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DENMARK AND GREENLAND
Report 1996/9

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An analysis of the origin, nature and distribution of visible fractures in a significant portion of the clay deposits, with a specific emphasis on the depth interval between 3 and 7 m below natural ground surface, at the Laidlaw Environmental Services facility in Lambton County, Ontarion

By K. E. S. Klint

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SUMMARY

The project was carried out by the University of Waterloo Dept. of Groundwater Research and GEUS (the Geological Survey of Denmark and Greenland) Dept. of Quaternary Geology.
The fieldwork was carried out in october-november 1995 by Knud Erik Klint from GEUS, Rick Gibson from The University of Waterloo and Jamie Christiansson representing Laidlaw.

More than 160 m of profiles were investigated in order to study the depositional history and the origin, nature and distribution of fractures in the clay deposits at the Laidlaw Environmental Services facility in Lambton County, Ontario.

The sedimentary history of the clayey deposits at the Laidlaw site includes two cycles of lacustrine deposition of fine-grained sediments mixed with deposition of dropmaterial from icebergs and possible turbidites. The two cycles are separated by a period of erosion when the area was above lakelevel or below a glacier. This transition represent a period of nondeposition (a hiatus) and may therefore belong to the Mackinaw Interstade approximately 13.5 to 13.2 KA BP. The Black Shale Till thus belong to the Port Bruce Stade (lake Maumee) before 13, 5 KA and the St. Joseph Till then is accordingly deposited during the Port Huron Stade (lake Whittlesey) between approximately 13.2 and 12.6 Ka BP (Lewis et al. (1994). During the period of deposition differences in grainsize of the sediment might respond fluctuating lakelevels or changes in the sediment input to the lake.

The sediment has been intensive deformed, possibly due to grounding icebergs and slumping, activated by drop material from icebergs as well as “sinking” sedimentflows (turbidites). This material appears as isolated pockets or lenses throughout the St. Joseph Till, with a concentration between 6,5 and 11 m b.s. An occurrence of black sand at the transition between the St. Joseph Till and the Black Shale Till might have a more continuous appearance, which could be verified by further investigations of boreholedata from the area.

The Fractures in the upper part of the St. Joseph Till is classified as nonsystematic, contraction fractures formed either by desiccation or freezing mechanisms or a combination of both.
There seem to be a clear relation between the fracture pattern and the topography of the area. The surface of the ground is characterized by a drainage-system consisting of long depressions with a relative difference in the relief at approximately 0,5 m. This depressions dries out slower than the “highs” and thus the fractures here are less developed and penetrate typically down to approximately 4 m b.s. while the major fractures between the depressions are penetrating to approximately 5.2 m b.s. but locally to more than 6,4 m b.s.
The fractures close to the depressions seems to develop in a more or less orthogonal pattern with the major fractures perpendicular or parallel to the depression, while fractures in areas farther from the depressions show a different fracture-pattern with development of higher order polygonal systems. These areas are characterized by a larger fracture-intensity, a deeper weathering, and formation of a kind of columnar clay, formed by 1’st order fractures penetrating typically down to approximately 5 m b.s. (max. 6 m b.s.) These fractures forms 1’st order columns approximately 40 cm wide and these columns are then cut by smaller 2’nd order fractures forming 2’nd order columns typically 4-6 cm wide. These 2’nd order fractures terminates approximately 4,5 m b.s.

1. INTRODUCTION

Disposal of solid industrial wastes occurs in excavations to a depth of 18 m in clay-rich Quaternary deposits at the Laidlaw Environmental Services facility in Lambton County, Ontario. The site is exceptionally well suited for waste disposal because the clayey Quaternary deposits are 40-45 m thick across the site. The thick zone of unweathered clayey sediment beneath the disposal pits protects the regional aquifer from contamination (Fig. 1).

Visible Fractures exist everywhere to a depth of 4 m and deeper at some locations. The Zone of visible fractures has some degree of hydrologic activity due to permeability imparted by the fractures. This permeability provides avenues for lateral movement of leachate from old (pre-1985) waste-disposal pits where leachate has locally entered into the fractured zone. The new disposal pits (post 1985) have a design that minimize entry of leachate into the fractured zone because of a 6 m thick compacted clay cap on the filled waste pits.

The occurrence and hydrogeologic significance of fractures at the site has been studied more intensely than any other site in Canada (Fig. 2). The deep excavations provide excellent opportunity for visual observations of the distribution and nature of fractures. Numerous monitoring wells provide detailed information on shallow groundwater conditions.

This study is part of a continuing effort to determine the relation between geology, fractures and subsurface hydrology of the Laidlaw site. The surficial geologic unit is the St. Joseph Till to a depth of 15-17 m across the site and the Black Shale Till between the St. Joseph Till and the sedimentary bedrock. The water table fluctuates seasonally between ground surface and the bottom of the weathered zone. Knowledge of the depth of hydrological active fractures and the occurrence and extent of the sandy zones is needed for improved interpretation of various types of hydrologic information such as water table behavior and distribution of environmental isotopes (tritium, oxygen-18, deuterium), and geochemical information such as natural major-ion distributions.

1.1 Goals and Scope

The main goal of this study is to determine the origin, nature and distribution of visible fractures in a significant portion of the Laidlaw site with emphasis on the depth interval of 3 and 7 m below natural ground surface. A secondary goal is identification of other features that could impart permeability to clayey Quaternary deposits such as lenses, or pockets of sandy or silty sediment within the till. In pursuit of these goals consideration is given to geologic origin of the St. Joseph Till and the sedimentological features at the contact between this till and the underlying Black Shale Till.

The fractures, lenses and other features of the till units were mapped by visual inspection of vertical and near vertical walls of the current waste disposal pits and trenches dug by alongside this pit. The area of walls mapped is much larger than the areas covered in previous fracture studies at the Laidlaw site. This larger mapped area indicated variability of fracture networks that appears to relate to local topography.

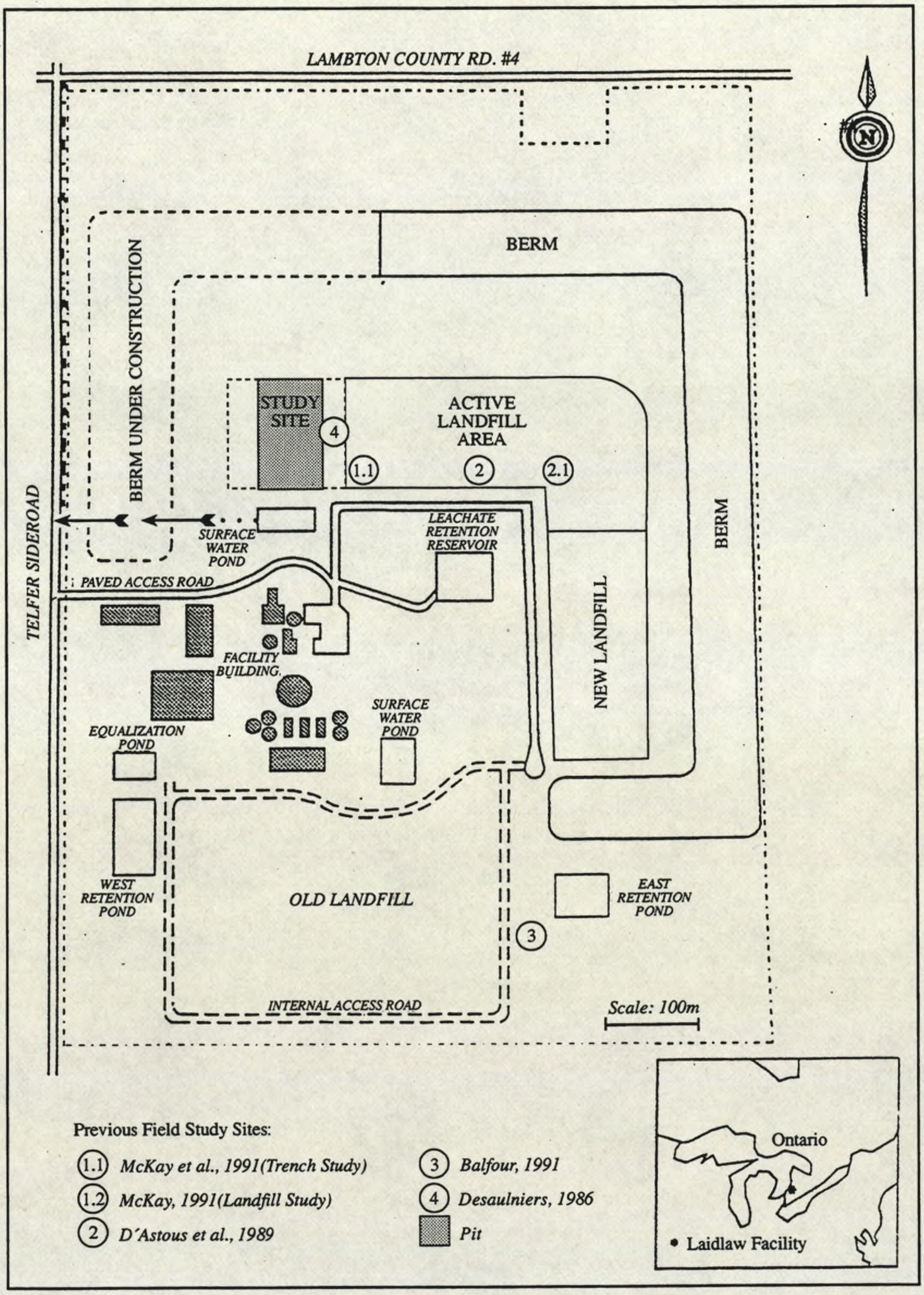


Fig. 2 Location of the field study site and previous study sites (modified after MacKay & Fredericia, in press).

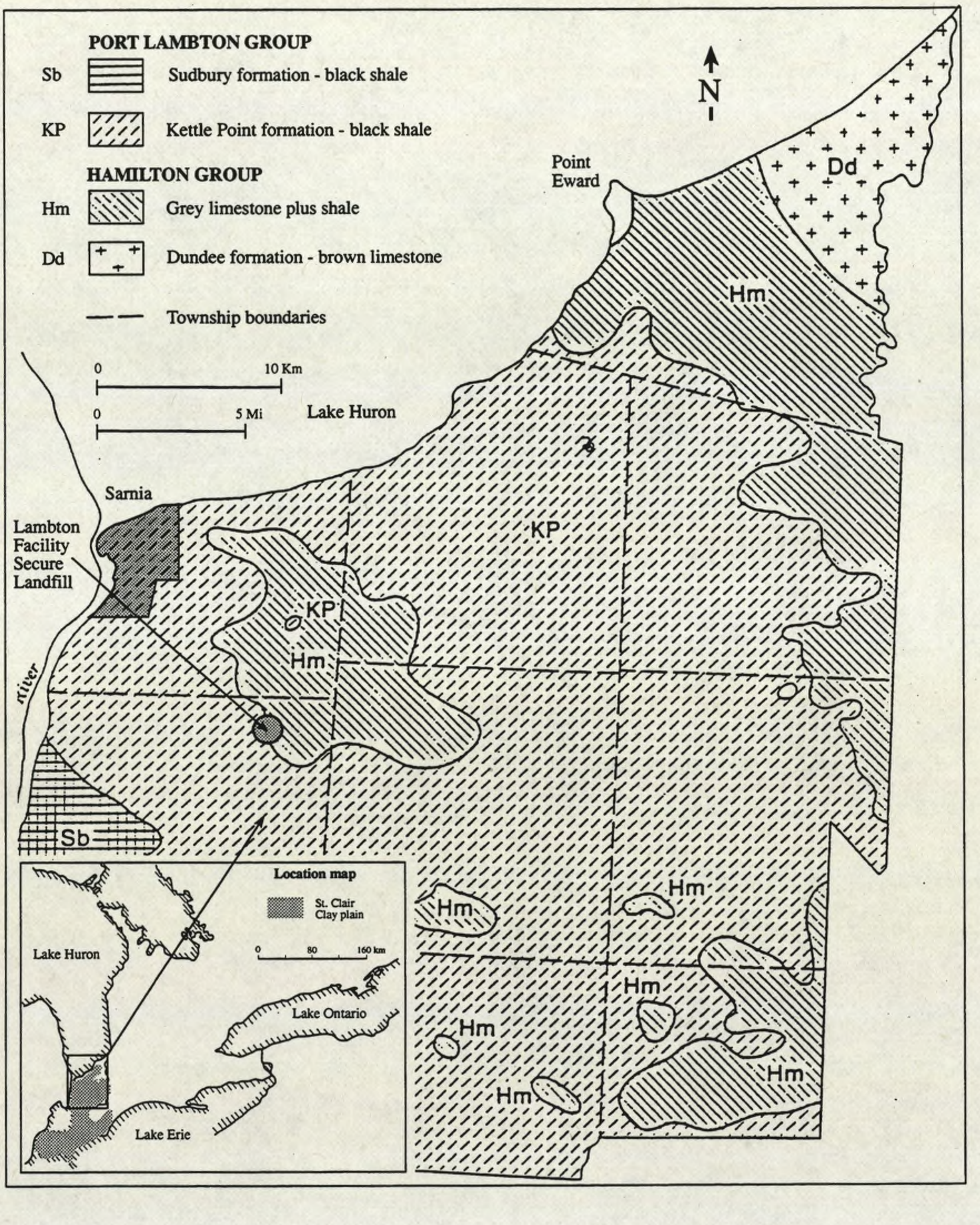


Fig. 1. Location-map of the Laidlaw Environmental Services facility and the distribution of the Pre-quaternary sediments.

