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ORIGINAL PAPER

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Quantification of recent movement potentials in Schleswig-Holstein (Germany) by GIS-based calculation of correlation coefficients

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Abstract In order to investigate connections between deep tectonic and halokinetic structures and the development of recent topography, GIS-based calculation of correlation coefficients was carried out between different stratigraphic horizons of the deep Northwest German Basin (NGB) according to the "Geotektonischer Atlas von NW-Deutschland" and surface topography of Schleswig-Holstein. The results show seven areas of high correlation that are traceable from the Base Zechstein up to the recent surface topography. Five areas with high correlation are connected to NNE–SSW trending salt structures within the Glückstadt Trough, i.e. the area of the salt domes Oldensworth, Tellingstedt, Eisendorf and, to the north of Hamburg, the area of the salt domes Elmshorn and Sievershütten. Two areas, however, with NW–SE trending high correlation are located in the northwest (restricted to the Westschleswig Block) and the northeast (south of Fehmarn) outside the Glückstadt Trough. These NW–SE trending correlation areas are not related to known salt structures and/or faults but match the general orientation of faults in the NGB.

Keywords GIS · Correlation coefficient · Northwest German Basin · Recent crustal movement · Trend analysis

Introduction

The study area Schleswig-Holstein is located in the north of Germany and is bounded there by Denmark and the North Sea. To the south the study area is bounded by the federal states Niedersachsen and Hamburg. The river Elbe marks the borderline. To the east the study area is bounded by the federal state of Mecklenburg-Vorpommern and by the Baltic Sea (Fig. 1).

Geologically the study area is positioned in the Northwest German Basin (NGB), which is a part of the Central European Basin (CEB). The NGB can be subdivided into four major structures, i.e. Westschleswig Block, Mittelholstein Block, Hamburger Block and Ostholstein Block (Weber 1977) (Fig. 2). The study area is characterised by a high number of tectonic faults and salt structures that are caused by diapirism of Permian salt (Baldschuhn et al. 1996) (Fig. 2).

This article illustrates a trend analysis of the influence of tectonic faults and salt structures on the development of recent surface topography by correlating several isopach maps of the "Geotektonischer Atlas von NW-Deutschland" (Baldschuhn et al. 1996) with a digital elevation model (DEM) of Schleswig-Holstein's recent topography.

Related studies investigated recent crustal movement. Since the beginning of the Rupelian, subsidence for the study area as high as 300 m is documented by Garetsky et al. (2001). For the area of the former GDR 20 recent active faults have been mapped (Ihde et al. 1987) and for the area of the river Hunte, Lower Saxony, active tilting of the NGB is documented by Szeder and Sirocko (2005). Sirocko (1998) investigated the development of the northeast German rivers and shows a connection between the courses of rivers and locations of neotectonic faults. Offhaus (1999) has analysed statistically the geological processes for the Salzwedel-Peckensen reservoir. We go one step further and try to quantify recent movement potential by a GIS-based calculation of correlation coefficients.

Method

The GIS-based calculation of correlation coefficients between several stratigraphic horizons of the NGB and a DEM of Schleswig-Holstein's recent topography is based on the Bravais-Pearson correlation coefficient r_{xy} (e.g. Mudelsee 2003).

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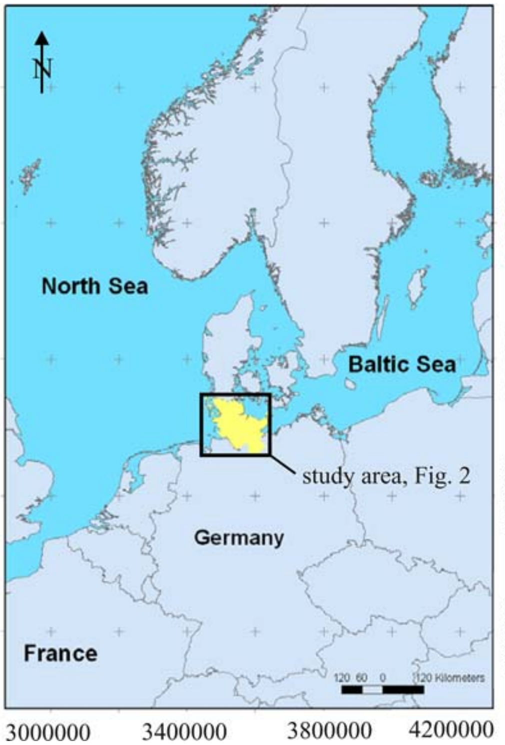


Fig. 1 Location map of the study area

Input data

The input data for the DEM of the recent topography of Schleswig-Holstein (resolution: 50 m×50 m/cell) was developed on the basis of contour lines of the topographic map of Schleswig-Holstein, which have a vertical resolution of 0.25 m (scale 1:50,000).

The input data for the stratigraphic horizons come from the "Geotektonischer Atlas von NW-Deutschland" (scale 1:300,000), which has 14 isopach maps altogether from the Base Zechstein up to the Base Middle Miocene/Pliocene, based on evaluated seismic lines (Baldschuhn et al. 1996). Each isopach map has a vertical resolution of 150 m and contains information about salt structures, tectonic faults and relief. Contour lines of each horizon have been interpolated to a grid (isosurface) with a horizontal resolution of 50 m×50 m/cell for the purpose of calculating correlation coefficients.

A horizontal cell size of 50 m×50 m has been selected for both the DEM of Schleswig-Holstein and the grids (isosurfaces) of stratigraphic horizons in order to synchronise input data for calculation of correlation coefficients.

