DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2002/30

Test grid established for the EU-project PROTECT at cliffed terrains in Denmark, England and France

Technical progress report for the 1st years project period of Partner 4 in PROTECT, EU-Contract EVK3-CT-2000-00029

Stig A. Schack Pedersen, Ingelise Møller and Lasse Gudmunsson

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MINISTRY OF ENVIRONMENT

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Introduction

The aims of the EU-project PROTECT (PRediction Of The Erosion of Cliffed Terrains), EU Contract No. EVK3-CT-2000-00029 are to develop predictive tools, which will identify sections of cliffed coastline, that are approaching a state of imminent collapse and allow accurate predictions to be made of the timing of the collapse. The main monitoring tool focused on are azimuthal resistivity measurements, and therefore the project also aims at contribute to the understanding of physical properties of rock masses, which leads to unstable cliffs.

The project will work closely with user communities, which will involve ensuring development adapted to the users requirements. This will include issue informed hazard warning in areas of cliffs, providing information for land-use planning for decisions in the coastal zone and conservation regulations, and maximise the use of the cliffed coastline as an amenity.

In the project the following nine partners are involved: 1) British Geological Survey (BGS), 2) University of Brighton (UoB), 3) Bureau de Recherche Géologiques et Minières (BRGM), 4) Geological Survey of Denmark and Greenland (GEUS), 5) Institut National de l'environement Industriel et des Risques (INERIS), 6) Isle of Wight Centre for the Coastal Environment (IWCCE), 7) Direction Departementale de L'equipement de la Seine Maritime (DDE76), 8) Urzad Morskiw Gdyni (PMA), and 9) Consorzio Ferrara Ricerche (CFR). Coordinator for the project is Dr. J. P. Busby (British Geological Survey, partner 1), and four of the other partners are responsible for one of the five work packages (WP1–5) in the project. A short description of the work packages is given below:

WP1 – Detection of fracture dilatency

Temporal azimuthal apparent resistivity measurements are made at the five research sites at bi-monthly intervals (three data sets). The parameters required to monitor variations in the rock mass are determined and fracture orientations are calculated for each research site.

WP2 – Detection of cracking

Five accelerometers and 5 geophones were installed at the Mesnil-Val test site and acquisition started on 8th January 2002. Initial investigations of the microseismic activity shows that a microseismic event can be recorded on one transducer, i.e. cracks happen close to the transducers or chalk is an attenuating medium. As a consequence, the microseismic network is strongly recommended compared to the waveguide system because the waveguide range detection is much narrower than microseismics. If cracks are difficult to detect with the microseismic systems, they will not be detected with the waveguide system. As a consequence humidity and total pressure sensors have replaced the waveguide system.

WP3 – Influence of rockmass and external parameters

Detailed rock mass data and erosion data has been collected for the UK research sites and some initial data has been collected for Mesnil-Val. A strategy for sampling and physical property and strength testing of the chalk has been organized. At Mesnil-Val, as no water level is present near the cliff front, no boreholes have been drilled for water level monitoring. However six water content probes were installed by BRGM at 3 and 6 m distance from the cliff wall at three different heights to monitor water content in the chalk. Water saturation is recorded every hour.

A meteorological station has been installed by BRGM near the cliff front at Mesnil-Val. External temperature, barometric pressure, velocity and direction of wind and rain precipitation are recorded every hour. Meteorological dates from the Danish site are submitted from the Danish Meteorological Institute from their observation station at the lighthouse at Møns Klint.

WP4 – Interpretation and integration of data

A database has been established for the diverse data sets collected by the PROTECT project. A first survey of fracturing was carried out by BRGM and INERIS at Mesnil-Val.. No statistics can be calculated on these measurements and the data sets cannot be used as input for cliff stability software.

Chalk was sampled by BRGM along a vertical profile every 2 m and sent to the University of Brighton for micropalaeontology analysis.

WP5 – Project monitoring and verification

The aim of work package 5, WP5, is to verify that the research is meeting the objectives of the project. In the first year project period this also included the establishment of a monitoring system for direct verification of pre-cursor movements in the terrains or actual collapse of cliffs which are the target for the research study. Five field sites were selected for study, and subsequent reporting from the monitoring system will be submitted be regularly measurements of the test grids established in the fields.

Aim of this report

The aim of this report is to describe the test grid established by GEUS, partner 4, and to present a documentation of the measurements carried out in the test grid.
After the research fields had been selected in May 2001 partner 4 established test grids in the areas for the purpose of regular measurements of possible earth dislocation within the field sites. Five areas were selected: two sites on the chalk cliff of Møns Klint in Denmark, two sites on the chalk cliff of Beachy Head near Eastbourne, UK, and finally one field sites was selected on top of the chalk cliff at Mesnil-Val near Le Tréport, France.
The monitoring test grids at Møns Klint, DK, were established in the end of May 2001, the test grids at Eastbourne, UK, and Mesnil-Val, F, were established in the end of August 2001. Each time the sites were visited the activities were carried out together with and in co-operation with at least one other project partners.
The test grids have subsequently been visited and measured three times a year. Thus the measurements of the first part of the project duration are now available and presented in this report.

Description of research fields

For testing the dislocations in the terrain a grid has been established at each research field. The grid consists of a number of fix points marked with wooden pegs hammered down in a small drill hole into the chalky soil. On top of the pegs, marked with red colour, a small nail marks the precise position of the grid point. Subsequent the grid points have been measured with Leica electronic total station (TC600, theodolite) with reflection prism distance calibration. In addition to the grid points a number of established fix points have been identified and measured.

Five fields have been established which are named as follow:

1. Dronningestolen – Møns Klint, DK
2. Jættebrinken – Møns Klint, DK
3. Beachy Head – Eastbourne, UK
4. Birling Gab – Eastbourne, UK
5. Mesnil-Val – Dieppe, F

Figure 1. *Establishment of a grid point in the Birling Gab, Eastbourne, test site. First a drill hole was prepared for hammering a wood peg into the ground, which hampered the hammering activity to avoid cliff collapse initiated by hammering along the edge of the cliff. On top of the peg a nail marks the precise position of the point.*

Test sites in Denmark

The test grid established in Denmark are situated along the steep cliff of Møns Klint (Fig. 2). Here two grids have been laid out, one at Dronningestolen and the other at Jættebrinken (Fig. 3).

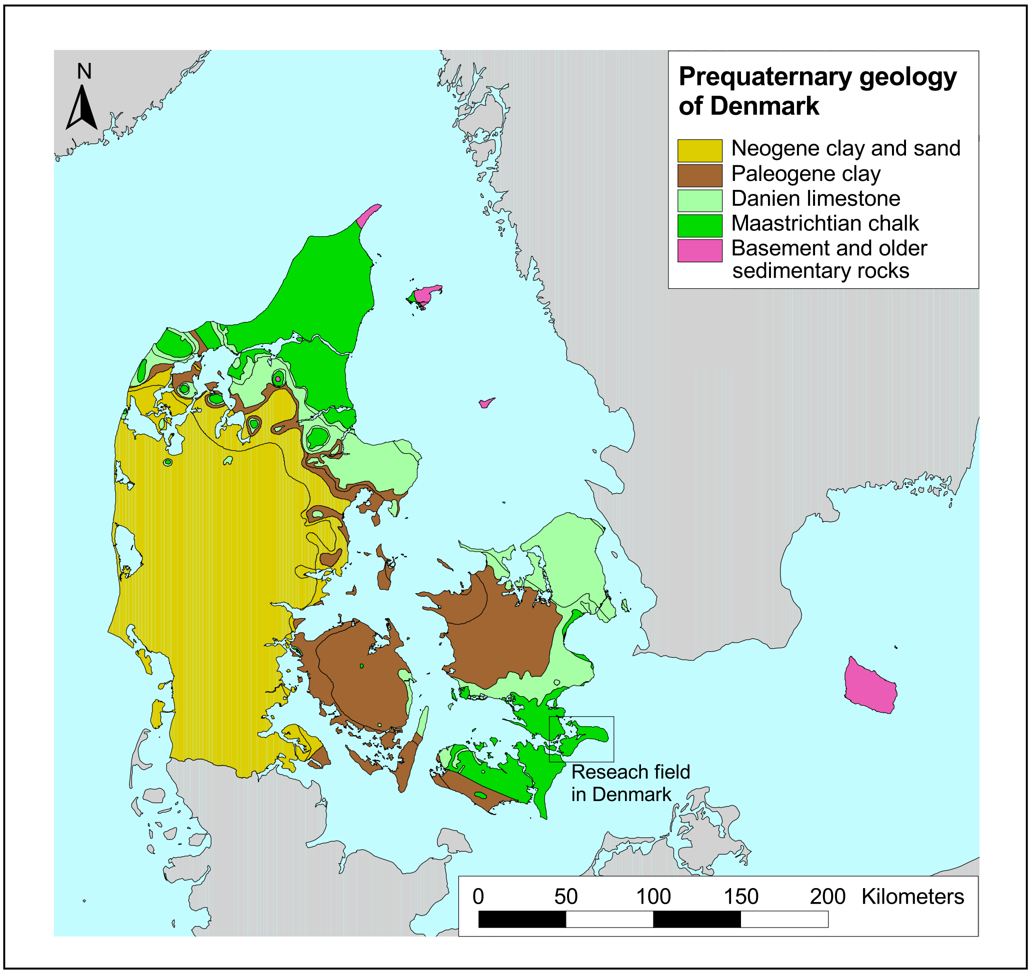

Figure 2. *Geological map of Denmark which shows the distribution of chalk and the location of the Danish research field.*