2.METHODS OF INVESTIGATION

2.1Theory

Fractures include all brittle failures as joints, fissures, cracks etc. which is not a fault, bedding or cleavage, and which is larger than the grainsize of the rock. Some fractures may however show a small displacement between the two fracture surfaces, with additional development of stria or "slickensides" on the surface, and is thus refereed to as shear fractures or microfaults.

2.1.1 Characterization and classification of fractures.

Fractures may be devided into either *systematic fractures* or *nonsystematic fractures*.

Systematic fractures develop in relation to the direction of a certain stress and the homogeneity and orientation of the rock or sediment exposed to the stress. Any stress may be divided into three principal stress-vectors or stress directions: The maximum stress direction, the intermediate stressdirection and the minimum stressdirection, each of them being perpendicular to each other. Tri-axial pressure tests on different rock samples (Hobbs et al) shows that different types of fractures develop in close relation to these stress directions.

A number of more or less parallel fractures makes up a *fractureset* and one or more fracturesets related to the same tectonic event often forms a *fracturesystem* with a regional preferred orientation.

Nonsystematic fractures are all fractures which is not systematic. They often have a very irregular surface and a random regional orientation.

Fractures in <u>glacial deposits</u> especially tills may normally be divided into the following main categories:

Systematic fractures:

1. *Glacitectonites* is a glacial breccie formed at the transition between a till and a soft basement (limestone, shale). It constitutes crushed basement mixed with till and is characterized by extremely high fracture density preferably in a horizontal plane.

2. *Anastomosing fractures* forms in extremely well consolidated tills, which has been exposed to a powerful shearstress. They are characterized by multiple closely spaced shear-parallel fractures with undulating fracture surfaces crass cutting each other, giving and overall pattern of elongated rohmb-shaped peds.

3. *Shearfractures* may form in all kind of glacial sediments subjected to a compressive stress. These fractures often forms relative straight, listric or sigmoidal, fractureplanes with a planar-smooth sometimes striated surface. They often have a considerable size (tens of meters), a rather constant spacing towards depth and may penetrate deeper into the subsurface than most other kind of fractures.

Shearfractures forms in the same way as faults, often with a secondary set of conjugating fracture-planes. If the fractures conjugate, the two set of fractures cross-cut each other, and in that case the maximum stress-vector will point into the acute angle (bisector) between the two fracture-set, while the minimum stress-vector will point into the obtuse angle and the intermediate stress vector will be oriented perpendicular to the others. It is thus possible to estimate the maximum direction of stress if Shearfractures are positively identified.

4. *Extension fractures* develop parallel to the maximum stress direction and perpendicular to the minimum stress direction. They forms fractures with an often irregular curved rough surface. The size varies largely and often a number of closely spaced extension fractures forms a fracturezone which develops into a shearfracture or reverse fault.

5. *Pressure release fractures* are fractures developed in a plan parallel to the minimum stress vector and perpendicular to the maximum stress vector. These fractures forms when a stress is released, for example when a heavy overburden is removed either by erosion of sediments or melting of a glacier. These fractures typically forms horizontal/subhorizontal fractures following naturally weakness zones as beddingplanes or tectonic layers (fissile tills).

6. *Hydrofractures* are fractures formed when high fluid pressure makes existing fractures progradate into the subsurface. Such conditions may be initiated in a small scale just by rising the groundwater level, or when icesheets melting basely, inject water into subglacially permeable beds under maximum head equivalent to the total ice pressure (Boulton et al. 1995). These fractures develop in relation to the lithology and general stress situation. Such fractures has normally an irregular, rough, undulating surface and they are often filled with intrusive fine sediment. They may be very difficult to identify as they often reactivate existing fractures with a different genesis and thus inherit older characteristics.

Nonsystematic fractures:

Contraction fractures:

1. *Desiccation fractures* (drying out processes).
Desiccation takes place during periods of low watertable in the subsurface. Especially clayey and silty sediments with high watercontent starts to shrink and form fractures in a characteristic orthogonal or polygonal pattern, The size and form of the fractures depend on the lithology (weakness zones as older

fractures, bedding planes etc.), or/and the direction and the speed of the drying out processes, but normally the fractures forms as vertical to subvertical fractures with an undulating, rough fracture surface and a decreasing fracture density towards depth.

2. *Ice and sand wedges* (freeze thaw processes)..
During periglacial conditions freeze and thaw processes may form a variety of contraction features, the most common being ice or sand wedges depending on the climate (wet or dry). These wedges may form polygonal nets, often with the first fractures forming parallel to a certain waterbody and new fractures forming perpendicular to the first ones. The formation of the fractures depend highly on the temperature, but in general the order of fractures increase with decreasing temperature (hexagonal systems instead of orthogonal).

2.2 Measurement techniques.

The main purpose of conducting fracture analysis in general, is to deduce the geological history and calculate the fractures influence on the hydraulic and geotechnical properties of a rock or sediment. A number of parameters add to the understanding of the origin and history of the fractures, and other parameters enable us to calculate hydraulic and geotechnical properties of the fractures. In order to calculate those parameters, a number of fracture data must be looked upon.

2.2.1 Fracture data

Physical data collected for fracture-analysis (see Fig. 4):

Position (placing): Is used for reconstructing a profile and calculate fracture-spacing and frequency.

Order/System: The fractures are classified as 1'st, 2'nd or 3'rd order fractures, with the 1'st order fractures as the dominating fractures cross cutting all other fractures (in general > 1 m long), 2'nd order fractures are less dominating fractures sometimes connecting 1'st order fractures without crossing them (in general between 0,25 and 2 m) and 3'rd order fractures are minor fractures (in general < 0,5 m), but the scale is relative, and in some cases where the 1'st order fractures maybe are more than 100 m long, the 2'nd order fractures maybe more than 10 m long.

If a clear systematic set of fractures can be recognized in the field it may be given a number as system 1 fractures and another set system 2 etc.

Orientation: The orientation is measured with a compass with a clinometer and the strike and the dip of the fractureplane is measured. Is used for reconstructing the profile and calculate fracturespacing and frequency.

Size: The visible minimum size of the fracture is measured, by measuring the tracelength and he depth of the fracture. The fracture is classified as an A (both termination's visible), B (one termination visible) or C (no termination's visible). Is used for reconstructing the profile and calculate fracture spacing and frequency.

Surface shape: The overall fracture shape (m scale) is described as listric, straight, sigmoidal or random. Is used for classifying the fractures and calculate rock stability.

Surface character: The surface character is described in cm scale as planar, undulating or irregular and the roughness index in mm scale as smooth, rough or slickenside (striae). Is used for classifying the fractures and calculate rock stability.

Aperture: The aperture or the opening diameter of a fracture is extremely important in order to calculate the hydraulic conductivity of the fracture, but it is difficult to measure in soft sediments, so samples with fractures are carefully impregnated, and the aperture is measured directly on thin-sections under a microscope. The only other way is to calculate the aperture is from hydraulic tests either in the field or in large samples in a laboratory.

Chemical and biological data:

Clay-mineralogy: Influence among other thing the chemical reactions with fluids and swelling abilities of the clay.

Percentage of CaCO3 in the matrix: Influence the geotechnical and chemical properties of the sediment.

Surface cover (precipitation): Reflect different chemical conditions, which changes with the depth and the hydraulic conductivity of the fractures.

Halo: Changes in colors in the matrix next to the fractures are connected with the hydraulic activity in the fracture.

Root-index: Reflects to some extend the aperture and the hydraulic conductivity of the fracture.

Burrows: Reflect the competence of the sediment and add to the total hydraulic conductivity.

Important Lithologic parameters:

Petrography analysis: Characterize the sediment and add information about the source-area of the diamicton, iceflow-directions and is used to correlate local diamictons.

Grainsize distribution: Characterize the sediment and influence the hydraulic properties of the matrix.

Clast fabric: Is used to characterize diamictons and classify the till as subglacial lodgement till, melt-out till, supra-glacial flow/melt-out till or marine/lacustrine drop till.

Internal deformations: Are used to classify sediments and measure glaciotectonic deformations, slump structures, flow-structures etc. which may be useful for calculating ice-push directions.

Rock strength: Add information about the consolidation and competence variation in the sediment.

2.2.2 Calculation of fracture-parameters

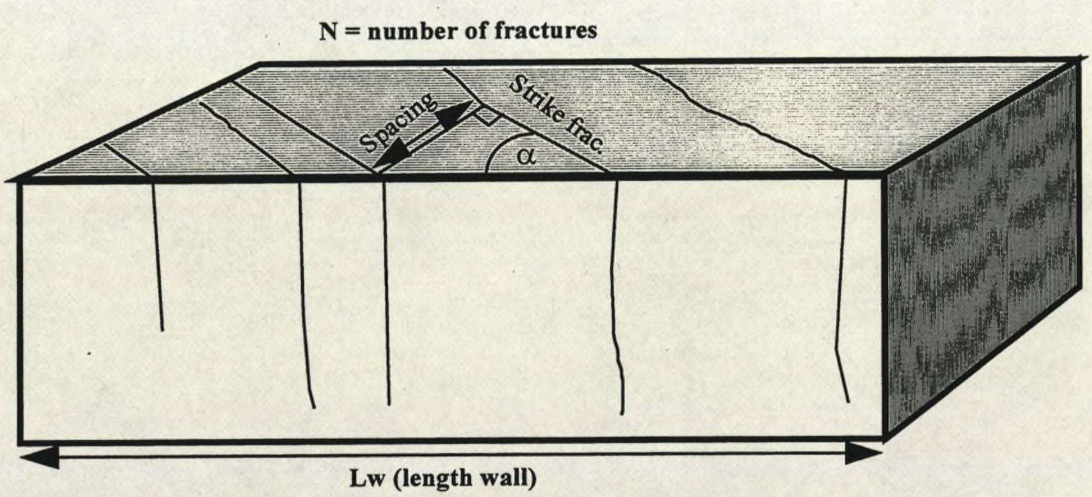
Fracture orientation is illustrated on *stereographic projections,* where all fractures are plotted as the pole to the fractureplane, or as a *fracture strike diagram* showing the strike variation, but this method do not account for the dip and should only be used if the fractures are vertical/sub-vertical.

Fracture spacing (S) is the average distance between almost parallel fractures in a fracture set. In areas with a random fracture distribution it might be difficult to estimate the true spacing as few fractures in each strike interval will result in a rather large uncertain factor. In such situations it might be better to include more fractures from a broader strike interval (20 degree instead of 10).

Fracture intensity (I): 1/S (number of fractures pr m) The spacing may be illustrated as the Fracture Intensity (1/S), which allows the spacing to be illustrated on a "Rose diagram". The total of all fracture sets is then showing the number of fractures in an average cubic-meter of clay.

Fracture frequency (N/Lw) is another way to illustrate the fracture distribution both lateral and vertical. But it must be noted that near wall parallel fractures are biased.

Fracture density (D) is mainly used on non-planar fractures (primary 3'rd order fractures) and is the total fracture tracelength/area unit. The different equations are illustrated on Fig. 3.



α = angle between the mean fracture strike and the strike of the wall.