Correlation coefficient

Generally the correlation coefficient r between two variables x and y is found by dividing their covariance S_{xy} by the product of their standard deviations $S_x S_y$:

$$r_{xy} = \frac{S_{xy}}{S_x S_y},$$

whereas

$$S_{xy} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})$$

describes the covariance and

$$S_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2},$$

$$S_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \overline{y})^2}$$

describe the standard deviation of variables x and y.

Values of r_{xy} lie in the dimensionless range -1 to $+1$. In the present case the two variables x and y are the stratigraphic horizons, Base Bunter and Base Middle Miocene/Pliocene (Fig. 3). The correlation is ideally $+1$ in the case of a perfect positive linear relationship (Fig. 3) and ideally -1 in the case of a perfect negative linear relationship (Fig. 3; Fahrmeir et al. 2001). Thus the Bravais-Pearson correlation coefficient indicates the degree of linear dependence between the two variables Base Bunter and Base Middle Miocene/Pliocene. The closer the coefficient is to either -1 or 1, the stronger the correlation. A correlation coefficient of 0 indicates a nonlinear relationship or no relationship (Fig. 3; Hartung 1998).

The software used for calculation was ArcView 3.2 with an additional "local-correlation" script extension. This script calculates correlation coefficients between two grids (= stratigraphic horizons) within n overlapping zones (focuses). A horizontal focus of 24 grid cells (= 1.2 km) was selected for all figures within this article. The centre cell of each zone was assigned with the respective correlation coefficient r. Using a moving window principle every grid cell was assigned a respective correlation coefficient r.

With regard to the focus on areas with highest movement potential the figures point out correlation coefficients between 0.75 and 1 (respectively, -0.75 and -1) (Figs. 4, 5, 6, 7, 8, 9, 10).

Calculation of errors

Even if the calculation of correlation coefficients does not include calculation of errors, errors may appear in input data, i.e. isopach maps and topographic map of Schleswig-Holstein. Thus errors in input data may propagate in correlation coefficients. On the basis of available information about location of reference points and seismic lines within the "Geotektonischer Atlas von NW-Deutschland" a detailed error discus-

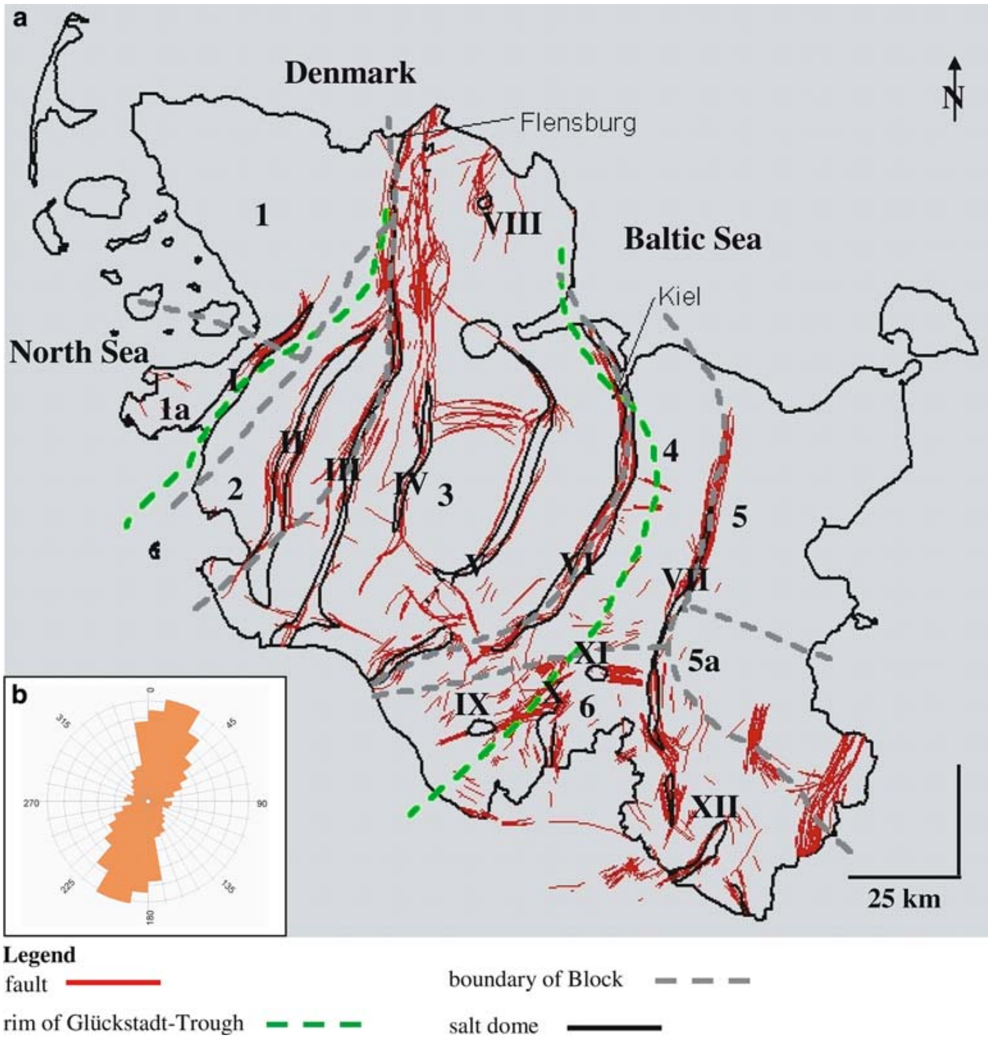


Fig. 2 **a** Study area with salt structures, faults from Base Zechstein to Base Middle Miocene/Pliocene, location of the Glückstadt Trough (after Baldschuhn et al. 1996) and the boundaries of blocks (after Weber 1977). **b** Strike direction of faults from Base Zechstein to Base Middle Miocene (after Baldschuhn et al. 1996). Salt structures: *I* Oldensworth, *II* Hennstedt, *III* Tellingstedt, *IV* Oldenbüttel, *V* Eisendorf, *VI* Warnau, *VII* Segeberg, *VIII* Sterup, *IX* Elmshorn, *X* Quickborn, *XI* Sievershütten, *XII* Geesthacht. Blocks: *1* + *1a* Westschleswig Block, *2–4* Mittelholsteinische Scholle (*2* Heider Trog, *3* Rendsburger Schwelle, *4* Bramstedt/Kieler Trog), *5* + *5a* Ostholstein-Mecklenburg Block, *6* Hamburger Scholle