Figure 3. *Location map of the test grids established at Møns Klint.*

Dronningestolen

This grid is situated on the highest cliff of Møns Klint c. 130 m above sea level (Fig. 3). The field is situated in a public forest area managed by the Agency of Natural Preservation and Forestry, Ministry of the Environment. Only 100 m away from the grid the last hazardous rock fall took place in 1994, which killed one person. The grid is vulnerable to public traffic and icy ground in the winter time (Fig. 5 and 6). Some of the grid pegs are difficult to find in the summer time due to the forest vegetation.

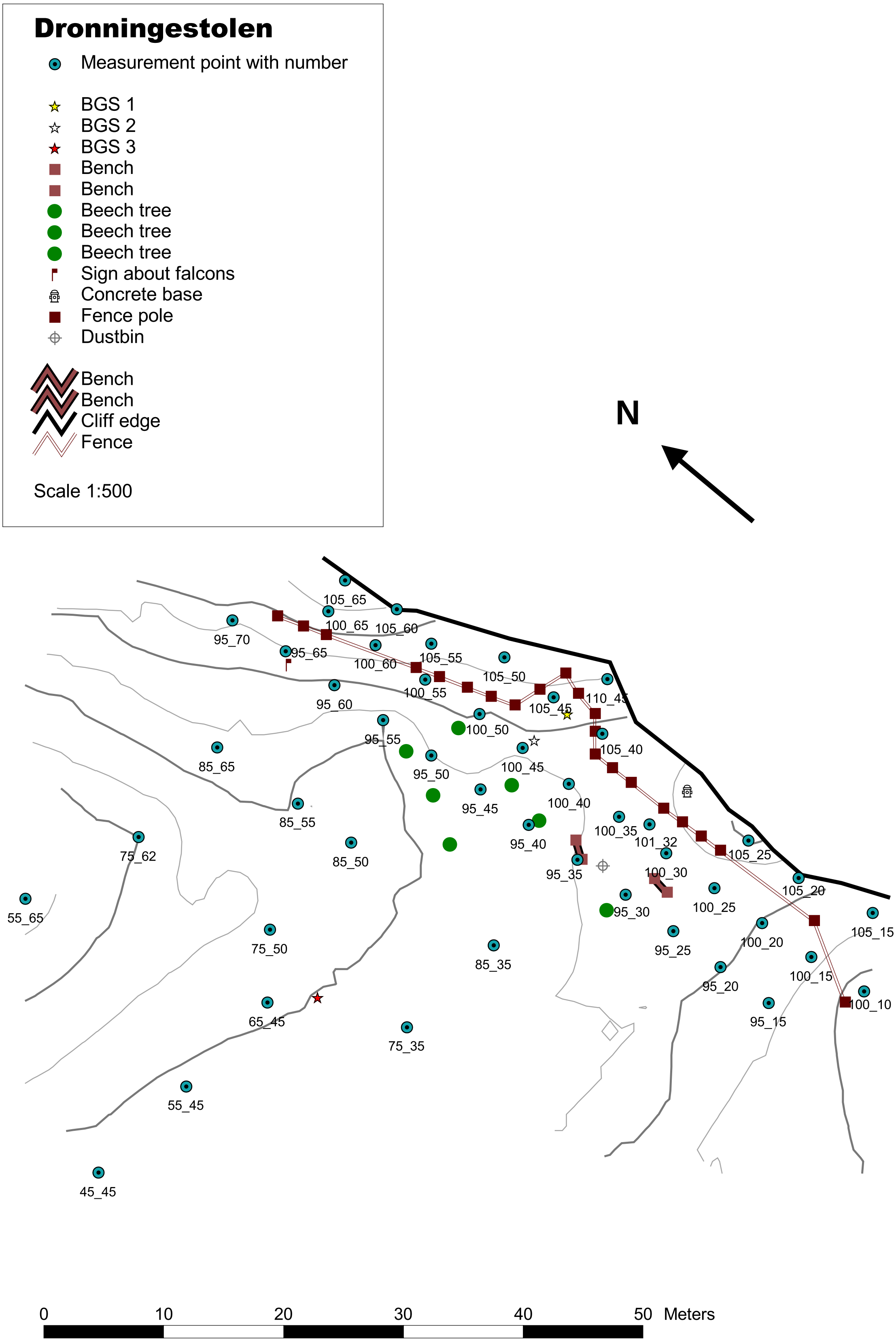

Figure 4. *The test grid established at Dronningestolen, Møns Klint.*

Figure 5. *View from the Dronningestolen towards the beach in January 2002 .*

Figure 6. *Icy ground on the test site of Dronningestolen a winter day in January.*

Jættebrinken

This grid is established in a grass field on top of the only 25–30 m high vertical cliff Jættebrinken on the southern part of Møns Klint (Fig. 7). The field is private owned and permission for access has been given by the local count of Klintholm. The field is well protected and easy accessible. A small landslide affected the cliff 100 m north of the grid in the end of February this year.

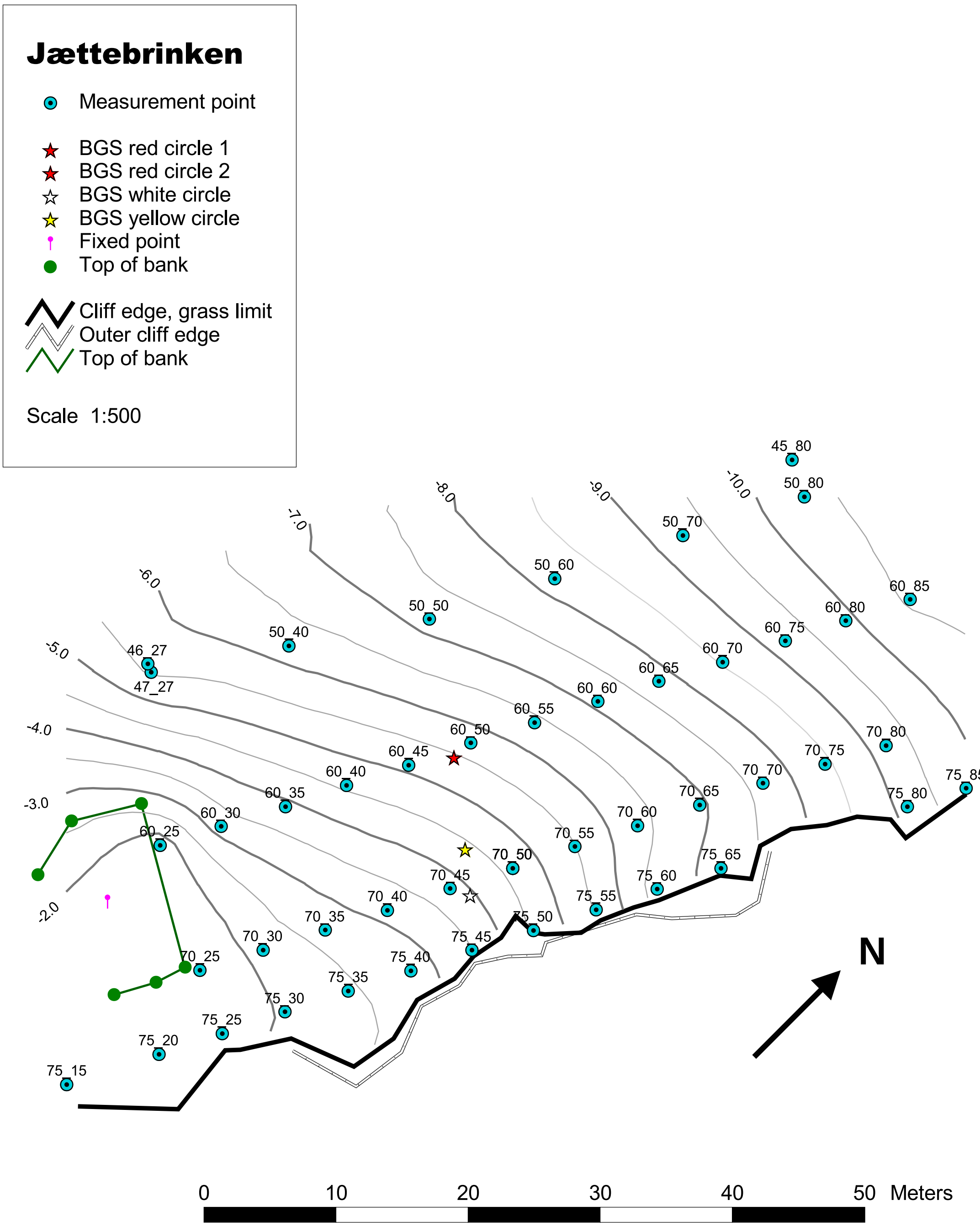

Figure 7. *The test grid established at Jættebrinken, Møns Klint.*

Figure 8. *The Jættebrinken test site, southern part of Møns Klint, September 2001.*