Mean spacing:	**$S = \sin\alpha \times ((Lw/(N+1)+(Lw/(N-1))/2$ (Only vertical/subvertical fractures)**
Intensity:	**$I = 1/S$**
Frequence:	**$F = N/Lw$**

Fig. 3 Calculation of fracture parameters

Location ______________________ Profile ________________________________ Kote/Date ________________ ______

Description of fieldsite: ____ Init:___

Profile (wall) Orientation: ________ Length: ______ Hight: ________ Dip : ________

Reference line: Length: ______ Placing in profile : _______ Depth m.b.s.: _________

Placing/ top frac. level. (m b.s.)	Order/ system	Orienta- tion	Tracelength / A-C*/ Depth.	Fracture shape (m) Listr.Str. SigmRan.	Surface character: Pl. OnIr Sm Ro Sl**	Surface cover (Precipita- tion) 1-5***	Rootindex R1 - R3 Low-high	Halo wideness of bleac- hed zone.	Remarks. Sample no.	Foto day, month, no.	No.
											1
											2
											3
											4
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											16
											17

Fig. 4 Fracture data chart used for collecting fracture data in the field.

2.3 Geological mapping.

Seven profiles numbered 1 to 7 were mapped (Fig. 4). Profile 1, 2, 3, 6 and 7, with a total length of approximately 110 m in the interval between 0,5 and 7 m b.s. were excavated by backhoes and later carefully chipped off by knifes and trowels in order to remove all the smeared clay and expose the fractures and other structures in the clay. The upper 2,5 m of the profiles were cut off in a 45 degree angle in order to stabilize the walls. Except from profile 1, and 7 the investigations were concentrated in the interval between 3 and 7 m b.s.

Intact samples for lithologic analysis and aperture measurement were collected immediately after excavation. In order to exclude all new fractures made by: the backhoe, desiccation and/or stress release, after the excavation, only fractures with some kind of surface cover were measured. This may exclude single fractures with no contact to other fractures, but it gives a better overall impression of the bulk hydraulic activity of the fractures.

The upper highly fractured zone from 0,5 to 4 m b.s. were described on profile 1 and partly profile 7. After chipping off the walls a reference line was measured in relation to a known (Surveyed) point. A gridnet with the grid-size of 1 x 2 m was then marked directly on the wall by spraypaint. Photos were taken and the profiles were drawn. The major sedimentary and tectonic structures were measured and described, the major transition zones between the weathered and the unweathered clay were plotted on the profiles and finally a measuringtape was attached along the profile at known depth between 3 and 5 m b.s., and all fractures were measured and described on a fracture data chart according to the methods described earlier in this report (Fig. 4).

2.3.1 Lithologic classification

Although no visible fractures were located below 7 m, profile 4 and 5, in the interval between 6 and 15 m b.s., were measured in the same way as the other profiles, in order to describe the geological history of the area and to support the interpretation of the formation and genesis of the fractures.
A vertical lithologic section were measured and a lithologic log was constructed. No samples were collected for petrographic analysis, as this has been done earlier by other authors (McKay & Fredericia in press). But fabric analysis of elongated clasts > 0,6 cm were carried out between 0,8 and 2 m b.s. in order to classify the upper part of the clay.

2.3.2 Fractureanalysis

After collecting all the data, a vertical profile was constructed and the fractures were reconstructed on this profile, primary from the measured data and partly from photos. The fracture spacing/intensity, fracture frequency, the orientation variation and the maximum depth variation were calculated for each profile and in some cases for smaller parts of the profiles, in order to evaluate the lateral variation. The fractures were classified and the occurrences of the fractures were compared with the lithologic and topographical data, in order to evaluate possible connections, and finally to evaluate the regional fracture distribution in the area.

3. RESULTS

3.1 Lithology

3.1.1 General description

The upper 15 m of sediments consist of stone-rich silty clay referred to as the St. Joseph Till, and below the 15 m consist of Black Shale Till . In general the term till refers to a sediment deposited directly from a glacier, either below the glacier as subglacial lodgment-till, sub or englacial melt-out till or as supraglacial flow-till from the surface of the glacier. (Dreimanis 1988, Krüger 1994). The lack of a clear till-fabric and the presence of varvig clay and dropstones contradict the use of the term "till" for the St. Joseph Till, instead the more general term, for a sediment related to deposition processes in a glacial environment, "diamict" is used.

Lithologic description (Fig. 5)

0 - 0,5 m b.s.: Topsoil. Organic-rich clay/silt/sand. Highly oxidized, aggregated, dark brown well consolidated, chalk poor matrix.

0,5 - 3 m b.s: (St. Joseph Till) Clayey/silty massive to laminated/weakly laminated weathered diamict with thin (0,2-4 cm thick) fine sand/silt layers and small deformed sand-pockets or horizontal to sub-vertical sand-sheets, few stones, primary limestone, dolostone, flint and black shale, and few igneous, and metamorphic rocks. Some stones are ice scoured with clear stoss-lee sides, but often with a random orientation and a steep dip of the lineations. The general color is light grayish-brown in the top and gradually grayish-brown below 1,2 m b.s. The matrix is chalk-rich below 0,5 - 0,8 m b.s.

3 - 6 m b.s.: Clayey/weakly silty massive unweathered diamict with thin deformed low to steep dipping sand/silt sheets (0,2 - 3 cm thick and up to 10 m long) and few deformed laminated deformed sand/silt/clay pockets (up to 1 m thick and more than 5 m long. few stones, primary limestone, dolostone, flint and black shale, and few igneous, and metamorphic rocks , few fossils (Brachiopods). The color is grayish brown. The matrix is chalk-rich.

6 - 14,5 m b.s.: Clayey/silty massive to laminated/weakly laminated unweathered diamict from 6,5 - 7,5 m b.s. which changes to clayey/weakly silty massive diamict below 7,5 m. Few stones, primary limestone, dolostone, flint and black shale, and few igneous, and metamorphic rocks. The color is grayish brown turning into olive gray below 12 m. The matrix is chalk-rich. between 12 and 14,5 m the diamict changes into a fine laminated silty/clayey sediment overlaying an almost continuos 0,1-30 cm thick layer of cross-bedded black medium sand (large content of black shale).

This section contains a characteristic level between 6,5 and 10 m. Several large sandbodies/pockets up to 7 m long and 3 m thick are concentrated in this level (Fig. 6). The sandbodies consist of to major lithologies. Either fine homogenous structureless or laminated silt/fine sand to medium sand with visible primary structures, or highly deformed sandbodies with clay-clasts in rather homogenous sand without primary sedimentary structures. All the sandbodies have a very irregular form downwards but a relatively flat horizontal top around 6,5-7,5 m below surface. This level is characterized by numerous thin almost horizontal fine sand sheets 0,2-4 cm thick and some of them more than 15 m long. Some of the sand sheets are connected with the sandbodies, and appear to origin from them. Between 12 and 14 m a third type of sediment body appears in the clay. it consist of a sandy/clayey/silty massive diamicton with few stones and with a characteristic reddish/gray color. The diamicton bodies forms 5-50 cm thick and more than 5 m long lenses just above the black sand lenses overlaying the Black Shale Till, but few occurrences are found further up in the sediment.

14.5 m b.s. Black sand lenses (layer). This level is characterized by an almost continuos layer of black, medium, small scale cross-bedded, sand with a large content of black shale grains (Fig. 6). The sand lens are up to 35 cm thick and but vary largely and in some places the sand is missing. The sand show no sign of being transported and the primary structures are largely intact. The presence of climbing ripples elsewhere indicates a probably fluvial or deltaic regime for depositing the sand (Fredericia J. pers. communication)

Below 14,5 m: (Black Shale Till) Clayey silty massive till, laminated/weakly laminated in the top. large content of shale fragments in gravel size. The clay have a characteristic ruptured appearance in the upper part, and seems fractured, but without any kind of staining or coating on the fracture surfaces. The color is dark gray and the chalk content is lower than the St. Joseph Till above.

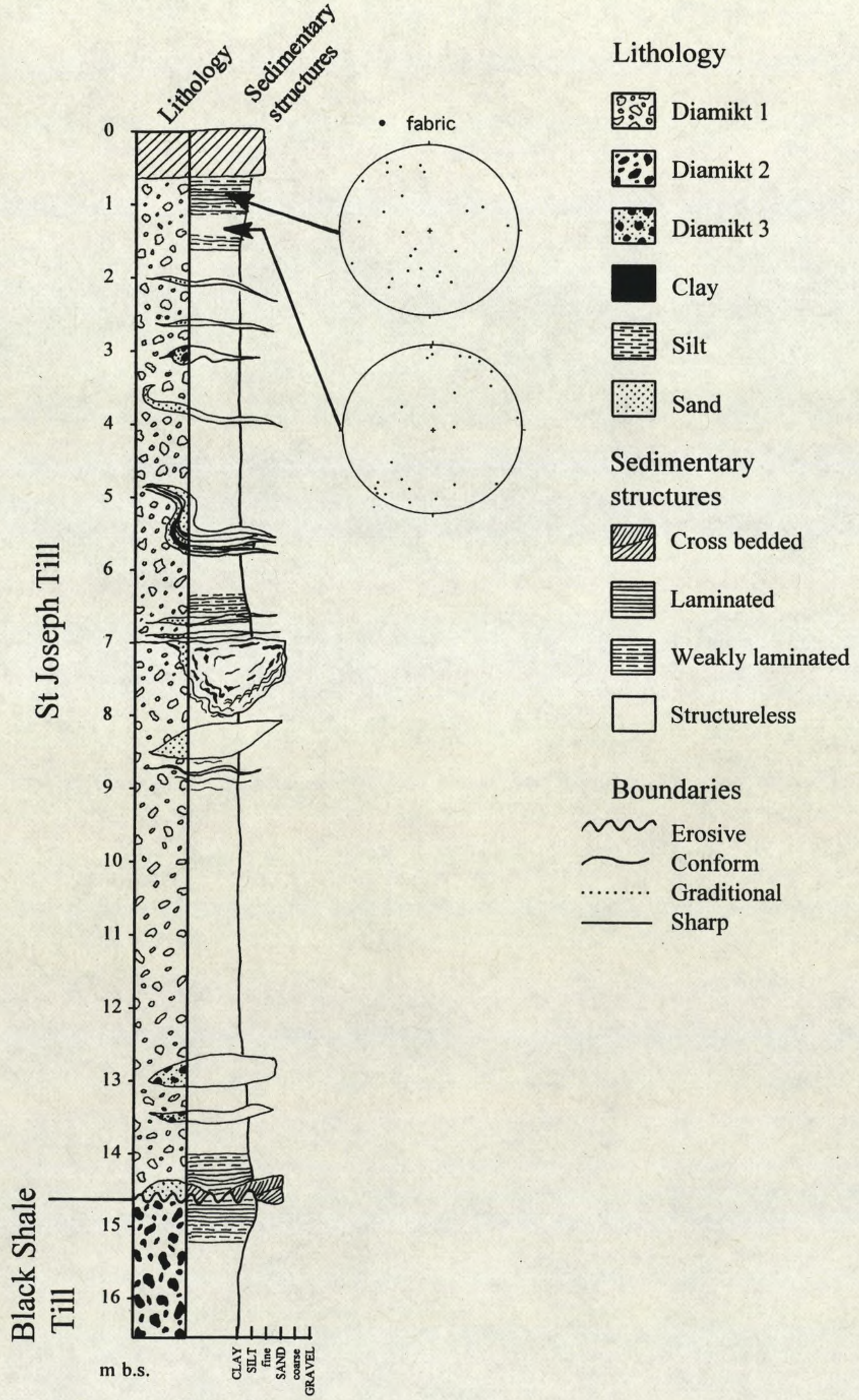

Fig. 5 Geological log. of the area.

