to cook their food and warm their houses. He writes about a people living in the delta of the river Rhine, now the Netherlands. Apart from this singular quote, almost nothing is recorded about the use of peat for fuel until well into the Middle Ages, and then only from the Low Countries (Flanders and the Netherlands). Yet millions of hectares of peatlands exist north of the Alps.

In the history of the use of peat for fuel it is neccessary to make a distinction between the peat digging for domestic use only and the peat production on a larger scale in a businesslike operation intended for larger markets. We will concentrate on the latter. Outside the Netherlands the literature on peat and his history appears to be very scarce or virtually nonexistent. If this means that elsewhere peat wasn't used for fuel or that is has never been a subject of scientific study has yet to be ascertained. In either case only of the Low Countries a comprehensive overview can be given.

The reason for the widespread use of peat for fuel in the Netherlands and Flanders lies in the lack of firewood on the one hand and the abundance of waterways (rivers and canals) on the other hand. The relatively low costs of transportation of the bulky material combined with the engineering skills of the Dutchmen in controlling the water and managing waterways were crucial in the proliferation of the use of peat for fuel. From the early Middle Ages on until well into de twentieth century peat (turf) was **the** source of fossil energy in the Netherlands.

The Flanders cities of Antwerp, Gent and Brugge were the first to invest in large-scale peat production from ca. 1250 A.D. onwards. From there it spread northwards so that in the fourteenth century the fens in a large parts of Holland, the most important province of the Netherlands (with cities like Amsterdam, Leiden, Delft and Haarlem) were brought into production. A crucial step in the development was the introduction in 1513 of the "dredger" (bagger-beugel), a bucket on a long wooden pole of about 4 meters. Now it was no longer necessary to drain the fens first before the peat could be cut and dried. The wet peatmud could be dredged directly from the water and stored into small boats and then be spread out on nearby fields to be cut and dried. The production soared and coincided with the strong economic and demographic growth of the Netherlands in the sixteenth and seventeenth century ('Golden Age'). It has been argued that the Dutch Golden Age was born of peat. If the total energy supply would have relied on wood, a quarter of the present area of the country would have been covered completely and permanently with producing forest. Furthermore, the absence of waterways would have required ca 100.000 horses for the transport of fuel and a further 600.000 ha of cultivated area to feed them. Thus the energy-attainability gave the Dutch Republic a tremendous advantage.

The dredging of low peat turf had one major disadvantage: the loss of land was enormous. In the course of time lakes replaced pastures en threatened the nearby countryside. Strict regulations were issued and taxes laid to form funds from which new polders could be formed. This, and the demand for energy caused the Dutch merchants to look elsewhere in the country.

PEAT AND CANALS

In the Pleistocene north-eastern part of the country 140.000 ha. of good quality black peat was available in 1500 A.D. From the middle of the seventeenth century onwards this was the most important area for the production of fossil fuel. Contrary to the dredging of low peat turf , the high peat areas had to be drained first. There is no possibility of commercial exploitation without the construction of a comprehensive system of waterways. The canals performed two vital functions. Firstly in the draining of the bogs and secondly in the transportation of the product (peat) to the markets.

Thus a complete infrastructure of waterways had to be build in order to drain before peat bogs could be taken into exploitation. This required large investments which only conglomerates of investors could make. Rich merchants from Dutch cities like Amsterdam and Leiden and also local nobility and city and regional governments formed Peat companies ("Veencompagnieën"), which were in effect mainly canal-companies. Most of the work in the peateries itself was done by subcontractors and private entrepreneurs.

THE CASE OF THE NORTHERN NETHERLANDS

In the period between 1550 and 1950 peat digging played an important role in the northern parts of the Netherlands. At the outset this was limited, but from the seventeenth century onwards it's role increasingly grew in importance. During these four hundred years around 100,000 hectare raised bog peat and 42,000 hectare fenland peat was converted to dry peat fuel. Some 16.6 x 10^{11} turfs were dug, representing a combustion value of 3.5 x 10^9 gigajoules. Comparable with 8300 million tons. This peat was excavated from 62 raised bog areas and 11 fenland areas that lay in the regions - later to become the provinces - of Groningen, Friesland, Drenthe and Overijssel. An average depth of 2 meters (12 layers) of winnable peat was reckoned with.