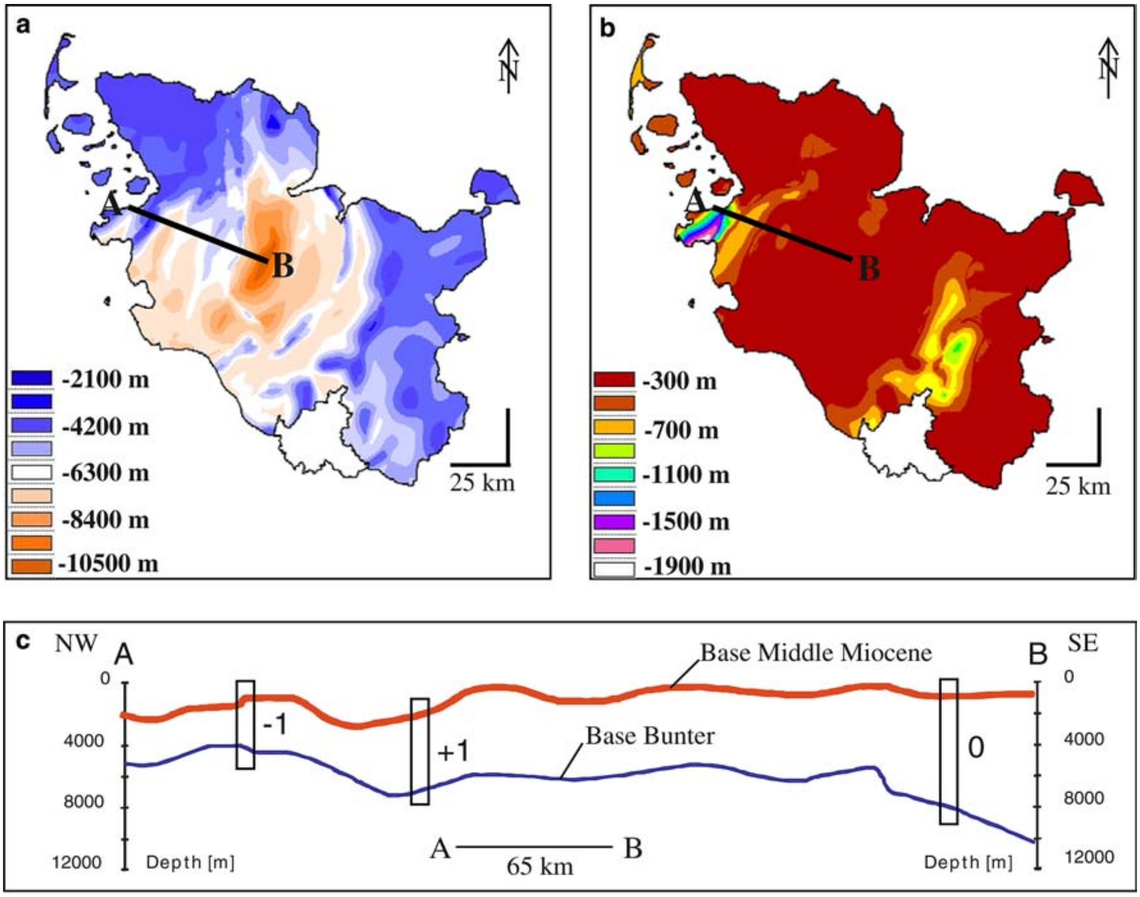
sion is not possible. Errors grow with increasing distance to reference points (evaluated cores) and seismic lines.

Results

The correlation between Base Zechstein and Base Bunter is dominated by a generally high positive correlation coefficient (Fig. 4). However, correlation areas are mostly restricted to areas where salt structures are located. The spatial dimension of salt structures is bound by the salt wall Oldensworth in the west of the study area (Fig. 4, I) and the salt wall Segeberg/Plön in the east (Fig. 4, VII). Outside the area where salt structures appear, subsidiary correlation areas are represented, i.e. the northwest (Fig. 4, XIII) and the northeast (Fig. 4, XIV) of Schleswig-Holstein. Thereby the correlation areas, especially in the northwest of the study area, show clear NW–SE trending (Fig. 4).

Figure 5 deals with the correlation between Base Zechstein and Base Lower Cretaceous. The results show that, compared to Fig. 4, areas of high positive correlation have decreased while areas of high negative correlation have increased.

The calculation of correlation coefficients between Base Zechstein and Base Upper Cretaceous reveals that areas of high positive correlation still dominate, while their appearance is increasingly concentrated on the extension of salt structures (Fig. 6). Two major areas of high positive correlation are located along the salt wall Oldensworth in the west of the study area (Fig. 6, I) and along the salt wall Segeberg/Plön in the east (Fig. 6,



Profile A-B (further explanation in the text)

Fig. 3 Isopach map of **a** Base Bunter and **b** Base Middle Miocene/Pliocene for the area of Schleswig-Holstein (basic data after Baldschuhn et al. 1996), with **c** profile *A–B* for Base Bunter (*blue*) and Base Middle Miocene/Pliocene (*orange*) and schematic description of linear relationships

VII). These areas of high positive correlation from the north of Schleswig-Holstein to the southwest reflect the western and eastern rims of the Glückstadt Trough.