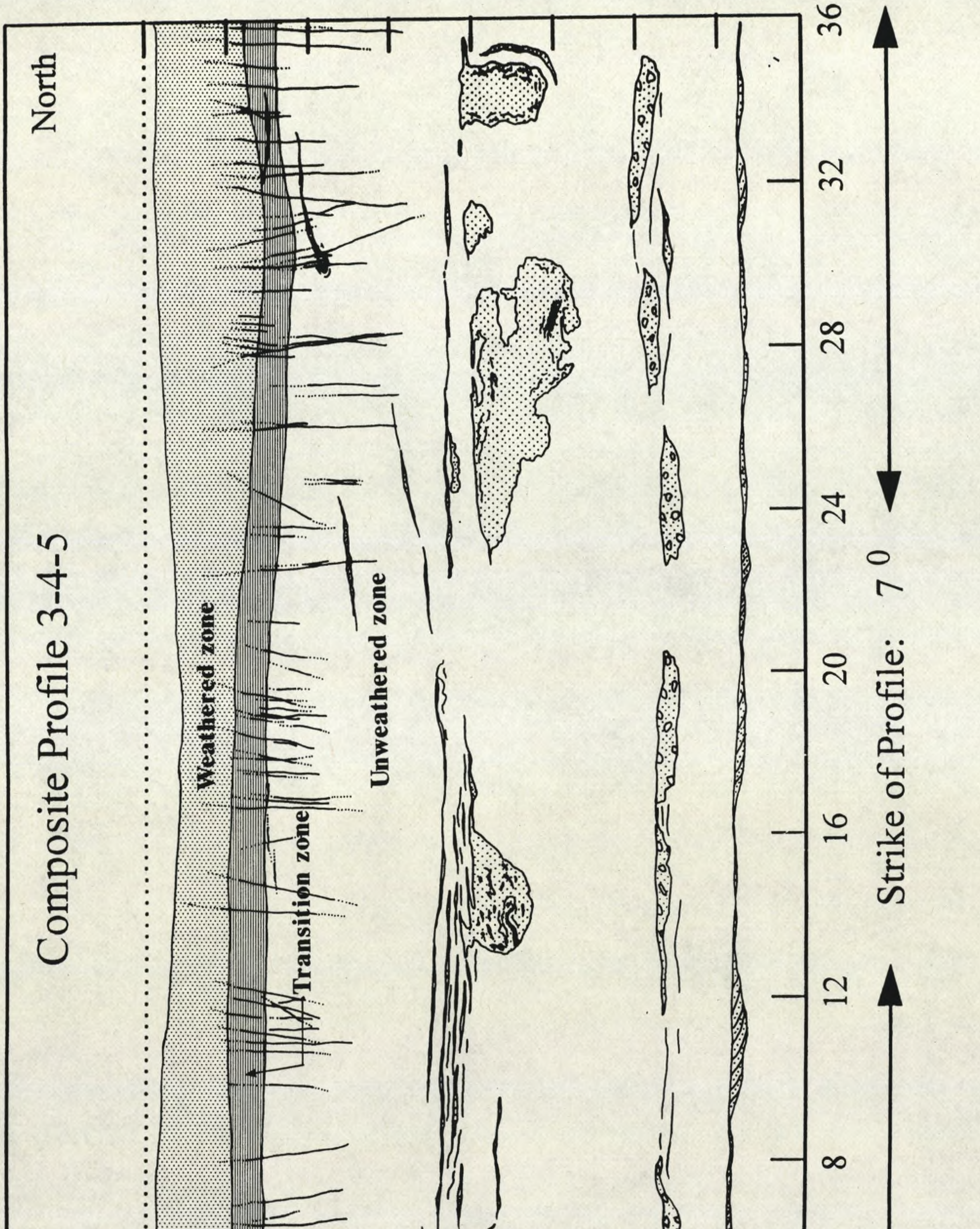

Fig 6. Composite profile of profile 3, 4 and 5 showing the changes in lithology down to 16 m b.s.

3.2 Fractures

3.2.1 General description.

0-3 m b.s.

The diamict is extremely fractured from 0,3 to approximately 2,5 m b.s. One system of horizontal/sub-horizontal 3'rd order fractures, with Fe-oxide staining on the surface, is very dominant at this depth. The orientation of the fractures follows the orientation of thin silt/fine sand laminae. The fracture density is in general larger in the upper part (Fig.), but seems heterogeneous distributed in 15 to 40 cm wide horizontal/sub-horizontal zones with an average spacing between the fractures of approximately 0,5 - 0,7 cm in the heavily fractured zones to approximately 1 - 2 cm in the less fractured zones. The heavily fractured zones are often, but not necessary associated with the thin silt/fine sand laminae. These fractures are truncated by small 3'rd order vertical fractures with a general larger spacing, thus forming a general systematic "brick" pattern of rectangular to rhomb shaped peds.

From approximately 1,8 to 3 m b.s. in profile 1 and from 3 to 4 m b.s. in profile 7 the systematically oriented 3'rd order fractures change to random oriented fractures with a very irregular yet zoned appearance. These fractures are associated with a general change in the induration of the clay from stiff competent sometimes weakly laminated clay to a more soft incompetent fat massive clay, which can be molded easily between the fingers. This interval is a transitionzone between the upper weathered zone and the lower unweathered zone and the clay gets gradually softer with a smaller stone content.

The whole section is penetrated by major 1'st order vertical/sub-vertical fractures intersecting each other and linked by smaller 2'end order vertical/sub-vertical fractures.

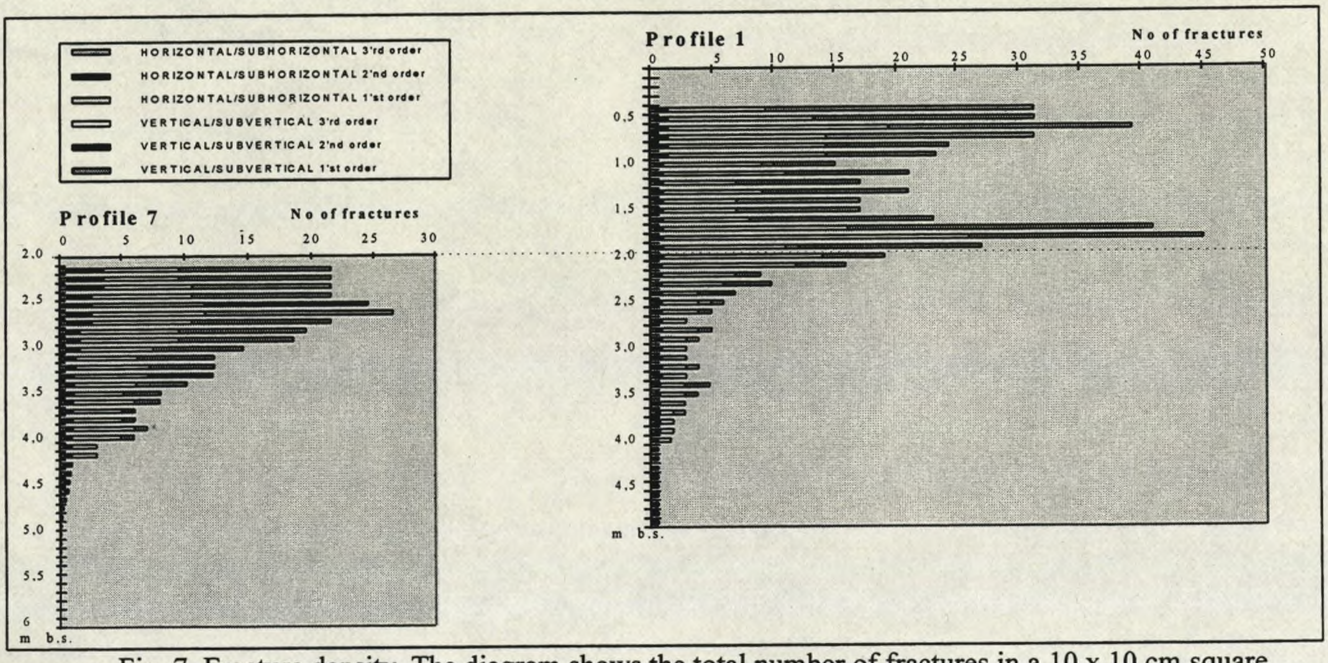

Fig. 7. Fracture density. The diagram shows the total number of fractures in a 10 x 10 cm square for each 10 cm downwards, note the zonation with high fracture density zones on profile 1.

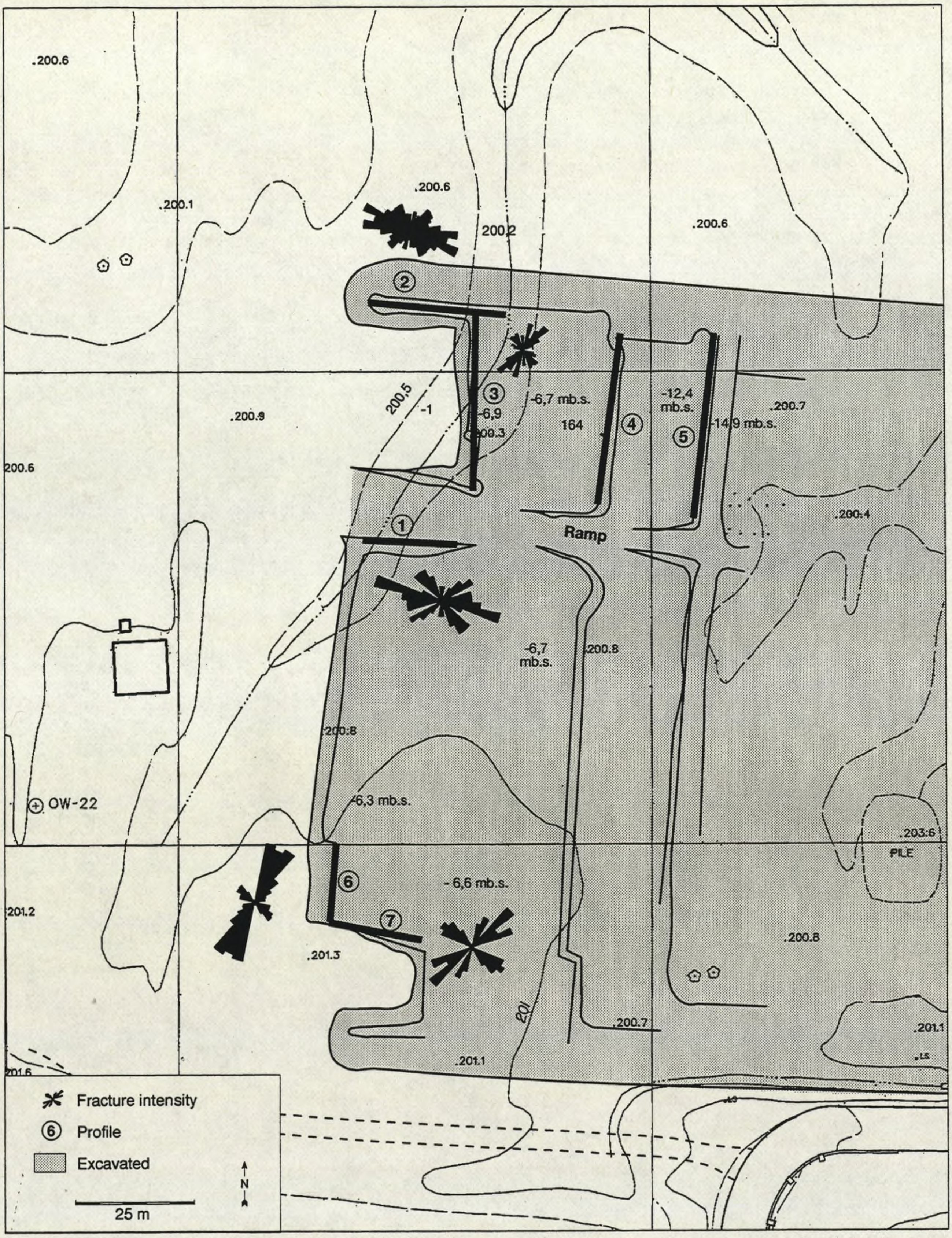

Fig. 8 Location map showing the location of profile 1-7 and the fracture intensity, and orientation compared with the original topography of the area.

3 - 7 m b.s.
Profile 1. 2 . 3. 6. 7. were all measured and the fracture data calculated. All the primary data are enclosed in Appendix 1. Fig. 8 shows the location of the profiles and the relative 1'st order fracture strike and intensity compared with the original topography of the area. There seems to be a clear reduction in the intensity of the fractures across the depression. The relative high concentration of fractures on profile 1 is primary due to the higher measuring level 1-4 m b.s., while the other profiles were measured below 3 m. It must be kept in mind that although the dominating 1'st order fractures were quit easy to recognize and excavate, a majority of the 2'nd order fractures were never found in some profiles, due to the smearing of the backhoe, this means that while the number of 1'st order fractures are quite reliable, the 2'nd order fractures vary to a large extend depending on the exposures. Most of profile 7 were very well exposed, as most of the face had collapsed leaving an almost intact surface without smearing. In the other profiles some exposures of large fracture surfaces was exposed by "plucking" of the clay with the backhoe, but in general the intensity of the 2'nd order fractures is underestimated and major comparison between the profiles should be done on 1'st order fractures only.

3.2.2 Profile 1

Description:
Profile 1 is striking east-west (100 degree) along the ramp down into the clay pit. The exposure was fair as most of the walls had fallen in leaving almost unsmeared clay. 15 m of the profile was measured from approximately 1 to 4 m b.s. 72 1'st and 2'nd order fractures were described and measured and the fracture density of the 3'rd order fractures were calculated. The 1'st and 2'nd order fractures were dominated by in general straight vertical/sub-vertical fractures with an undulating rough surface character. Most of the fractures had roots or traces of roots on the surface and intense weathering of the matrix as the 3'rd order fracture density was intense.