Figure 9. *The Leica electronic total station and reflection prism applied for the grid measurements.*

Test sites in England

Two test sites were selected along the south coast of England, namely Beachy Head and Birling Gab, situated 5–10 km west of Eastbourne (Fig. 10).

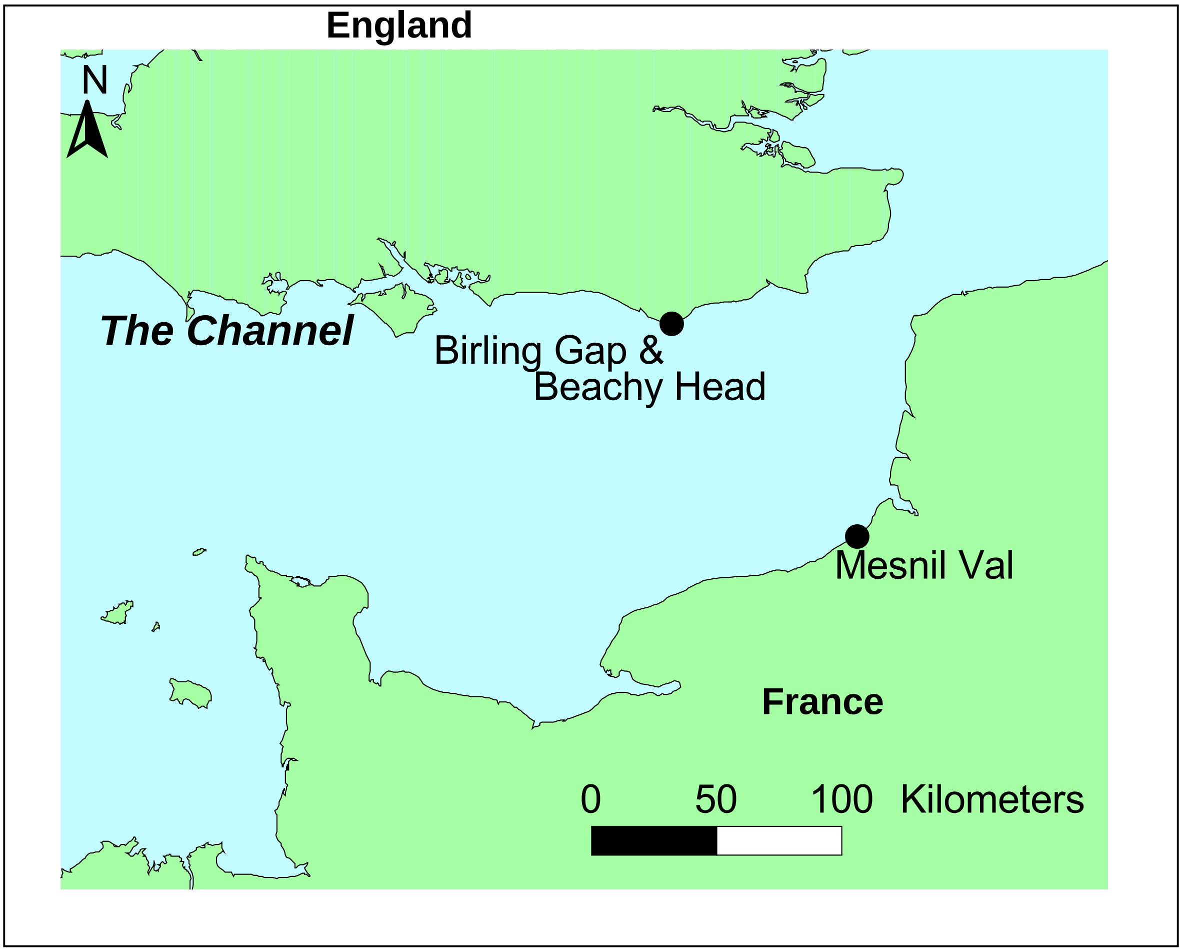

Figure 10. *Location of the test sites at the chalk cliff coast of the Channel, near Eastbourne in England and Treport in France, respectively.*

Beachy Head

The grid at Beachy Head is established in a public grass field west of Eastbourne, very close to the site where a rock fall took place two years ago near the light house at the sea point of Beachy Head (Figs 11, 12 and 13). The field is managed by the local county of Eastbourne and permission for access has been given by the local ranger. The grid is vulnerable to public traffic, but no grid points has been damaged until now. However, a reference point 100 m away from the cliff edge has been destroyed by the grass cutter machine.

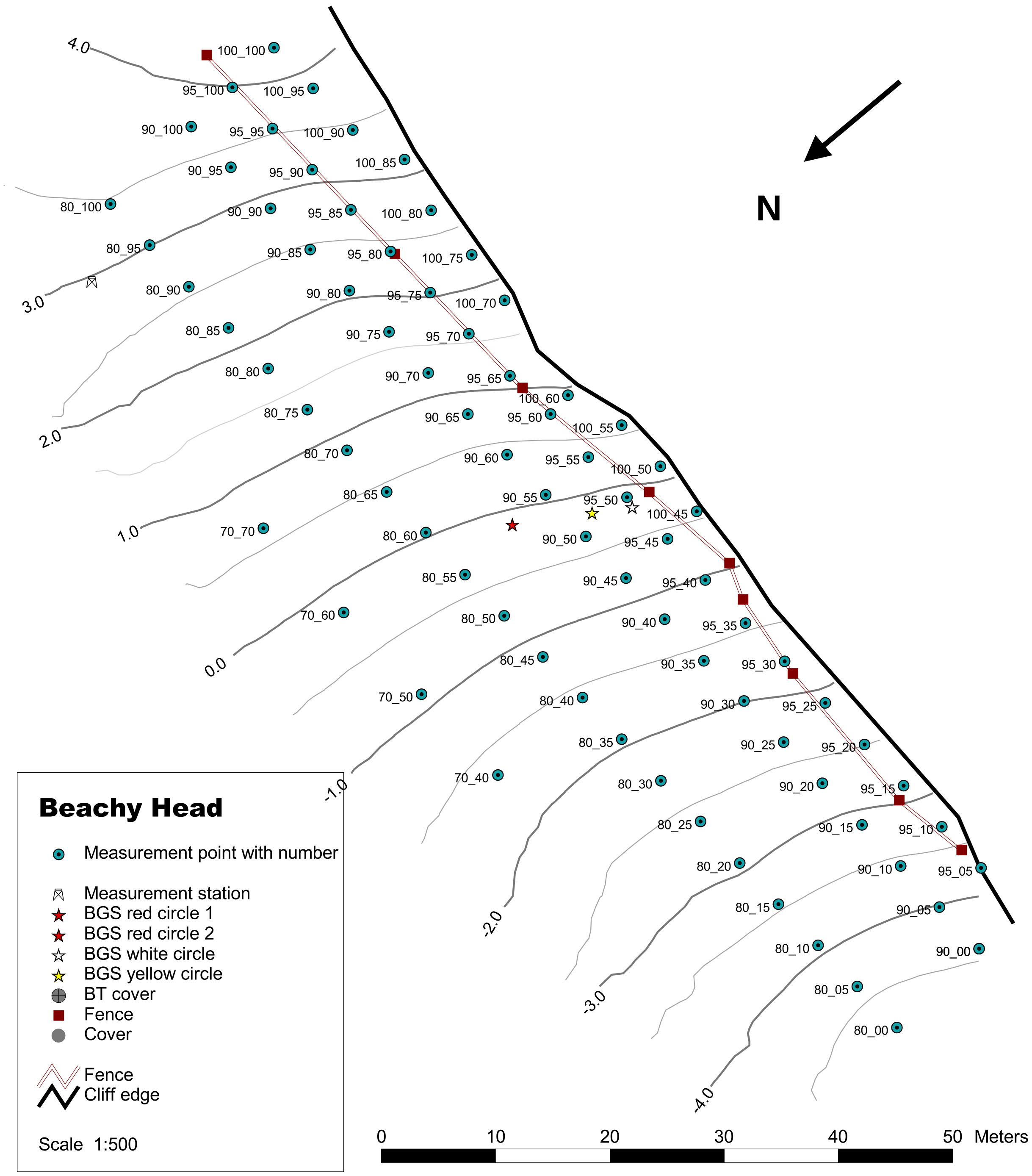

Figure 11. *The test grid established at Beachy Head.*

Figure 12. *The lighthouse at the sea at Beachy Head.*

Figure 13. *The field above the chalk cliff at Beachy Head, where the test grid is established. Note the field team carrying out the azimuthal resistivity measurements.*

Birling Gab

The grid is established in a public grass field at the cliff top above the local pub and parking area of Birling Gab (Fig. 14, 15 and 16). The field is managed by the National Thrust and permission for access has been given by the local ranger. A major fault zone is crossing the grid and it is expected that dislocation of the surface will be related to this tectonic feature.