Areas of high negative correlation are larger. Altogether four major negative correlation areas can be detected: around the salt dome Sterup (Fig. 6, VIII) in the north of Schleswig-Holstein; between the salt walls Oldensworth (Fig. 6, I) and Hennstedt (Fig. 6, II); east of the salt wall Oldenbüttel (Fig. 6, IV); and between the salt walls Warnau (Fig. 6, VI) and Segeberg (Fig. 6, VII). The correlation areas around the salt dome Sterup illustrate the dependence between salt rise and the development of a marginal area of depression with its circular structure.

The NW–SE trending high positive correlation areas in the northwest of the study area are still traceable (Fig. 6, XIII). It should be noted that they are located outside the Glückstadt Trough.

Correlation of Base Zechstein with Base Middle Miocene shows a further decrease in areas of high positive correlation, associated with an increase in areas of high negative correlation (Fig. 7). Thus two major negative correlation areas are located between the salt walls Oldensworth (Fig. 7, I) and Hennstedt (Fig. 7, II) and to the west of the salt wall Segeberg/Plön (Fig. 7, VII). Major areas of high positive correlation are concentrated around the salt domes Sterup (Fig. 7, VIII), Oldensworth (Fig. 7, I), Tellingstedt (Fig. 7, III), Segeberg/Plön (Fig. 7, VII), Eisendorf (Fig. 7, V) and the salt walls Elmshorn (Fig. 7, IX) and Quickborn (Fig. 7, XI) to the northwest of Hamburg. Several minor areas of positive correlation are also associated with salt structures. The NW–SE trending positive correlation areas have also decreased, but they are still traceable (Fig. 7, XIII).

Due to poor data coverage for the horizon Base Middle Miocene correlation coefficients could not be calculated area wide (Fig. 7).

Figure 8 shows the result of the correlation between Base Zechstein and a DEM of Schleswig-Holstein's recent topography. The allocation pattern of both areas of high positive correlation and areas of high negative correlation is more scattered than before; the extension of the single correlation areas is also smaller. The reasons for this change are the Quaternary ice-age sediments and Holocene deposits, which cover the entire area of Schleswig-Holstein to a thickness of 0–500 m. The Quaternary cover in the eastern part of Schleswig-

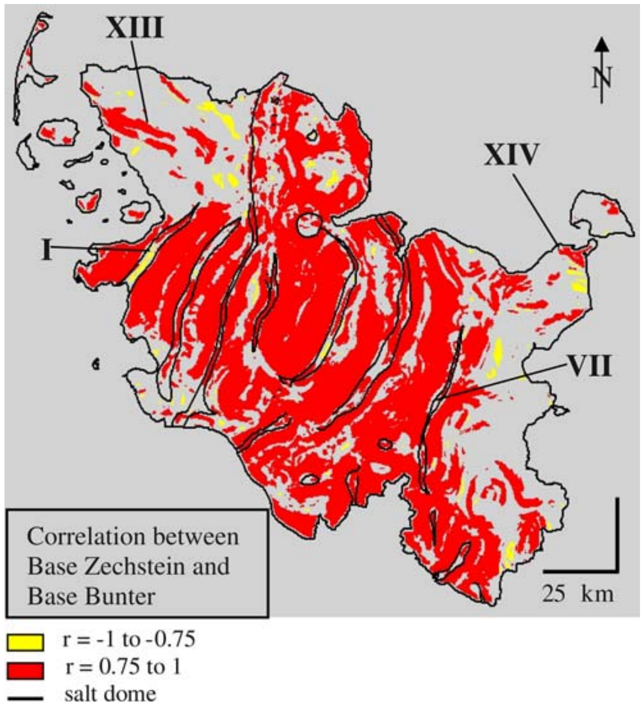


Fig. 4 Result of the correlation between Base Zechstein and Base Bunter for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a high negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition, the salt structures (after Baldschuhn et al. 1996) are displayed. Salt structures: *I* Oldensworth, *VII* Segeberg

Holstein is thicker than in the west, as represented by the smaller size of correlation areas in the east compared to larger coherent correlation areas in the west. The push of Quaternary ice shields and glaciers together with the deposition of Quaternary sediments apparently reshaped the pre-Pleistocene surface morphology and overprinted the Tertiary relief.

Nevertheless, several coherent correlation areas are visible compared with deeper horizons. Altogether nine areas of high positive correlation are traceable from the Base Zechstein up to the recent surface topography, i.e. the northeaster area of the salt dome Oldensworth (Fig. 8, I), the area of the salt domes Tellingstedt (Fig. 8, III), Sterup (Fig. 8, VIII), Eisendorf (Fig. 8, V), Segeberg/Plön (Fig. 8, VII) and to the north of Hamburg, the area of the salt domes Elmshorn (Fig. 8, IX) and Sievershütten (Fig. 8, XI). In addition, there are traceable areas of positive correlation in the northeast (Fig. 8, XIV) and the northwest (Fig. 8, XIII) of Schleswig-Holstein that still show NW–SE trending (Fig. 8). The NW–SE trending correlation areas in the northwest of the study area are mainly restricted to the Westschleswig Block. While areas of high positive correlation describe salt diapirism, areas of high negative correlation describe both the development of marginal areas of depression and the proceeding development of subsidence areas.