Fracture orientation:
The orientation of the fractures is illustrated on Fig. 9. The fractures are widely orientated, but there is a moderate domination of almost vertical fractures striking 40-60 degree, 100-120 and 130 to 160 degree.

Fracture spacing:
The average fracture spacing of the dominating fracture directions varies from approximately 0,7 m around 110 degree, to approximately 1 m around 50 and 150 degree. It must be noticed that the spacing of fractures striking close to 100 degree is based on very few fractures as they are near parallel to the face of the profile. This spacing is thus rather questionable.

Fracture intensity:
The total fracture intensity of profile 1 is approximately 5-6 1'st order fractures/m, with a maximum of fractures striking 100-120 degree. Totally the fracture intensity is close to 10 fractures/m.

Spatial distribution (lateral and vertical frequency):
The depth frequency could not be measured as the profile only extended to approximately 4 m b.s. to the east end of the profile and 1 m b.s. in the west end of the profile.

Profile 1 Fracture data chart

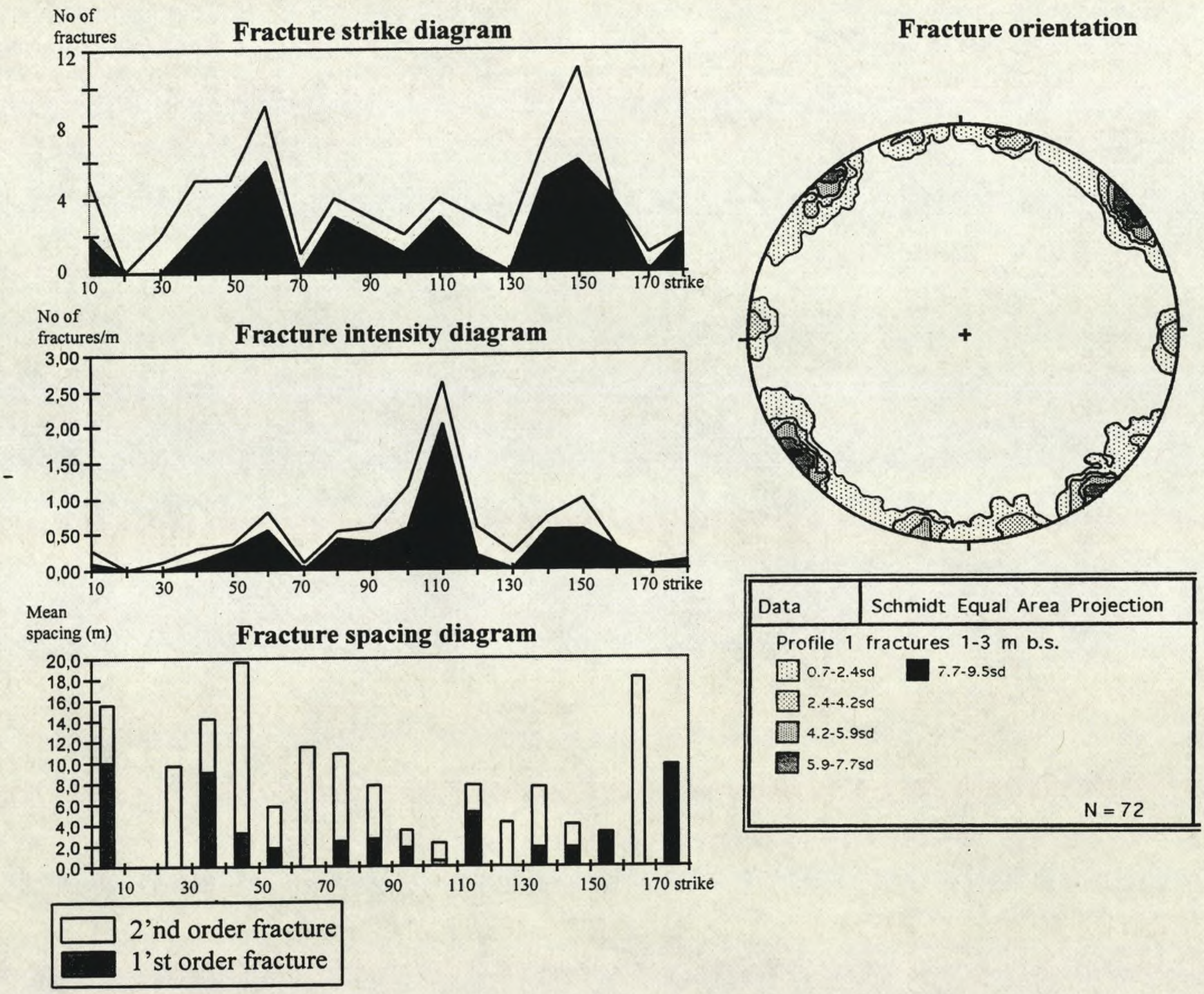

Fig. 9 Fracture data chart profile 1. The stereographic projection shows the density of the poles to the fracture surface on a Schmidt equal area projection (lower hemisphere)

3.2.3 Profile 2

Description:
Profile 2 (Fig. 10.) is striking east-west (102 degree). 26 m of the profile were investigated between 2,5 and 6-6, 5 m b.s. A total of 178 1'st and 2'nd order fractures were measured and described. The section is approximately 0,5 m lower in the eastern than in the western end. The clay was highly fractured in the weathered zone down to approximately 2 m, where the matrix gradually becomes unweathered in a approximately 40 cm thick transition zone. The clay is rather massive, but occasional thin sand layers appears between 0 and 12 m. The sand layers are 0,2- 4 cm thick, up to 10 m long and dipping gently (approximately 20 degree) towards SW. Around 16 - 20 m a steeply dipping 1 m thick lens, of fine laminated clay/silt/sand and small pockets of gravel, is folded in a "slump" like way. The foldaxis is gently dipping towards NNE. Other folded sand layers around 14 m and 26 m indicate a general deformation in the entire section. Seepage was observed from 8 major fractures between 5,8 and 6,4 m b.s. immediately after the profile was excavated. After 3 days the clay was moist around these fractures. Roots were fairly abundant down to approximately 4,8 m b.s. between 10 and 18 m on the profile.

Fracture orientation:
The orientation of the fractures vary to some degree along the profile. As illustrated on Fig. 10 the fractures changes orientation from two dominating fracture directions between 0 and 14 m on the profile, to a more random distribution with at least three dominating fracture directions between 14 and 26 m. The general direction is NE-SW and NW-SE in the Eastern part of the profile changing to a domination of fractures striking more WNW-ESE and E-W in the western part of the profile.

Fracture spacing:
The fracture spacing changes, but in general the fractures striking 80-120 degree dominates with a fracture spacing of approximately 0,6 - 1,0 m 3 m b.s. (20 degree interval) and slightly higher 0,7 - 1,0 m 5 m b.s. while the fractures striking 40 - 60 degree has a spacing on approximately 1,8 m (3m b.s.) and 2,3 m (5 m b.s).

Fracture intensity:
The total fracture intensity for 1'st order fractures is approximately 5,5 fractures/m (3 m b.s.) and 2,8 fractures/m (5 m b.s.). The reliability is high due to the large number of data.

Spatial distribution (lateral and vertical frequency):
The penetration depth changes along the profile (Fig. 10 and 11) from a fracture frequency on 1 frac/m down to 5,2 m b.s. from 0-12 m to 1,3 frac/m down to 5,6 m b.s. from 12-26 m. The maximum depth could not be measured as some of the fractures continued below the floor of the excavation 6,4 m b.s., but they are probably not continuing below 7 m.

Profile 2 fracture data chart

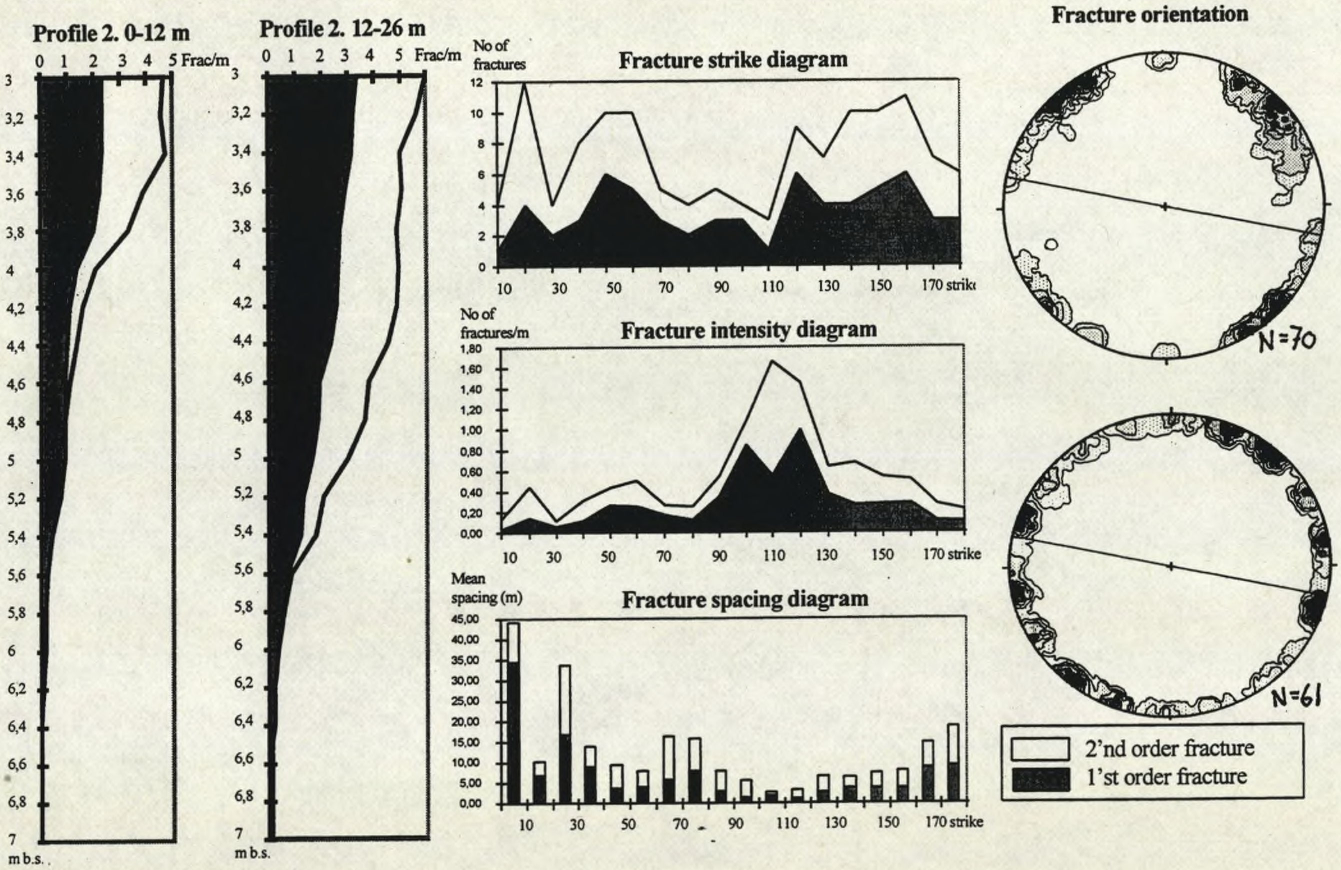

Fig. 9 Fracture data chart. The stereographic projections show the orientation of the profile (the line) and the concentrations of the poles to the fractureplanes on a Schmidt equal area projection (lower hemisphere).

The upper projection shows all fractures between 0 and 14 m. while the lower projection shows the fractures between 14 and 26 m.