The first quarter of the seventeenth century saw the appearance of numerous new peat companies. By 1625 we can talk of a considerable output. It is estimated that this fulfilled around forty percent of national energy requirements of the time. In the second half of the seventeenth century a decline set in that was to last until around 1750. A gradual expansion set in after 1750, which increased rapidly in the first quarter of the nineteenth century, due in main to the fact that a number of large new peat bogs were brought into production. Peat production was at its peak between 1875 and 1925, with 1920 being the top year, when under the influence of the First World War, a record production of 165,000 man days was reached. During the structural crisis which afflicted the peat industry thereafter production collapsed. By 1939 peat was providing just 3 percent of the national energy requirements, and by 1950 this figure must have been even lower.

It is possible however, to detect various waves of development in the exploitation of the peat bogs in the northern Netherlands. The first wave occurred in the first half of the seventeenth century. A second wave occurred in the second half of the eighteenth century, when the national economy began once again to expand. In the second quarter of the nineteenth century new and important peat bogs were developed. Finally, after 1850 two important peat bogs were brought into production. During these four waves of development a certain shift from centre to periphery can be observed. First to be developed were the areas which were most accessible and relatively easy to open up. The centre can be defined as the cities, such as *Groningen*, *Leeuwarden*, *Kampen* and *Zwolle*, and also main connecting waterways such as the *Zuiderzee* and to a lesser extent the *Waddenzee* and the river *IJssel*. This shift from centre to periphery can also be seen within various peat colonies. Starting out from a main waterway digging would proceed inwards into the peat bog. Although a natural progression from one area to another can be detected, new initiatives were always taken, as has been mentioned above, for economic motives. Some initiatives can clearly be seen to be the result of exhaustion of older peat bogs.
There was often a period of twenty years between the signing of a contract or the granting of a charter and the transportation of the first turf.

In 1650 approximately 3,000 workers plus their families were sustained for the greatest part of the year by work in the peat colonies. On top of this another 2,500 found seasonal work during the so-called *campaign*. In 1650 there would have been around 3,975 boatmen involved in the shipment of peat, on an average of 100 days per annum. By 1875 however, due to the increase in the carrying capacity of both the canals and boats this figure had declined to 2,600, that is 0.025 boatman per *dagwerk* production from the peat colonies. In the peat markets one *dagwerk* peat provided some 4 man days work. For packers, who would pack standard measures in baskets; for stevedores who would load and unload the boats and for hauliers who would carry the peat to the customer.

THE TRANSPORTATION OF PEAT

Transportation costs were a very large part of the consumer price for peat: forty percent or more. Part of these costs is to be accounted for by tolls for the use of canals, locks and moorings and another part can be accounted for by duties.

Canal ownership and management was not generally a lucrative business. The high cost of construction and maintenance of the infrastructure ruined many a peat company. Most company failures can be traced back to this. Where an initiative survived this was due to extra capital injections. The costs were nearly always underestimated and the revenues over exaggerated. Until around 1830 the cities were the main beneficiaries of that other large component of the transportation costs, duties. Especially those cities outside peat digging regions profited most. Despite the difficulties faced by many peat and canal companies, the Dutch waterways were perfectly suited for this energy form. Central to the transportation of peat, and in fact to the waterways in general, was the *Zuiderzee (IJsselmeer)*. It was the perfect link in the inland water transportation system, between the west of the country on the one hand and the north and east on the other.

RESULT

Of the 140,000 hectare of peat bogs in the north of the Netherlands only a few small remnants, in the form of nature reserves, remain. The rest has been turned either into agricultural land or woodland or earmarked for property development. With the peat bogs we can talk of two phases of cultivation, the first being the peat digging itself and the second being the cultivation of the land underneath. Between the ending of the first and the beginning of the second were sometimes centuries. In order to turn the excavated peat bogs into arable land a large amount of fertilizer was needed. It was only with the arrival of artificial fertilizers at the end of the nineteenth century that large scale re-cultivation could begin. As a result of the peat digging a close-meshed system of waterways evolved that was not merely of importance for the peat industry, but was also of importance for drainage of water from the land and the transportation of other products to and from the north. To a degree this is still the case. It has been calculated that 700 kilometres of waterway were dug for the peat industry. The transportation of peat led to a class of boatman, who besides the distribution of energy played an important role in the transport of other bulk good. Due to the excavation of peat countless new settlements arose, some of which have developed into small cities and some of which have grown into relatively heavily populated regional centres. The peat industry was an important driving force in the national economy. A considerable part of the peat industry output was exported from the region, but much remained, supplying, as well as domestic users, various forms of industry with energy. For the region itself thus, peat digging played a vitalizing role. Peat production was a powerhouse both in and outside the region.

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