The calculated correlation coefficients between Base Middle Miocene and the DEM of Schleswig-Holstein's recent topography partly confirm the results of correlations from Fig. 4 to Fig. 8, i.e. recent movement potential for the areas Oldensworth (Fig. 9, I), Tellingstedt (Fig. 9, III), Eisendorf (V), Elmshorn (Fig. 9, IX) and Sievershütten (Fig. 9, XI). All traceable correlation areas are restricted to the extension of salt structures and their marginal areas of depression in the region of 150,000-year-old Saalian morainic topography (Fig. 11). Thus on the basis of calculation of correlation coefficients recent crustal movement can be expected for these areas. The absence of correlations in the northwest, northeast and centre of Schleswig-Holstein is caused by poor data coverage for the horizon Base Middle Miocene (Fig. 9).

Correlation coefficients confirm the results of other applied methods for quantifying recent movement potentials in Schleswig-Holstein (Lehné 2005), i.e. location and geometric analyses of salt structures, tectonic structures and Elsterian tunnel valleys, fault projection and linear mapping. The synthesis of all applied methods shows areas of increased movement potential, which are the areas Oldensworth, Eisendorf, Sterup, Tellingstedt, Sievershütten, Elmshorn, Segeberg/Plön and the northwest and northeast of the study area. Accordingly, recent crustal movement can be expected for these areas (Lehné 2005). While movement potential in the areas Oldensworth, Eisendorf, Sterup, Tellingstedt, Elmshorn, Segeberg/Plön and Sievershütten is caused by diapirism and resulting faults, movement potential in the north-

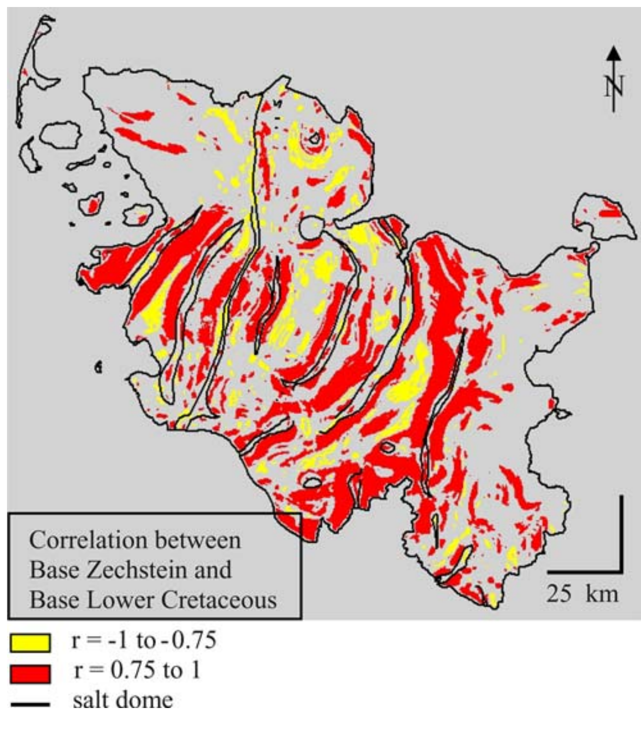


Fig. 5 Result of the correlation between Base Zechstein and Base Lower Cretaceous for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a high negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition the salt structures (after Baldschuhn et al. 1996) are displayed

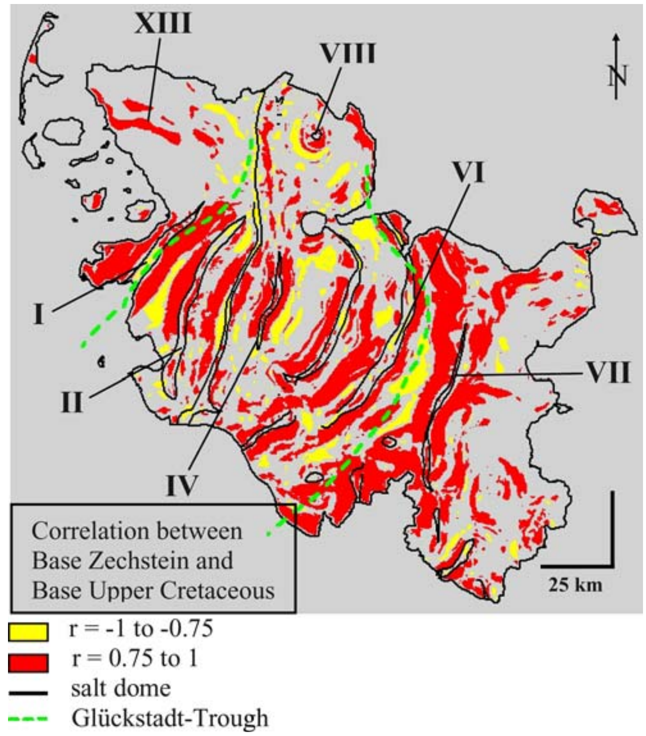


Fig. 6 Result of the correlation between Base Zechstein and Base Upper Cretaceous for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition the salt structures (after Baldschuhn et al. 1996) are displayed. Salt structures: *I* Oldensworth, *II* Hennstedt, *IV* Oldenbüttel, *VI* Warnau, *VII* Segeberg, *VIII* Sterup, *XIII* NW–SE trending correlation area in the northwest of the study area. *Green* rim of the Glückstadt Trough

west and northeast of the study area is not related to known salt structures and/or faults.