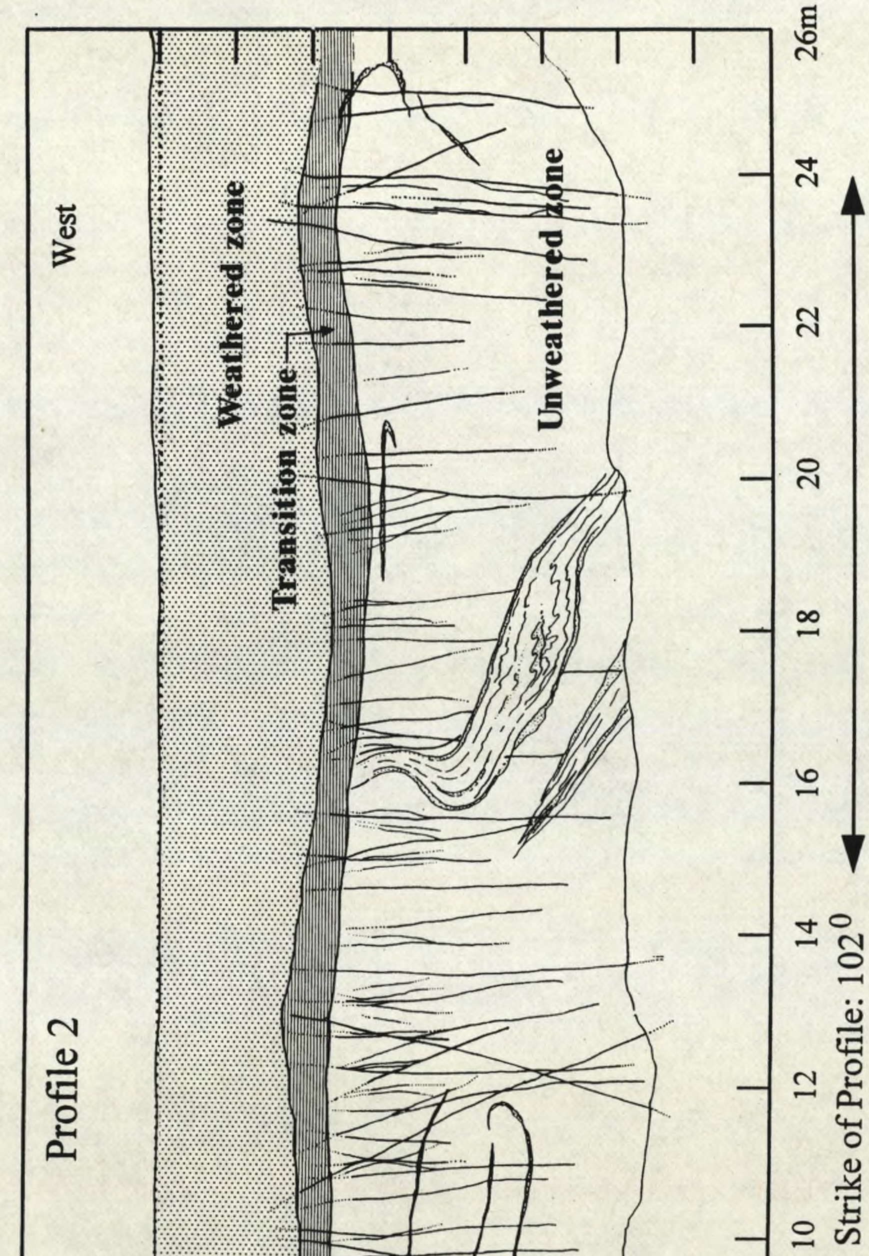

Fig. 10 Profile 2

3.2.4 Profile 3

Description:
Profile 3 (Fig. 12) is subvertical striking north south (7 degree), dipping approximately 75-80 degree towards east. 32 m of the profile were investigated between 2,5 and 6-6,5 m b.s. and a total of 88 fractures were measured and described. The clay was highly fractured in the upper 2 m and became rather massive further down. Few thin sand layers occurred with a general gentle dip (20-30 degree) towards south. This profile was the longest continuing profile measured, but considerably lesser fractures were measured than in profile 2, but some of the major fractures had developed into regular fracture zones, with up to 7-10 closely spaced, mainly 2'nd order fractures, in a 6-10 cm wide zones. 17 of these "fracture zones" were measured along this profile and intact samples were collected for analysis in the laboratory. Some of the major fractures in the northern en d of the profile could be followed around the corner to profile 2 and the minimum size of the largest dominating fractures were thus more than 6 x 6 m.

Fracture orientation:
The orientation of the fractures vary to some degree along the profile. In the northern end fractures striking NW-SE is dominating and in the southern part of the profile fractures striking NE-SW is very dominating.

Fracture spacing:
The spacing of the fractures vary to a great extend along the profile, but it is in general smaller than in profile 2. The average spacing 3 m b.s. is shown on Fig. 11, and the minimum spacing is approximately 2,3 m for fractures striking close to 50 degree, but as illustrated on Fig. 12 the fractures seem to concentrate in 2-4 m wide zones separated by zones with almost no fractures, so locally the fractures might have a considerably lower spacing than the average.

Fracture intensity:
The total fracture intensity of profile 3 is around 1,8-2 1'st order fractures/m and approximately 3 2'nd order fractures/m giving a total of 5,1 fractures/m around 3 m b.s.

Spatial distribution (lateral and vertical frequency):
Fig 16 shows the intensity variation of the fractures compared with the relative topography of the area. As illustrated profile 3 has a considerably lower intensity than the other profiles and at the same time it is situated in a depression in the landscape. On profile 3 (Fig. 12) it is clear that the fractures distribution varies along the profile, especially when it comes to maximum penetration depth of the fractures. In the northern-most part of the profile the fractures are penetrating deepest (down to 6,1 m b.s.), as illustrated on Fig. 11 as well, and in the central part of the profile, where the original surface was lowest, the fractures stops approximately 4,3 m b.s. Finally, in the southern-most end of the profile, the fractures penetrates down to 4,8-5 m b.s. M b.s. refers to 200.7 m a.s.l. in profile 1, 2 and 3, which actually means that the relative difference in penetration depth is even larger, as the surface is approximately 40 cm lower in the central part of the profile than in the ends.

Profile 3 fracture data chart

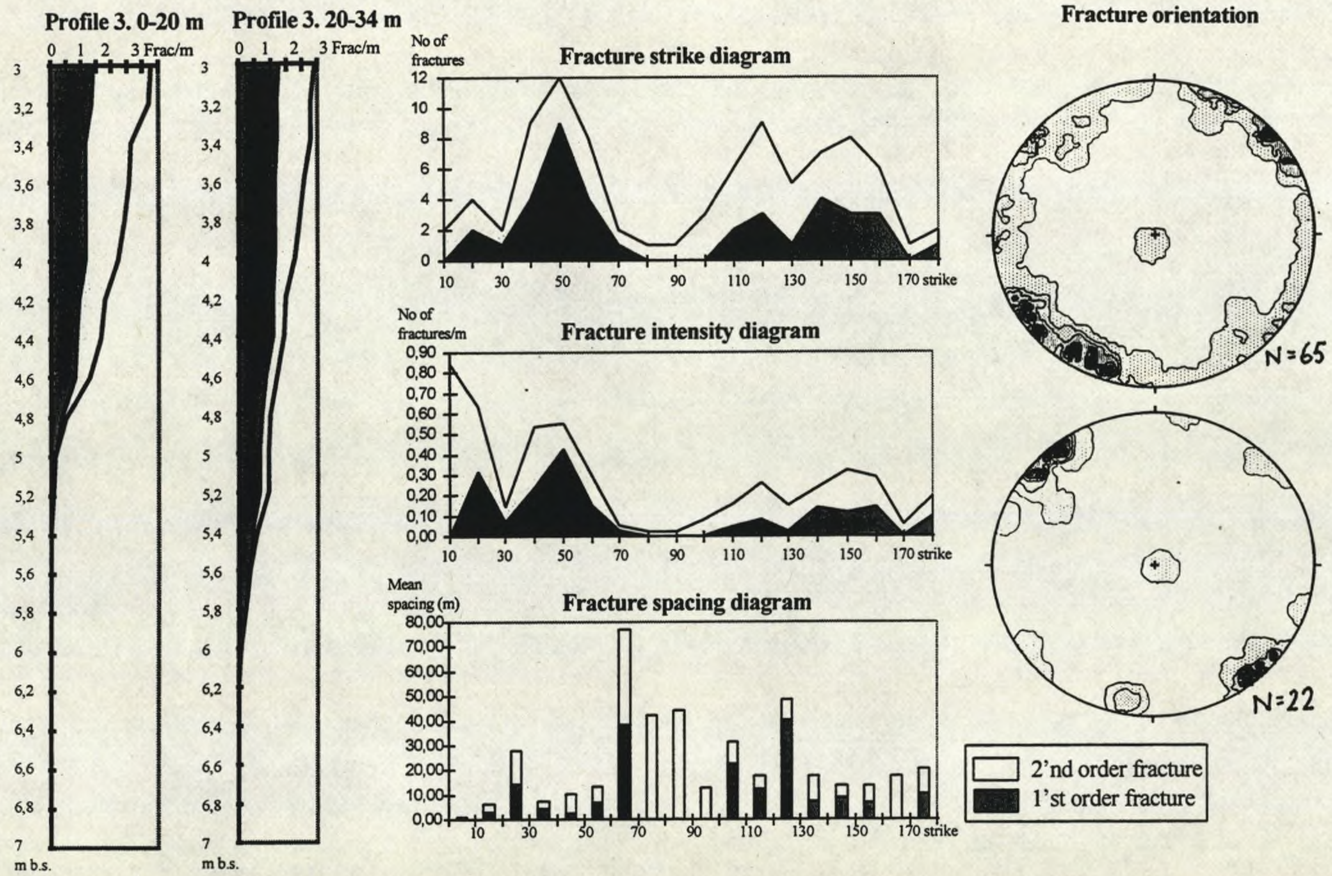

Fig. 11 Fracture data chart. The stereographic projections show the orientation and the concentrations of the poles to the fractureplanes on a Schmidt equal area projection (lower hemisphere).
The upper projection shows all fractures between 0 and 20 m. while the lower projection shows the fractures between 20 and 34 m.

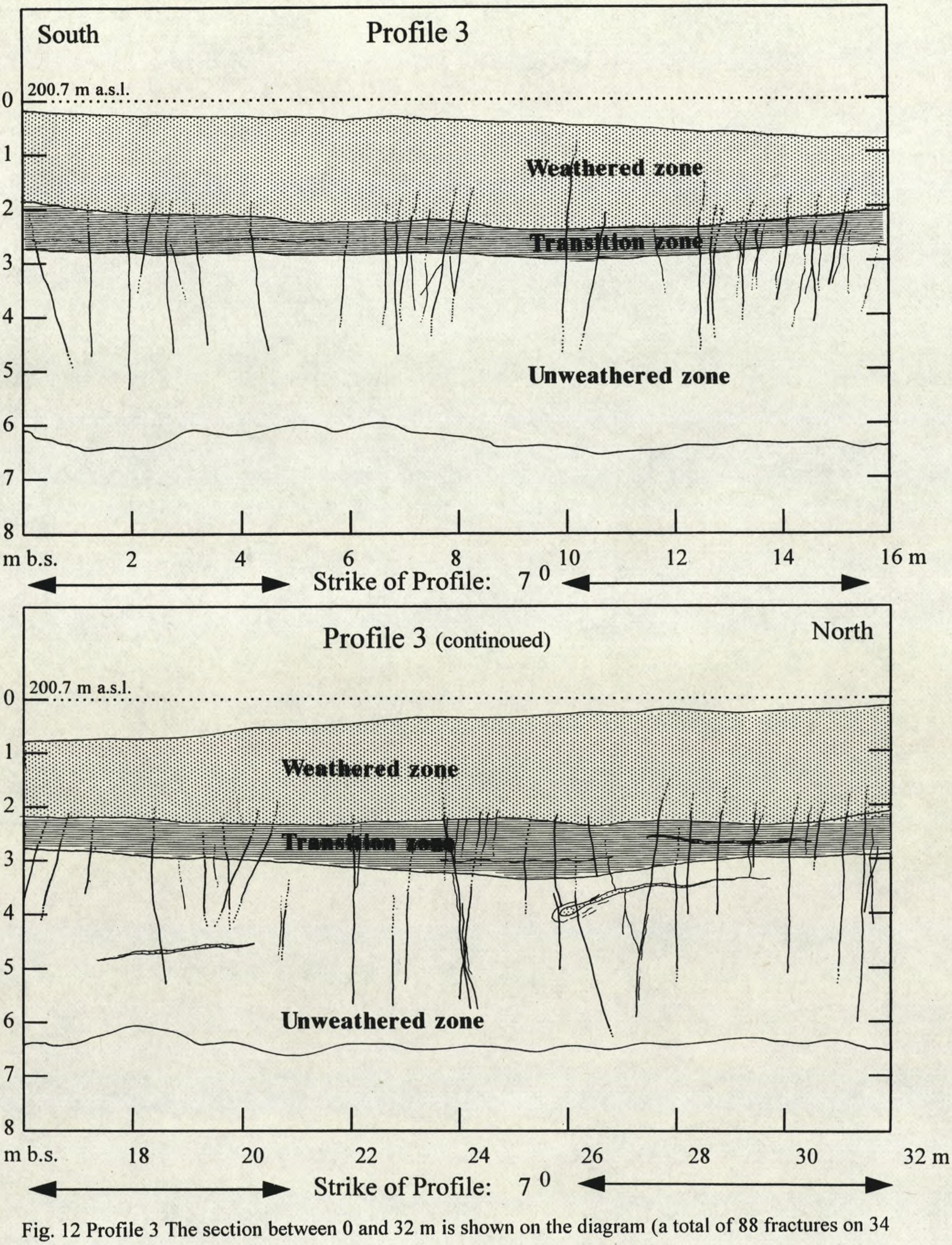

Fig. 12 Profile 3 The section between 0 and 32 m is shown on the diagram (a total of 88 fractures on 34 m of profile were measured).