Figure 14. *The test site at Birling Gap looking towards the Seven Sisters to the west.*

Figure 15. *The emplacement of one of the wood pegs, which mark the grid points in the test grid, September 2001.*

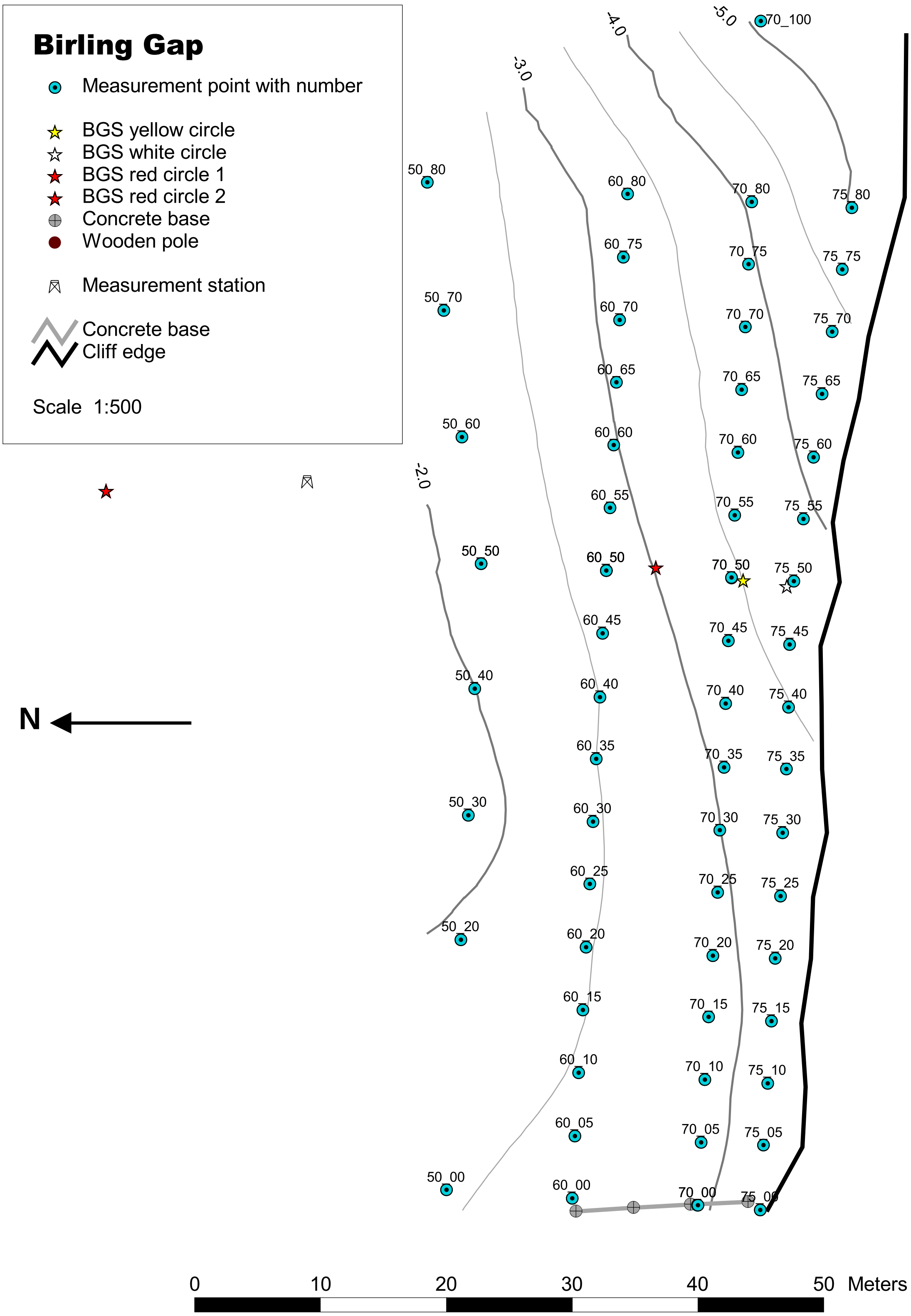

Figure 16. *The test grid established at Birling Gap.*

Test site in France

In France one test site has been chosen on the edge of the steep coastal cliff between Dieppe and Tréport at the village Mesnil-Val (Fig. 17).

Mesnil-Val

The grid is established in a local private hay field east of the local village Mesnil-Val. The established grid has suffered minor destruction during the activities of organising and putting up the sensors and equipment for the acoustic measurements. This part of the grid was subsequent re-established with new grid points in January 2002.