Discussion

The comparison of calculated correlation coefficients with other studies shows some noticeable correspondence. Geomorphologic mapping has been carried out for the area of Sterup (Wünnemann 1993). Results show an influence on the course of Weichselian ice sheets by pre-Weichselian geomorphologic structures. For the area of the former German Democratic Republic (GDR) recent crustal movement has been detected on the basis of levelling in the years 1954–1959 and relevelling in 1974–1982 (Ihde et al. 1987). The result shows up to 20 faults altogether with a predominant NW–SE trend. Five large active faults can be prolongated to the area of Schleswig-Holstein, i.e. the Rostock-Gramzow Fault, the Güstrow-Müritz Fault, the Wittenburg-Havelberg Fault, the Kalkhorst-Mesendorf Fault and a fault that is not labelled (Fig. 10). The prolongation illustrates a possible connection between fault locations and the appearance and orientation of correlation patterns in the northeast and the northwest of the study area (Fig. 10). The "Geotektonischer Atlas von NW-Deutschland" does not show faults in the northeast and northwest of the study area (Baldschuhn et al. 1996).

Thus, NW–SE trending correlation areas appear to be caused by as yet unknown NW–SE trending isosurfaces with corresponding faults which are most likely decoupled from salt structures.

As well as the NW–SE dominated trending of correlation areas in the northeast and the northwest of Schleswig-Holstein, this trending can also be proved by linear mapping on the basis of satellite imagery and aerial photographs (Dulce 1983; Jäger 2003; Lehné 2005).

Recent crustal movement caused by

Glacial isostatic rebound

Repeated precise levelling data from Fennoscandia, on the basis of geodetic measurements with GPS and very long baseline interferometry show recent crustal uplift with a maximum uplift rate of 11.2 ± 0.2 mm/a for the

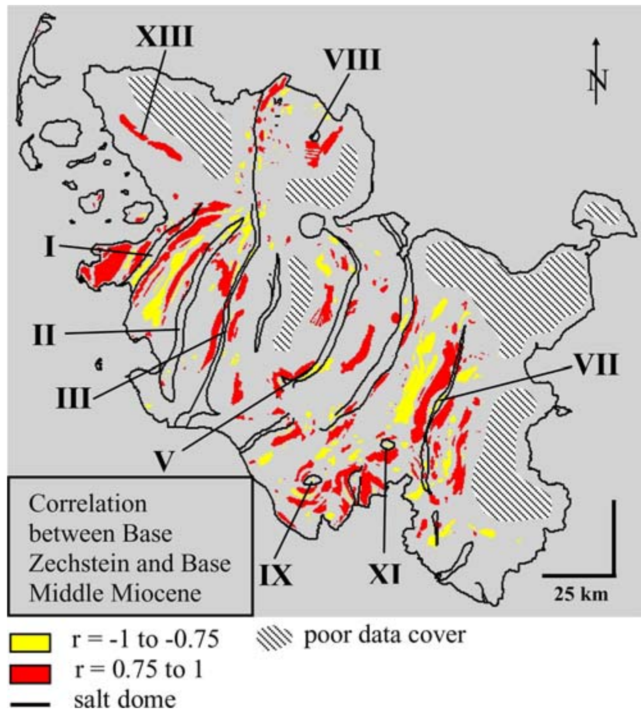


Fig. 7 Result of the correlation between Base Zechstein and Base Middle Miocene/Pliocene for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition, the salt structures (after Baldschuhn et al. 1996) are displayed. Salt structures: *I* Oldensworth, *II* Hennstedt, *III* Tellingstedt, *V* Eisendorf, *VII* Segeberg, *VIII* Sterup, *IX* Elmshorn, *XI* Quickborn, *XIII* NW–SE trending correlation area in the northwest of the study area

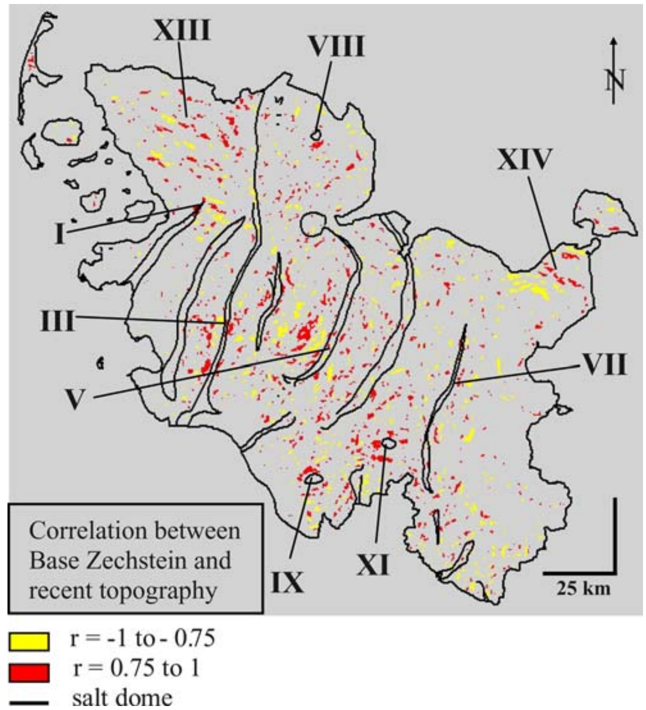


Fig. 8 Result of the correlation between Base Zechstein and recent topography for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition, the salt structures (after Baldschuhn et al. 1996) are displayed. Salt structures: *I* Oldensworth, *III* Tellingstedt, *V* Eisendorf, *VII* Plön, *VIII* Sterup, *IX* Elmshorn, *XI* Quickborn, *XIII* NW–SE trending correlation area in the northwest of the study area, *XIV* NW–SE trending correlation area in the northeast of the study area

area of Umea (Sweden) (James and Lambert 1993; Milne 2001).