3.2.5 *Profile 6*

Description:
Profile 6 (Fig. 14) is striking north-south (15 degree). 14 m of the profile was investigated between 3 and 6 m b.s. A total of 48 fractures were measured and described. Due to time shortage and safety problems the measurement was concentrated on the 1'st order fractures, and only 14 2'nd order fractures were measured in the southern-most part of the profile. Several sand layers and larger sand pockets occurred in the area, and the lower penetration depth were often controlled by sand layers as the fractures ended when the reached the sand layers.

Fracture orientation:
The fracture orientation in profile 6 shows a clear concentration of fractures striking approximately 40 degree and 130 degree. A weaker concentration around 110 degree is observed.

Fracture spacing:
The fracture spacing is measured on 1'st order fractures only as the number of 2'nd order fractures measured is to sparse to calculate spacing. The spacing of the dominating fracture direction around 40 degree is approximately 40 cm (20 degree interval) 70 cm (10 degree interval), while the less dominating direction around 130 degree the average spacing is around 2 m (20 degree interval) 3,5 m (10 degree interval).

Fracture intensity:
The total fracture intensity of 1'st order fractures is approximately 5 fractures/m. The 2'nd order fractures were only measured between 0 and 3 m on this profile, but a rough estimate is an average intensity around 8 frac/m, giving a total of 13 fractures/m 4 m b.s.

Spatial distribution (lateral and vertical frequency).
The distribution of fractures is partly controlled by sand lenses, but in general the fracture frequency is high down to 4,4 m b.s. and then the frequency decreases quickly towards depth and below 5,2 m only very few fractures are seen. The lateral variation is rather constant.

Profile 6 Fracture data chart

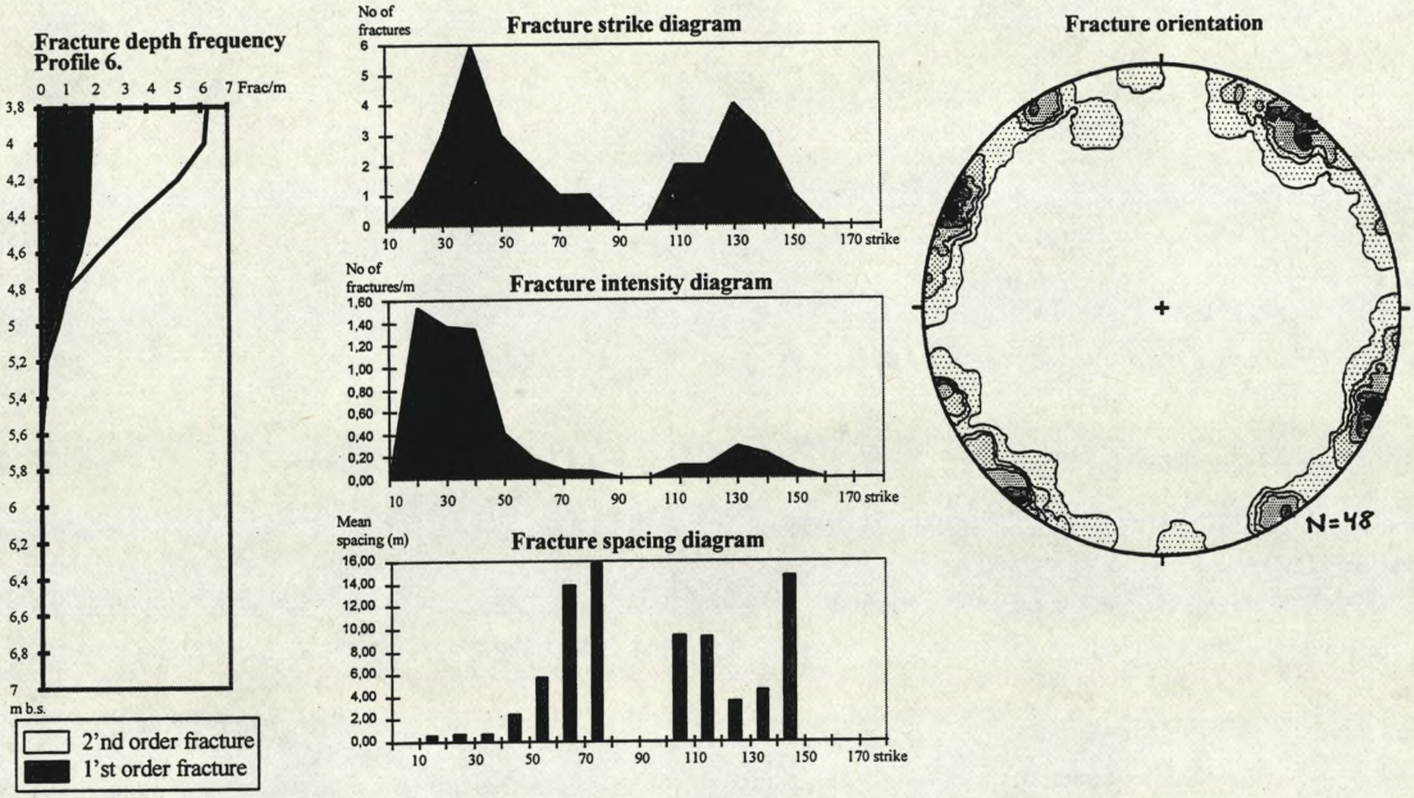

Fig. 13 Fracture data chart. The stereographic projections show the orientation and the concentrations of the poles to the fractureplanes on a Schmidt equal area projection (lower hemisphere).

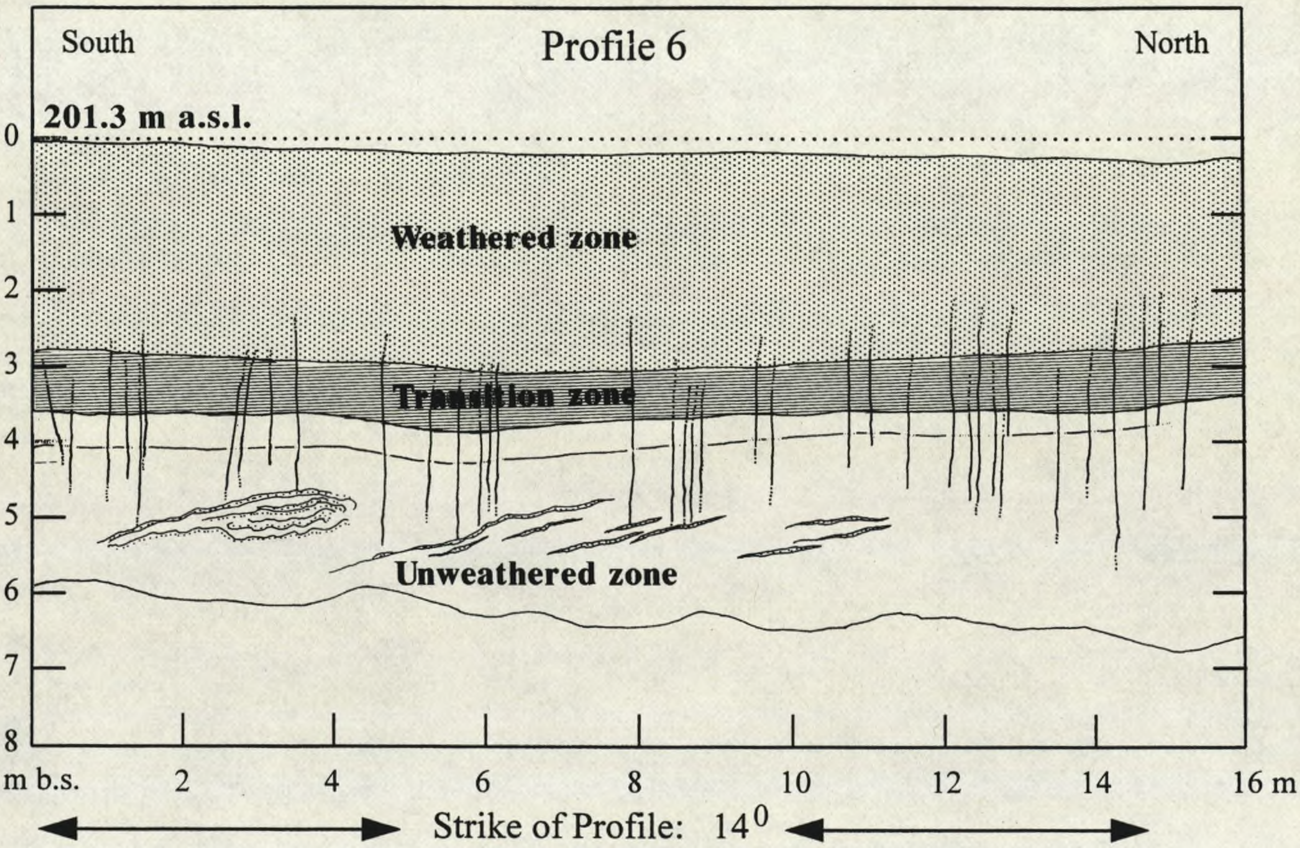

Fig. 14 Profile 6

3.2.6 *Profile 7*

Description:
Profile 7 (Fig. 16) is striking east-west (100 degree). 18 m of the profile was investigated between 3 and 6 m b.s. A total of 172 fractures were measured and described. Due to time shortage and safety problems only the first 6 m of profile were completely described. From 6 to 18 m only the placing, fracture size , fracture order and penetration depth were measured in order to describe the spatial distribution.
The exposure of the fractures and lithology were excellent, as most of the wall had collapsed, leaving the remaining face almost unsmeared. Several thin sand layers (0,1-3 cm) and small sand pockets occurred in the area with a general dip (10-30 degree) towards south-west. The 1'st order fractures formed very characteristic clay-columns, and the 2'nd order fractures parted this columns further into "rods" of clay (4-10 cm thick and > 50 cm long). The wall was considerable more stabile than the wall in profile 6 (perpendicular to profile 7), thus indicating a larger number of major fractures striking north-south (parallel or sub-parallel to profile 6), than east-west. North-south striking walls were in general more unstable than east-west striking walls throughout the area.

Fracture orientation:
The fracture orientation in profile 7 showed a clear concentration of fractures striking approximately 50 degree and 140 degree. A weaker concentration around 70 and 30 degree was observed.

Fracture spacing:
The spacing of the dominating fracture direction around 50 degree was approximately 60 cm (20 degree interval) 80 cm (10 degree interval), while at the less dominating direction around 140 degree the average spacing was approximately 80 cm (20 degree interval) 1,70 m (10 degree interval).

Fracture intensity:
The total fracture intensity of 1'st order fractures was approximately 5 fractures/m. The 2'nd order fractures had an average density around 8 frac/m, giving a total of 13 fractures/m 4 m b.s.

Spatial distribution (lateral and vertical frequency).
The total fracture frequency is very high down to 4,6 m b.s. and then the frequency decreases quickly towards depth and below 5 m only a few 1'st order fractures were seen. The lateral variation is rather constant and the thickness of the highly weathered zone is in general 40-60 cm thicker than Profile 1-3.