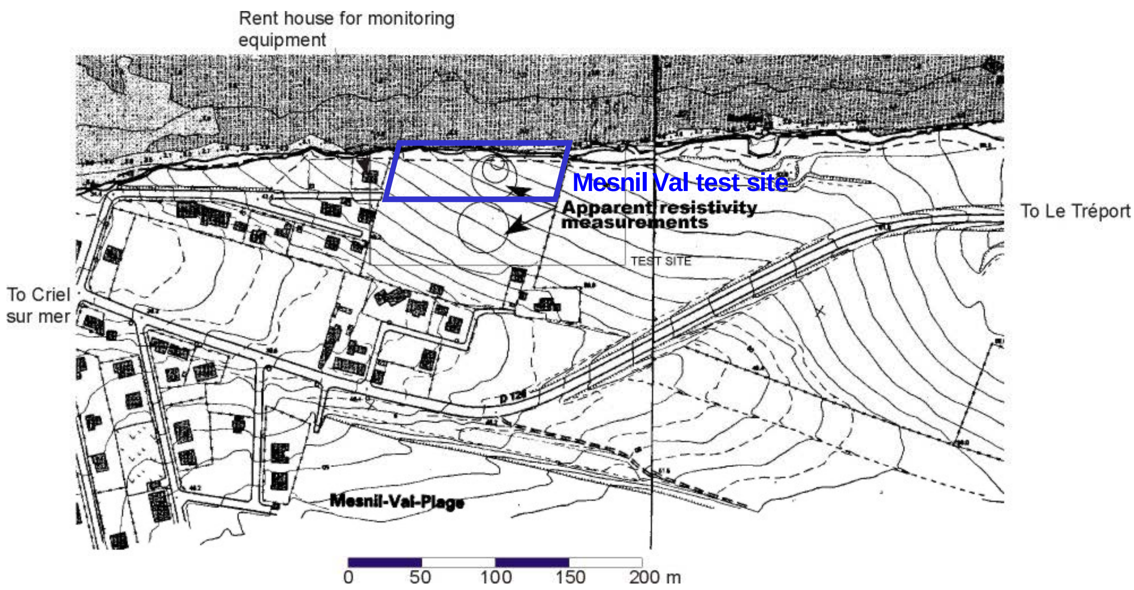

Figure 17. *Map of the location of the test site in Mesnil-Val.*

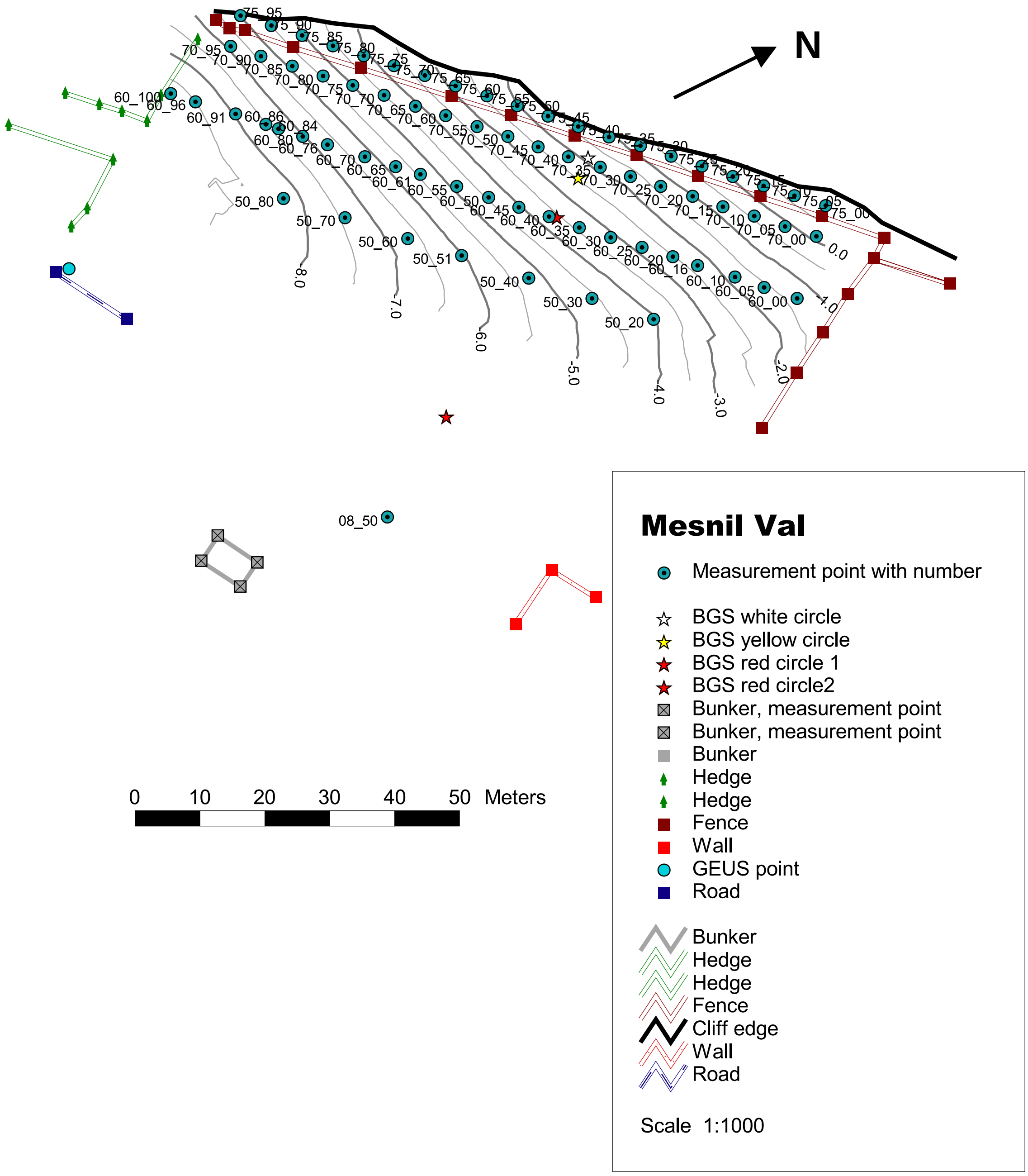

Figure 18. *The test grid established at Mesnil-Val.*

Figure 19. *The grid line at the outer edge of the Mesnil-Val test field.*

Figure 20. *Measurements carried out with the Leica total station at the Mesnil-Val site.*

Figure 21. *The steep cliff section below the Mesnil-Val test site seen from the tidal flat at low tide.*

Figure 22. *Grid point established in the test grid consists of a wooden peg about 30 to 50 cm long (left) hammered into the chalky ground. In part of the Mesnil-Val grid the points were destroyed during the constructional work related to the establishment of the acoustic sensors (right), and these point had to be re-established subsequently.*

Presentation of measurements

In this chapter the statistics of the measurement rows carried out from the start and until the beginning of 2002 are presented. Thus the figures below demonstrate the accuracy of the repeated measurements of the position of the grid points in the test grids.

The test grids were established so, that along the edge the grid point have the smallest distance to be sure minor rock falls would be caught up in the net. More open space of the net 20 m away from the cliff edge was regarded as sufficient for adaptation of eventual major landslides. Finally test point were located so far from the cliff that they could be regarded as secure reference points during the project duration. The extension of the grid along cliff strike was considered in relation to the measurements carried out by the other partners taken care of WP1 and WP3.

Sources of errors

In general the deviation of the measurements is within +/-1 cm on the z-coordinate. The x and y coordinates have a somewhat larger deviation, which is mainly below +/-3. The explanation for deviation is related to one or more of the five sources of errors recognised.

1) Instrument accuracy

The Leica total station has a standard mode accuracy on 3 mm +3 ppm (=3mm/km).

2) Reflector position instability

Small vibrations occur during the hand hold positioning of the reflector in the field. Especially in strong wind this may add to a large deviation on the x and y coordinates, whereas the z coordinate is not significantly affected by these vibrations. The measurement error due to a reflector not in perfect vertical position is orders of magnitudes larger on the horizontal components than on the vertical component. Thus a horizontal deviation of 0.5 cm on the reflector on top of an 1.60 m long rod corresponds only to 0.0125 mm vertical deviation. The corresponding numbers for 1 cm and 5 cm are 0.05 mm and 1.2 mm respectively.

3) Positioning deviation

Transfer of errors during rotation calculation of measurements of reference point accumulates to minor errors. A good example of this is the measurement row of Beachy Head (fig. 27), where the sequential accumulation of deviation is regarded to reflect this type of error.

4) Ground expansion and contraction

During different weather conditions we believe that there will be some minor differential ground expansion and contraction. At present we have no estimates of the importance of this factor, but we expect it will be possible to see when the weather records are available.

5) Distortion and damage of grid points

Finally a number of accidental small disturbances may occur. Naturally larger damage of grid points by machinery etc. can easily be recognised (Fig. 22). However, smaller distortions due to animal activities and passing pedestrians or even vehicles may occur without being noted by the measuring team. A few points are excluded in the calculation of standard deviation due to the suspicion of this type of error.

Below the table gives the preliminary standard deviations for the measurements carried out in the grids. We expect that a grid point should fall beyond two times the standard deviation to be a detection of a tectonic displacement. Secondly we expect that a grid point should show a sequential displacement to be regarded as tectonically displaced.

Site	Time difference	Mean X (m)	Standard deviation X (m)	Mean Y (m)	Standard deviation Y (m)	Mean Z (m)	Standard deviation Z (m)
Dronnin-gestolen	May 2001 Sep 2001	0.0004	0.01	0.0026	0.010	0.0048	0.0028
	May 2001 Jan 2002	0.0072	0.01	0.013	0.013	0.0029	0.0019
	Sep 2001 Jan 2002	0.0077	0.0050	0.014	0.0061	0.0069	0.0038
Beachy Head	Sep 2001 Jan 2002	0.0002	0.0066	0.0003	0.0068	0.0011	0.0036
Birling Gap	Sep 2001 Jan 2002	0.0027	0.0061	0.0036	0.0052	0.0021	0.0024
Mesnil-Val	Sep 2001 Jan 2002	0.0037	0.0073	0.0059	0.010	0.0012	0.0049

Due to a systematic error the standard deviation calculated from the Jættebrinken site will first be represented later in the project.