For the study area, Ehlers (1990) gives ice thicknesses of the Weichselian North European ice shield as high as 500 m during the Brandenburg stage, as high as 1,000 m for the Frankfurt stage and as high as 500 m for the Pommeranian stage. Thus a glacio-isostatic crustal rebound within the study area, especially in areas where salt structures are located, can be inferred. Recent rebound models illustrate the influence of glacio-isostatic adjustment such as seismicity, fault instability and fracture formation on the crustal area (Lagerbäck 1990; Stewart et al. 2000; Wahlström 1993; Wu et al. 1999; Zoback and Grollimund 2001). The calculated correlation coefficients show an increased movement potential for the area of the salt dome Sterup, where a high number of near surface faults are located (Baldschuhn et al. 1996; Lehné 2005). In addition, the end-moraines of the Frankfurt stage and the Pommeranian stage are located in the area of the salt dome. Thus the location of the salt dome Sterup, the location of faults, the course of end-moraines and the calculated correlation coefficients all indicate a recent crustal/halokinetic movement within this area (Lehné 2005).

Late Tertiary depocentres

The study area is located within the CEB system, which extends from the North Sea to southern Poland. Subsidence as high as 300 m has been documented for the study area since the beginning of the Rupelian stage (Stackebrandt et al. 2001). During the Middle Eocene large depocentres arose in the area to the north of Hamburg (Fig. 3b) and in the western part of the study area (Oldensworth Trough, to the northwest of the salt dome Oldensworth) (Walter 1992; Baldschuhn et al. 1996). As a result of the tectonically caused subsidence and salt diapirism on the shoulders of the former Glückstadt Trough (with consequential development of marginal areas of depression) thick sediments were deposited within subsidence areas (Walter 1992). From the Middle Eocene to the Middle Oligocene, deposited sediments with thickness up to 1,000 m for the Oldensworth Trough and the area to the north of Hamburg are documented (Baldschuhn et al. 1996). From Middle Oligocene to the Lower Miocene, sediments of 700 m thickness were deposited. From the Lower Miocene to the Middle Miocene, sediments were deposited with thicknesses of 1,300 m for the Oldensworth Trough and 800 m for the area to the north of Hamburg (Baldschuhn et al. 1996). The strongest subsidence phase is documented from Middle Miocene to Quaternary,

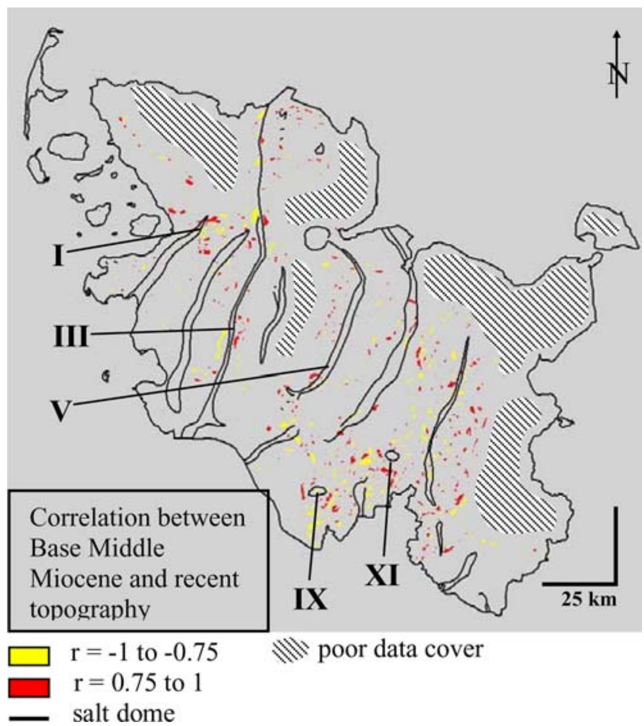


Fig. 9 Result of the correlation between Base Middle Miocene and recent topography for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition, the salt structures (after Baldschuhn et al. 1996) are displayed. Salt structures: *I* Oldensworth, *III* Tellingstedt, *V* Eisendorf, *IX* Elmshorn, *XI* Quickborn

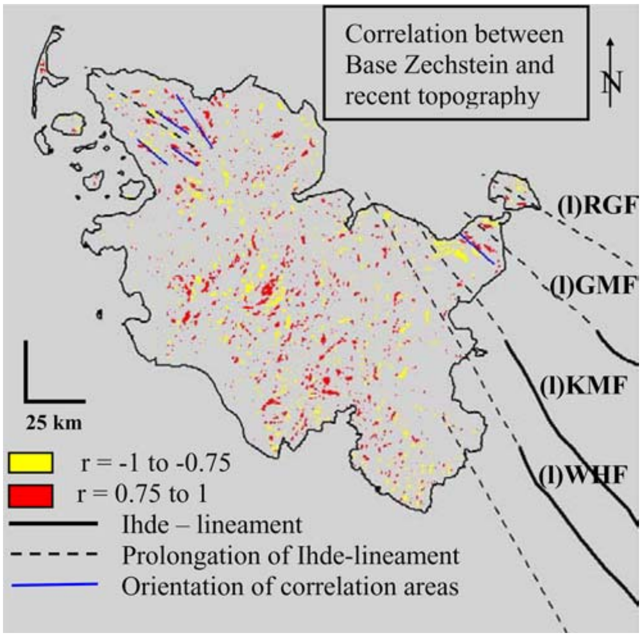


Fig. 10 Result of the correlation between Base Zechstein and recent topography for the area of Schleswig-Holstein. A high positive correlation coefficient ($r = 0.75$ to 1) is coloured *red*, a negative correlation coefficient ($r = -0.75$ to -1) is coloured *yellow*. In addition, the lineaments of vertical crustal movement for the area of the former GDR, their prolongation to the area of Schleswig-Holstein and NW–SE orientation of correlation areas are displayed. Lineaments of vertical crustal movement: *(l)RGF* Rostock-Gramzow Fault with prolongation, *(l)GMF* Güstrow-Müritz Fault with prolongation, *(l)KMF* Kalkhorst-Mesendorf Fault with prolongation, *(l)WHF* Wittenburg-Havelberg Fault with prolongation