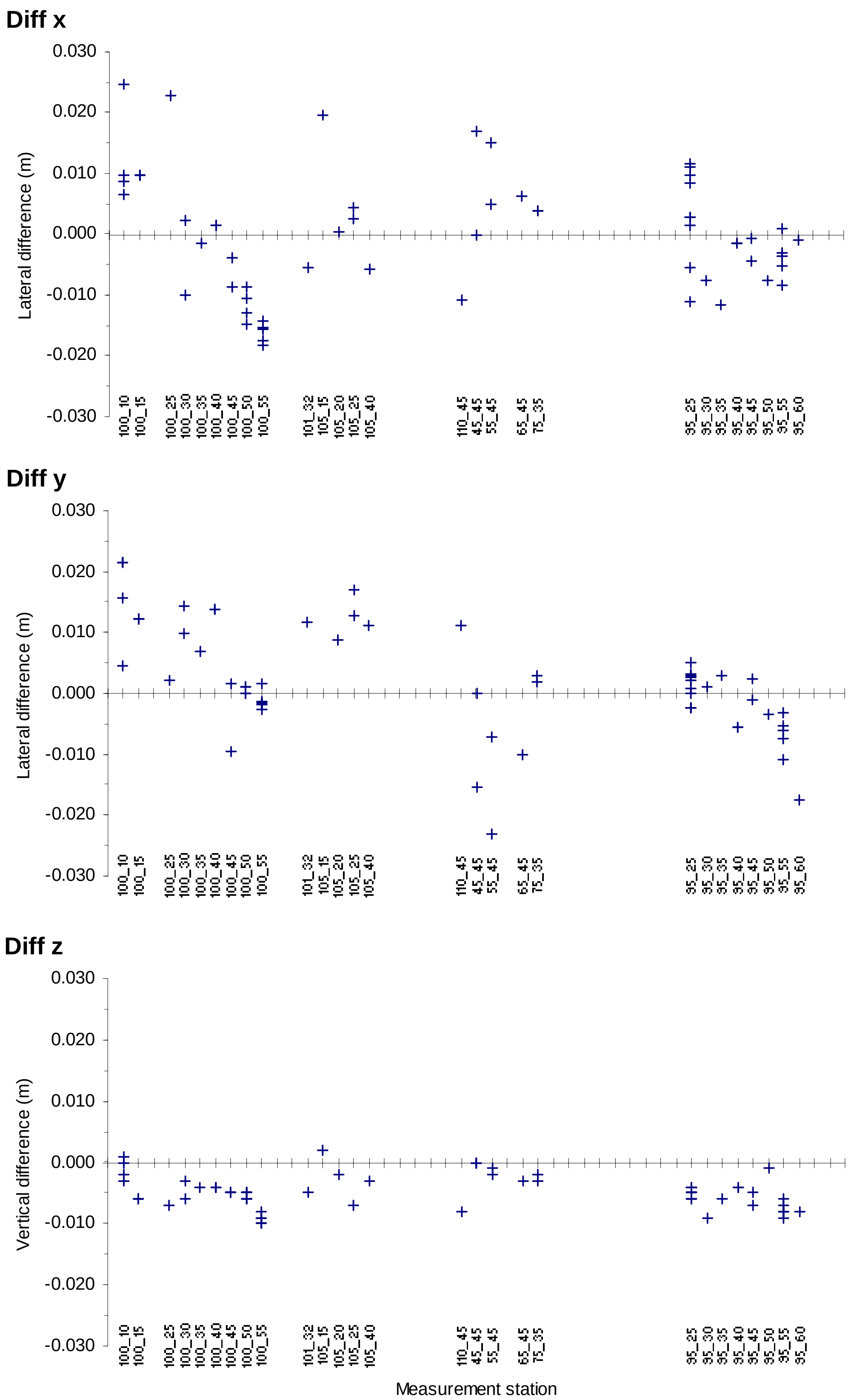

Figure 23. *Dronningestolen, difference between May 2001 and September 2001*

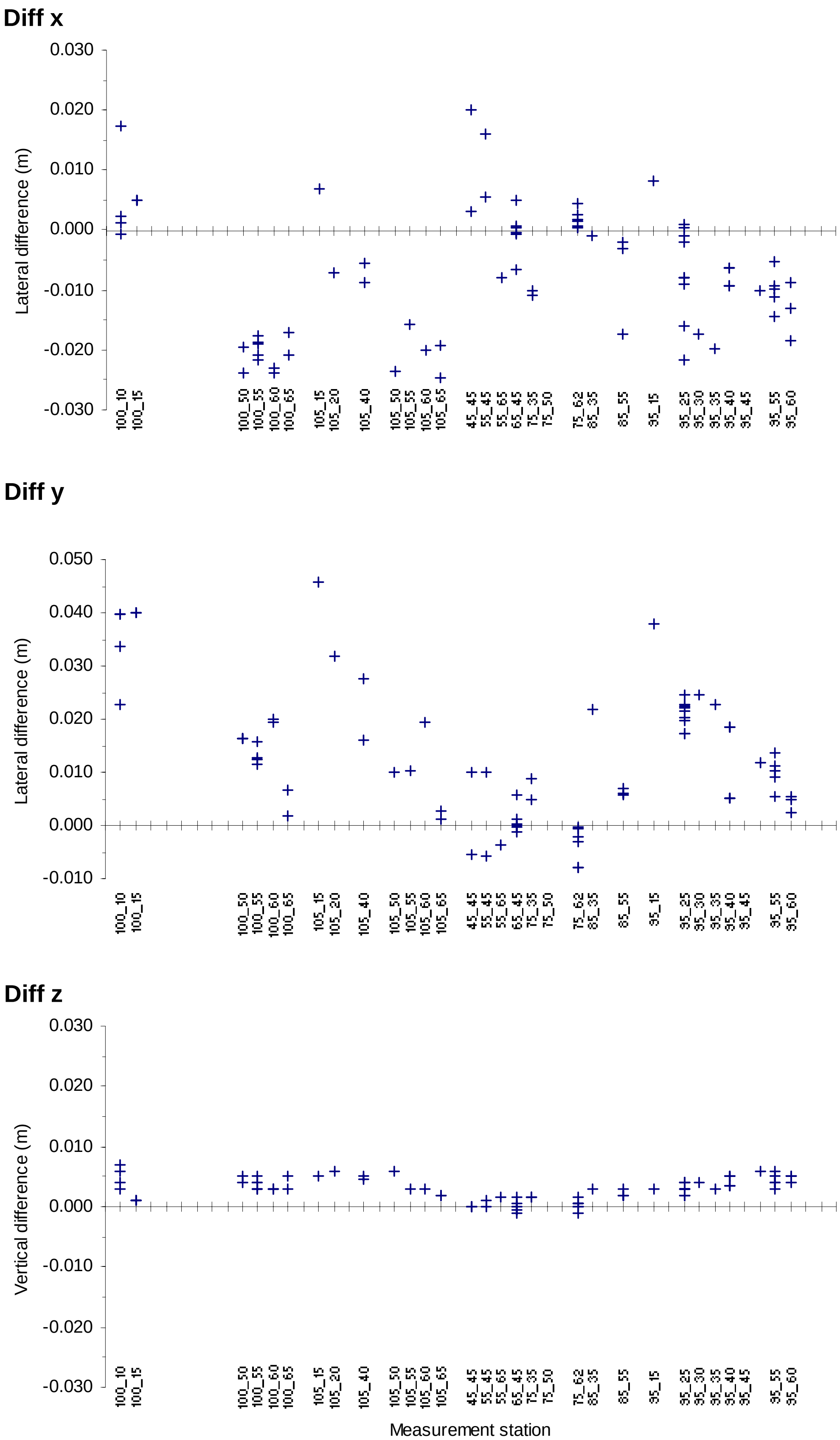

Figure 24. *Dronningestolen, difference between May 2001 and January 2002.*

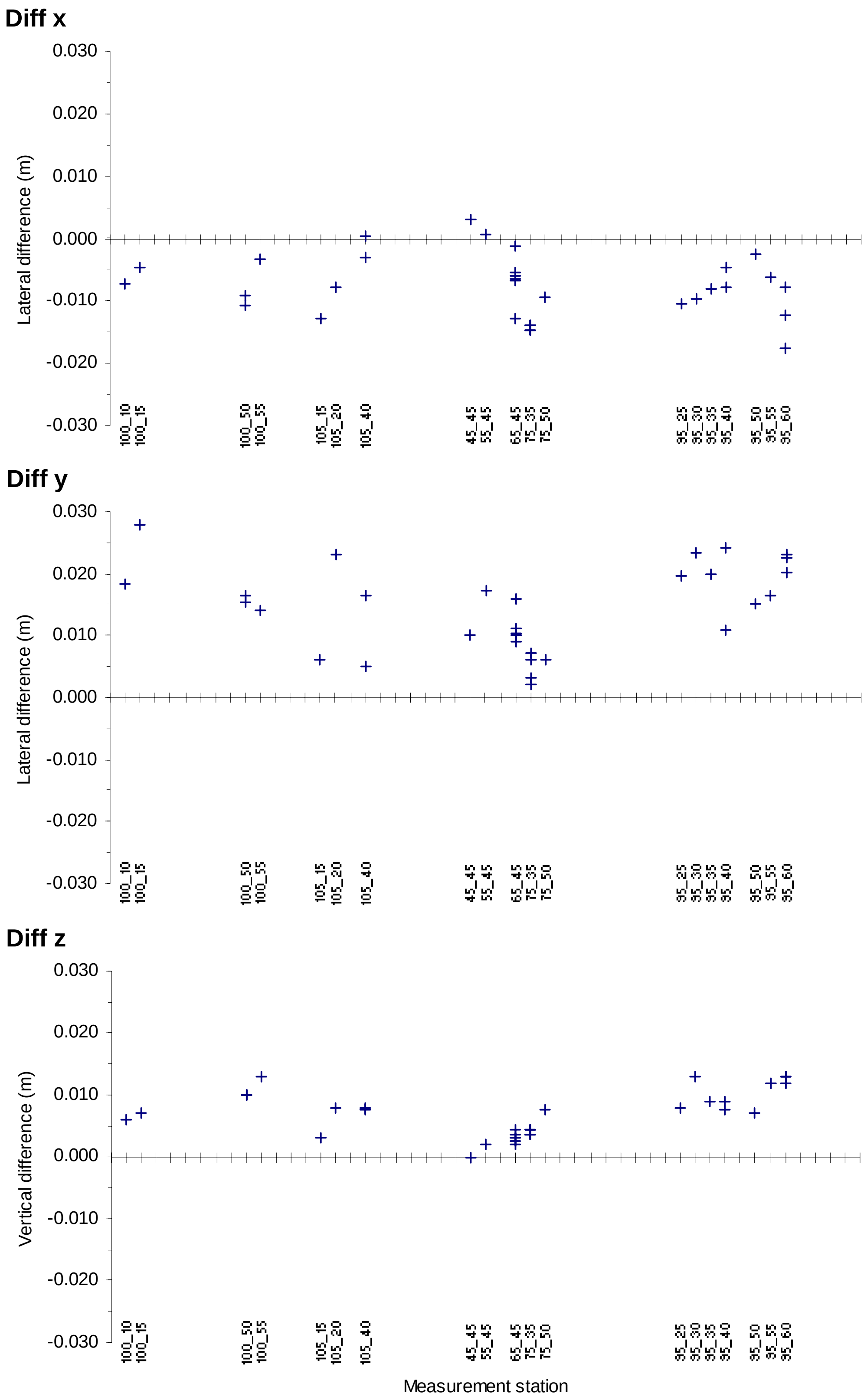

Figure 25. *Dronningestolen, difference between September 2001 and January 2002.*