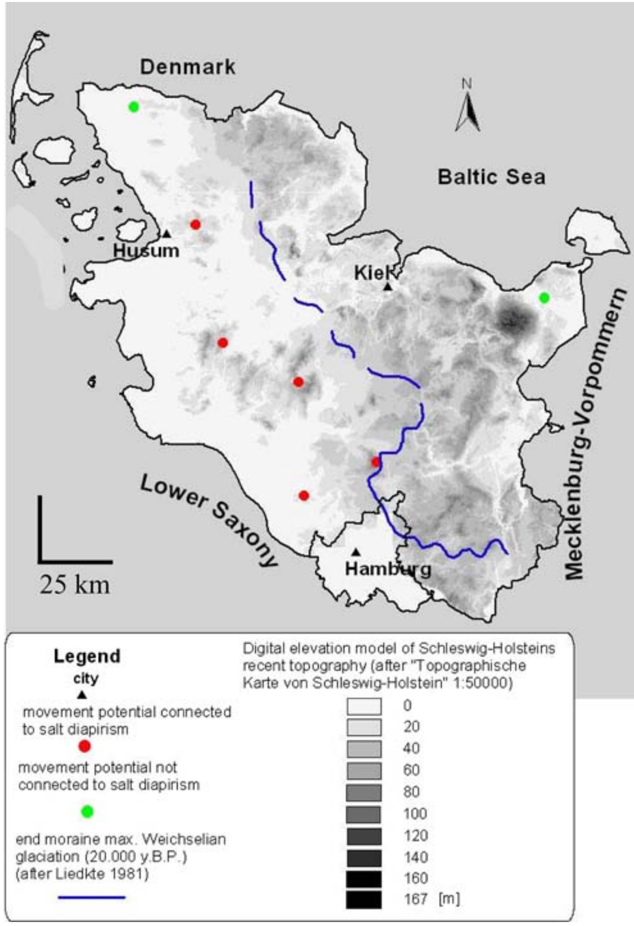


Fig. 11 Digital elevation model of Schleswig-Holstein's recent topography. Areas with expected recent crustal movement are shown in *red dots*. They are connected to salt diapirism and restricted to Saalian morainic topography in the west of Schleswig-Holstein. Two areas with expected recent crustal movement cannot be explained by salt diapirism (*green dot*). The maximum Weichselian ice extent (*blue line*) describes the borderline between Saalian and Weichselian morainic topography

where Tertiary sediments with thicknesses as great as 1,900 m were deposited in the area of the Oldensworth Trough (Baldschuhn et al. 1996). The deposition centre of the subsidence area to the north of Hamburg migrated from the south during the Upper Paleocene to the northeast by Miocene time (Baldschuhn et al. 1996). Within the Oldensworth Trough the centre of deposition during the time period Upper Paleocene to Middle Miocene was constantly located in the northwest of the salt structure Oldensworth (Baldschuhn et al. 1996). Causes for the development of Tertiary diapirism, depocentres and their migration need to be discussed in the context of plate tectonic processes and consequent lithospheric stresses (Anzidei 2001; Devoti 2002; Zoback 1992; Fuchs and Müller 2001; Ziegler 1990; Kaiser et al. 2005; Scherneck et al. 1998). Nevertheless, we observe recent movement potential in these depocentres, most likely caused by ongoing subsidence and diapirism. The result of the calculation of correlation coefficients points out both high positive and high negative correlations for the western part of the study area (Fig. 7). Predominantly high positive correlation coefficients were calculated for the area around Hamburg where salt structures are located (Fig. 7). In addition this region shows a high number of faults (Fig. 2; Baldschuhn et al. 1996).

Elsterian tunnel valleys

The draining of ice sheets and glaciers during the Elsterian stage gave rise to a network of tunnel valleys that covers the entire study area (Schwab 1996). These tunnel valleys reach depths of 400 m. Piotrowski (1994) suggests that the initiation of tunnel valleys is caused by differential response of bed materials to ice overriding on top of and between the salt structures. The flanks of tunnel valleys, with a total depth of more than 200 m, generally have a slope between 10° and 25° (Hönemann et al. 1995). Thus, a movement potential is possibly caused by ongoing compaction of sediment fill (Lehné 2005).

Conclusions

- The method of calculating correlation coefficients is suitable for trend analysis of recent movement potential.

- Correlation coefficients point out seven areas that are traceable from Base Zechstein up to the recent surface topography (Fig. 11).
- Five correlation areas are connected to marginal area of depressions and corresponding faults within the Glückstadt Trough. Their appearance is restricted to the region of Saalian morainic topography (Fig. 11).
- Two detectable NW–SE trending correlation areas in the northwest (restricted to the Westschleswig Block) and the northeast of Schleswig-Holstein are outside the Glückstadt Trough. The cause of these correlations cannot be explained yet, partly because the Miocene or seismic data for the upper strata are missing.
- Together with other applied methods (i.e. linear mapping, fault projection, statistic analysis of faults, salt structures and Elsterian tunnel valleys) correlation coefficients indicate recent crustal movement caused by salt structure activity and faults (Lehné 2005).

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