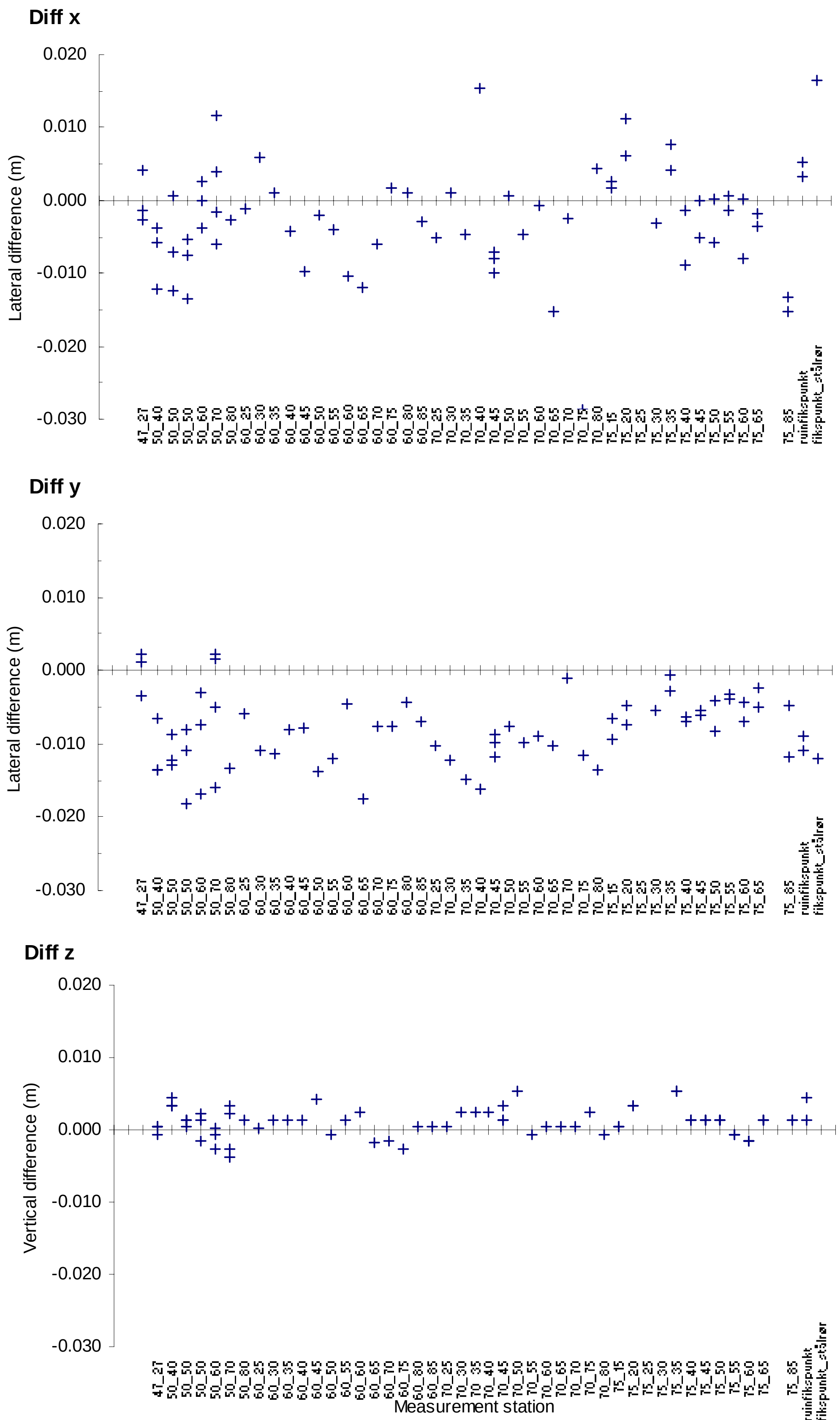

Figure 26. *Jættebrinken, difference between September 2001 and January 2002.*

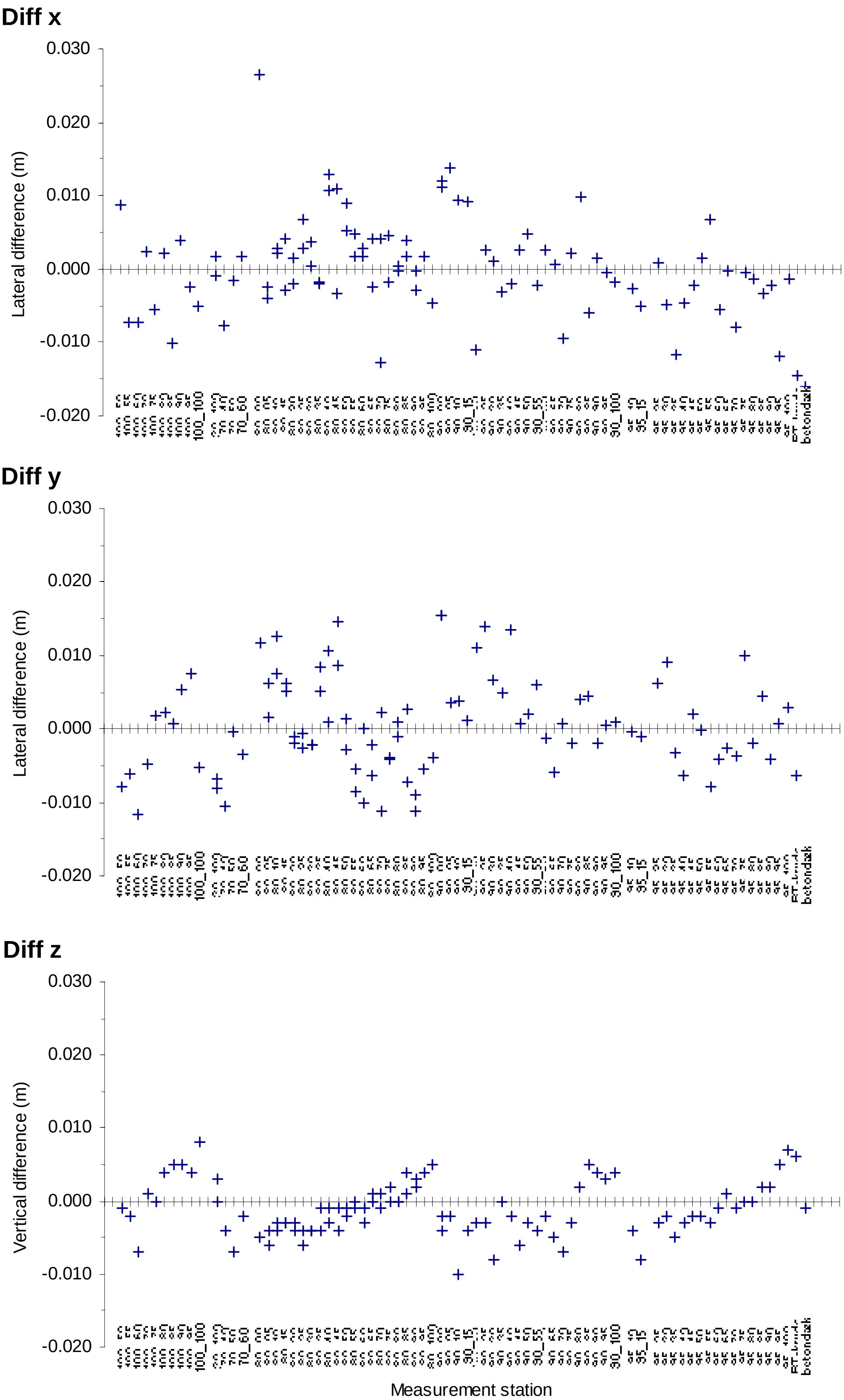

Figure 27. *Beachy Head, difference between September 2001 and January 2002.*

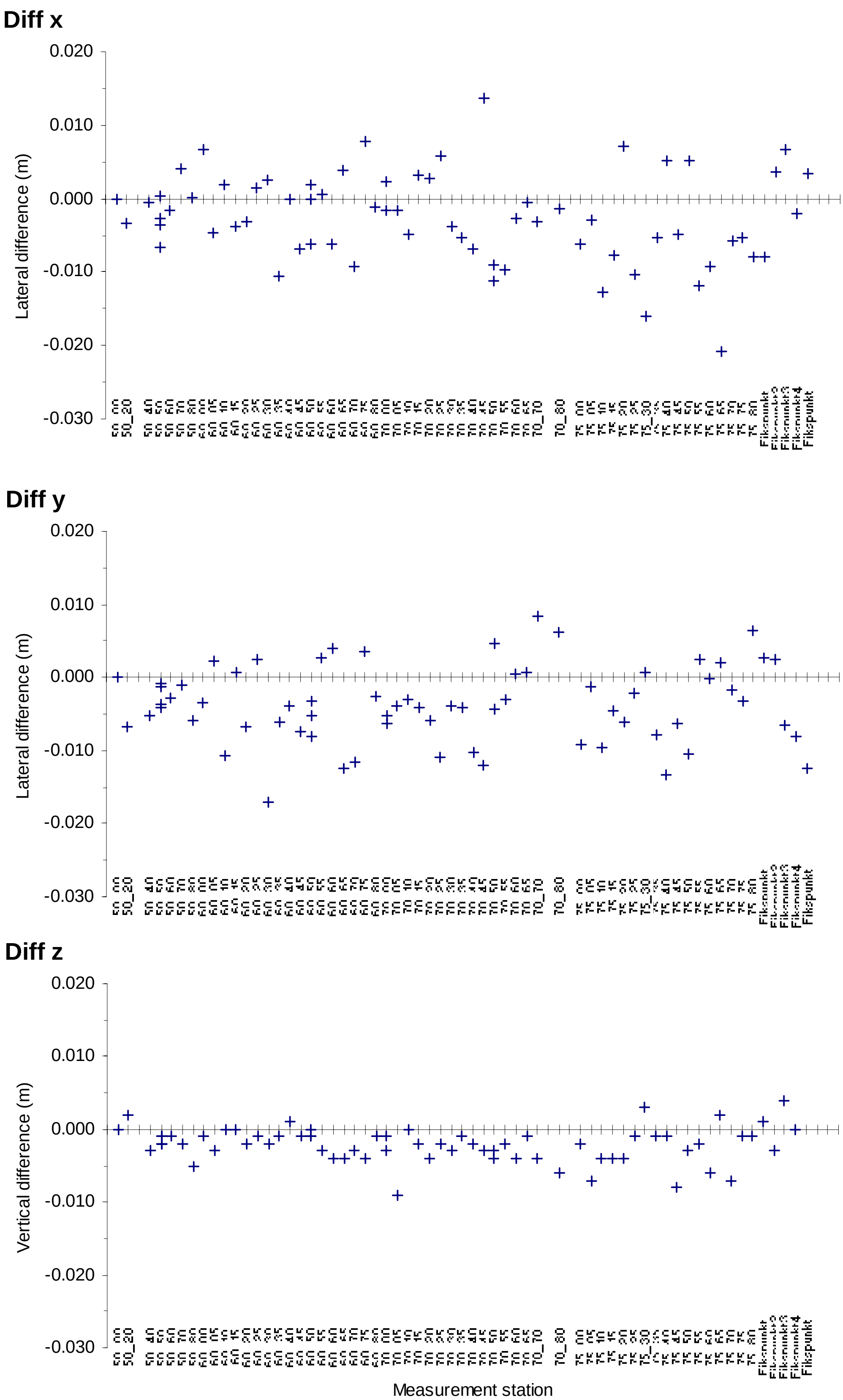

Figure 28. *Birling Gap, difference between September 2001 and January 2002.*

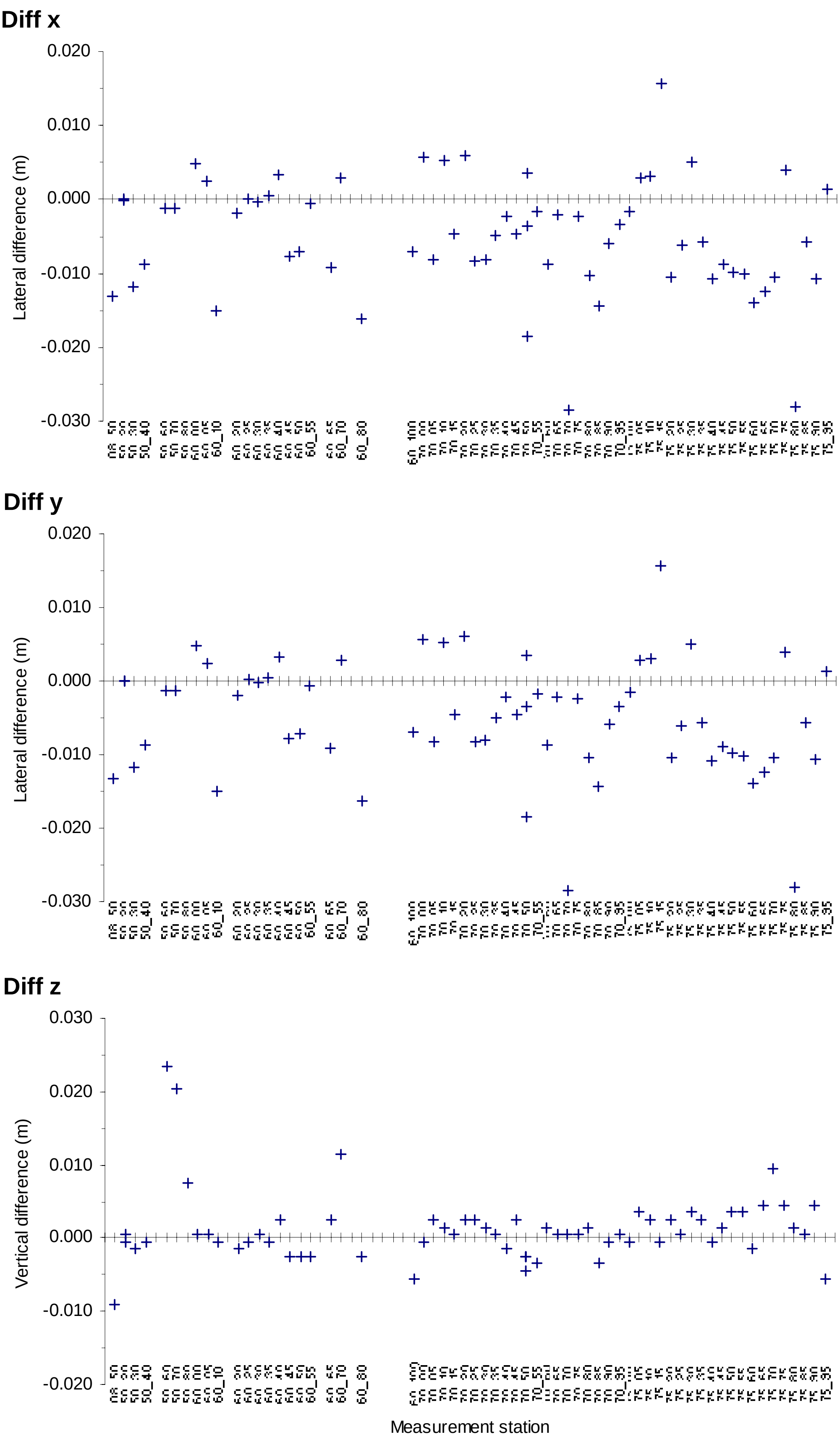

Figure 29. *Mesnil-Val, difference between September 2001 and January 2000.*

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