Profile 7 Fracture data chart

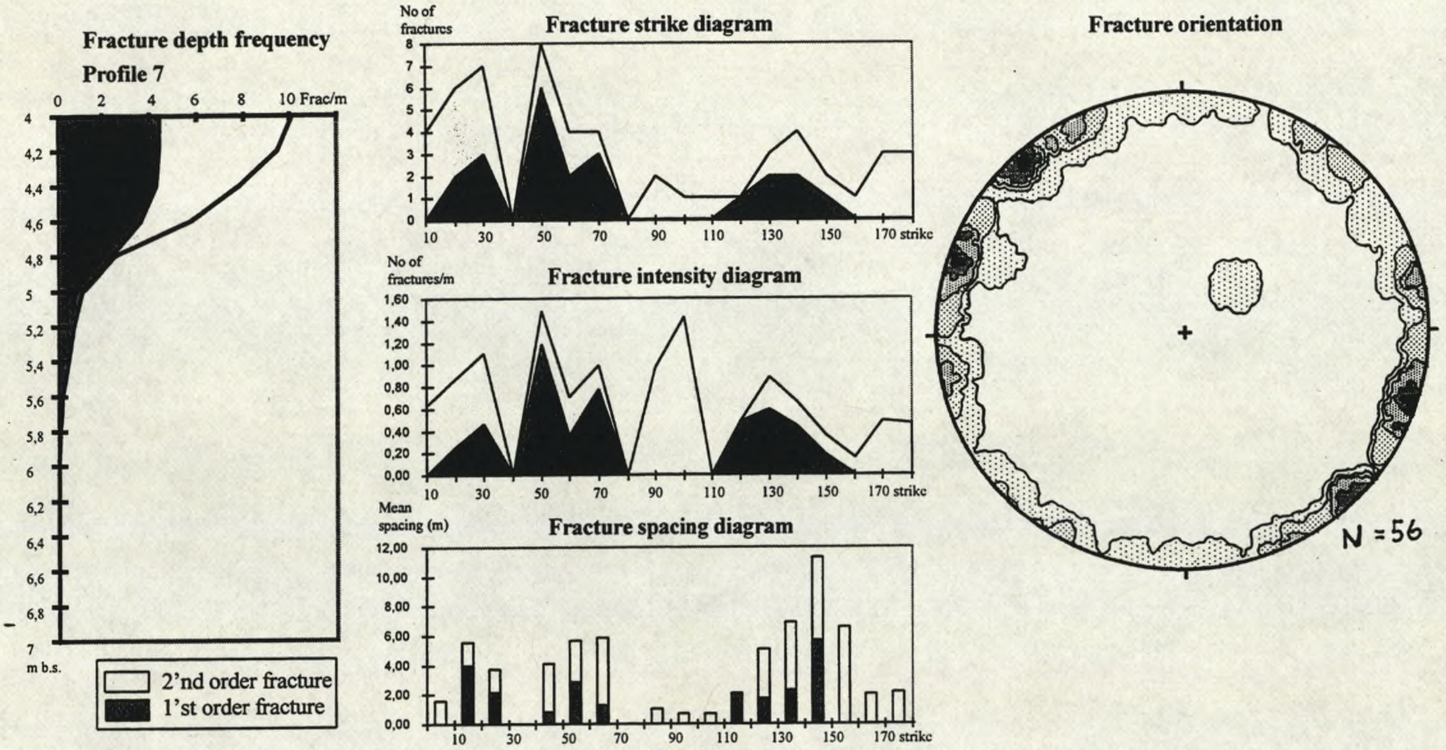

Fig. 15 Fracture data chart. The stereographic projections show the orientation and the concentrations of the poles to the fractureplanes on a Schmidt equal area projection (lower hemisphere).

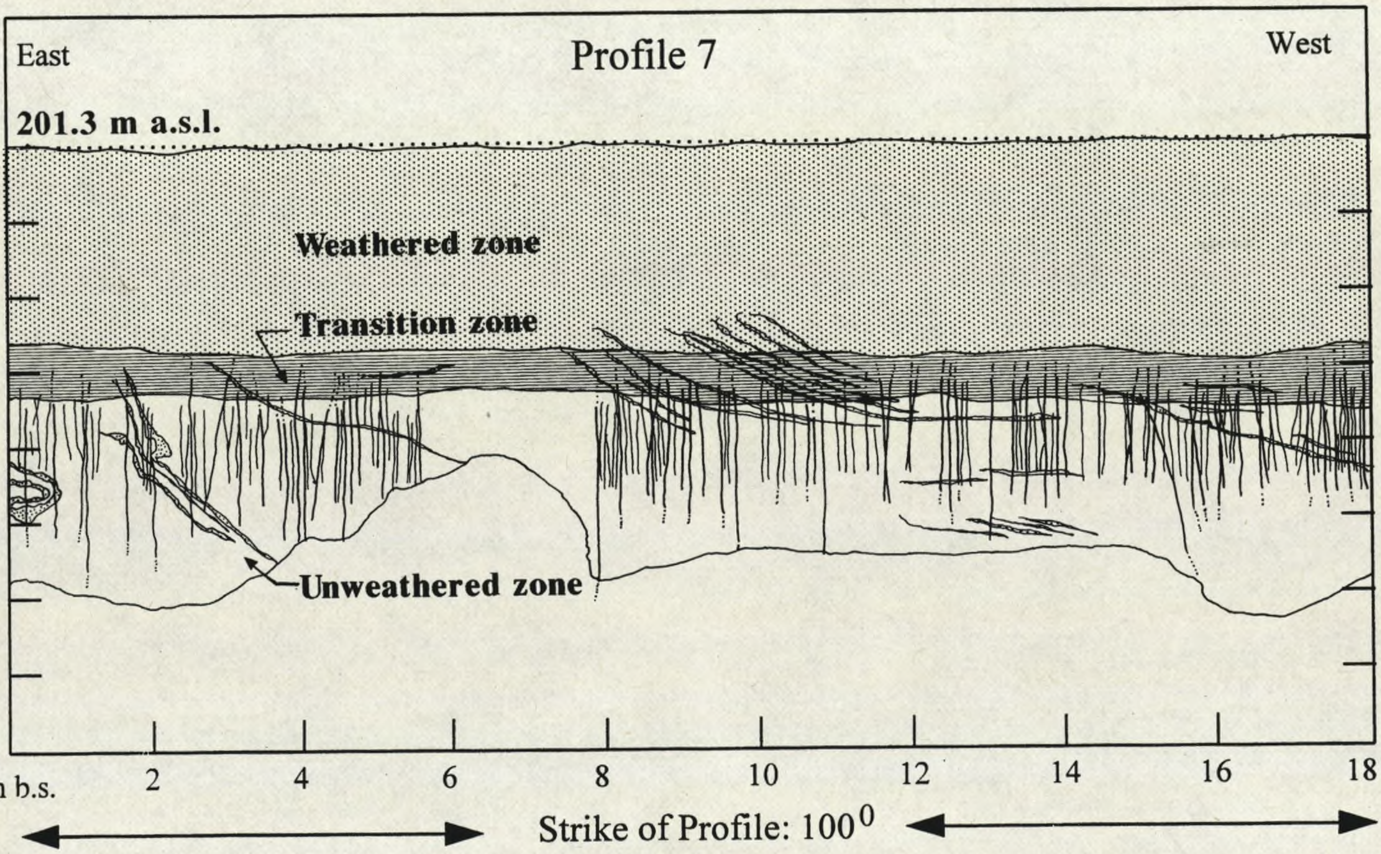

Fig. 16 Profile 7

4. MAIN FINDINGS

4.1 Depositional history

4.1.1 The St. Joseph Till.

The St. Joseph Till is approximately 15 m thick and consist primary of silty clay with a large content of stones, gravel, thin sand-sheets and pockets/bodies of sand and diamict material. The geological origin of the St. Joseph Till has been interpreted by earlier authors (McCay & Fredericia, in press, Putnam, 1984), to be lacustrine sediments mixed with dropped material from melting icebergs/rafts. McKay and Fredericia (in press), performed a number of analysis which confirmed this assumption, but new investigations showed that the uppermost part of the clay was densely fractured in moderate dipping zones, giving an appearance of almost fissile nature. This could be formed by shearing from an overriding glacier or it could origin from desiccation of fine laminated clay, which for some reason had been deformed at a later stage. In order to solve this problem a two fabric analysis were carried out 0,8 and 1,3 m b.s.

The result shows no preferred orientation on elongated clasts longer than 0,6 cm, on the contrary a large part of the clasts were dipping more than 45 degree, which is typical for dropstones. The presence of laminated to weakly laminated clay/silt support the conclusion that this area has never been overridden by glaciers after the deposition of the St. Joseph till.

The sediments are nevertheless deformed in different ways, Two major mechanism may be considered in this case. The clay may either be deformed by grounding icebergs or subjected to intense internal deformation due to slumping of weakly consolidated highly porous fine sediments or maybe a combination of both.

The presence of icebergs is well documented by the dropmaterial in the clay. Typical ice-contact features as ice-scoured stoss-lee side stones were widely distributed in the clay but often in a sub-vertical position. Numerous rapid lakelevel changes in this area are documented by other authors (Lewis at al. 1994., Putnam 1984), and icebergs do ground with sometimes major deformation of the seabottom as a result. Any kind of disturbance or loading of the soft sediment could initiate slumping and internal deformation of the clay.

Input of coarser material as flood/storm-sand or turbidites would also be a naturally effect of a drop in lake level as the coast comes closer and such material would naturally “sink” into the “soft” clay and deform it. It seems that both mechanisms has been working in the St. Joseph Till as documented from the sand and diamict pockets/bodies sheets in the clay. The different material and the different appearance indicate different deposition mechanisms. The thin sand sheets probably originate from sediment input due to especially high energy conditions, Storms, springfloods, glacier-surges etc. while the sandbodies/pockets probably originates from “sinking” turbidites or thicker sand-sheets. The diamict lenses probably originates from icebergs either as droppings or melt-out till from grounding icebergs.

4.1.2 The Black Shale Till

At the transition to the underlying Black Shale Till an almost continuos layer of cross-bedded medium sand with a large content of black shale appears. Primary structures indicate that this sand has been deposited in situ, and it may have a much larger regional distribution than the more or less isolated lenses and bodies in the rest of the St. Joseph Till. This Black sand is probably a near shore deposit and reflects the first or the last occurrence of a lake. Due to the high content of black shale and the erosion of the sand in some places, this unit probably belong to the Black Shale Till and the transition between the two units is regarded to be at the transition between the black sand and the laminated clay above it. This transition represent a period of nondeposition (a hiatus) and may therefore belong to the Mackinaw Interstade approximately 13.5 to 13.2 KA BP. The Black Shale Till thus belong to the Port Bruce Stade (lake Maumee) before 13, 5 KA and the St. Joseph Till then is accordingly deposited during the Port Huron Stade (lake Whittlesey) between approximately 13.2 and 12.6 Ka BP (Lewis et al. (1994).

The Black shale Till underlies the St. Joseph Till and differ in many senses from it. Petrographical the Black Shale Till, as the name indicate, has a much larger content of black shale and finegravel-analysis (McCay & Fredericia in press.) shows that the content of limestone is significant lower. The shear strength in the clay is high and the ruptured surface of the clay indicates the presence of fractures in this upper part.

4.2 Fracture Classification and distribution

4.2.1 Fracture classification

The Fractures in the upper part of the St. Joseph Till is classified as nonsystematic, contraction fractures formed either by desiccation or freezing mechanisms or more probably as a combination of both. This classification is made on basis of:

1. The regional non-systematic behavior of the fractures.
2. The domination of fractures with undulating rough surface characteristics.
3. The lack of conjugating fractures, fractures with listric shapes and stria on the surface.
4. The lithologic evidence of a lacustrine origin, without tectonic features from overriding glaciers.
5. The gradually decrease in fracture spacing/intensity towards depth.
6. The fact that some fractures do not penetrate sand lenses imply that the fractures are depending on contraction rather than compressive stress.

4.2.2 Fracture depth variation

The surface of the ground is characterized by a drainage-system consisting of long depressions with a relative difference in the relief at approximately 0,5 m (fig. 8). The variation of the penetration-depth of the fractures are illustrated on fig. 17. There is a clear indication that fractures in the topographical low areas are less developed than fractures on topographical high areas. The high area fractures penetrate thus more than 0,5 m lower than the low area fractures, in spite of a relative difference in elevation on approximately 0,5 m, thus giving a relative difference in the average fracture length on more than 1 m. The explanation could be that the depressions dries out slower than the “highs” and thus the “desiccation” fractures here are less developed and penetrate typically down to approximately 4 m b.s. (relatively) while the major fractures between the depressions are penetrating to approximately 5.2 m b.s. but locally to more than 6,5 m b.s.

The fractures at profile 6 and 7 have the highest fracture frequency but a lover penetration depth than the fractures in profile 2. In general fractures sometimes tends to increase frequency if the fracture size is reduced. It depends normally on the lithology, the drying out speed for desiccation fractures or temperature for frost cracks, and all those mechanisms could be working here as the area is higher elevated and with a relatively higher content of sand layers than profile 2 and 3.

Fracture depth and frequency variation

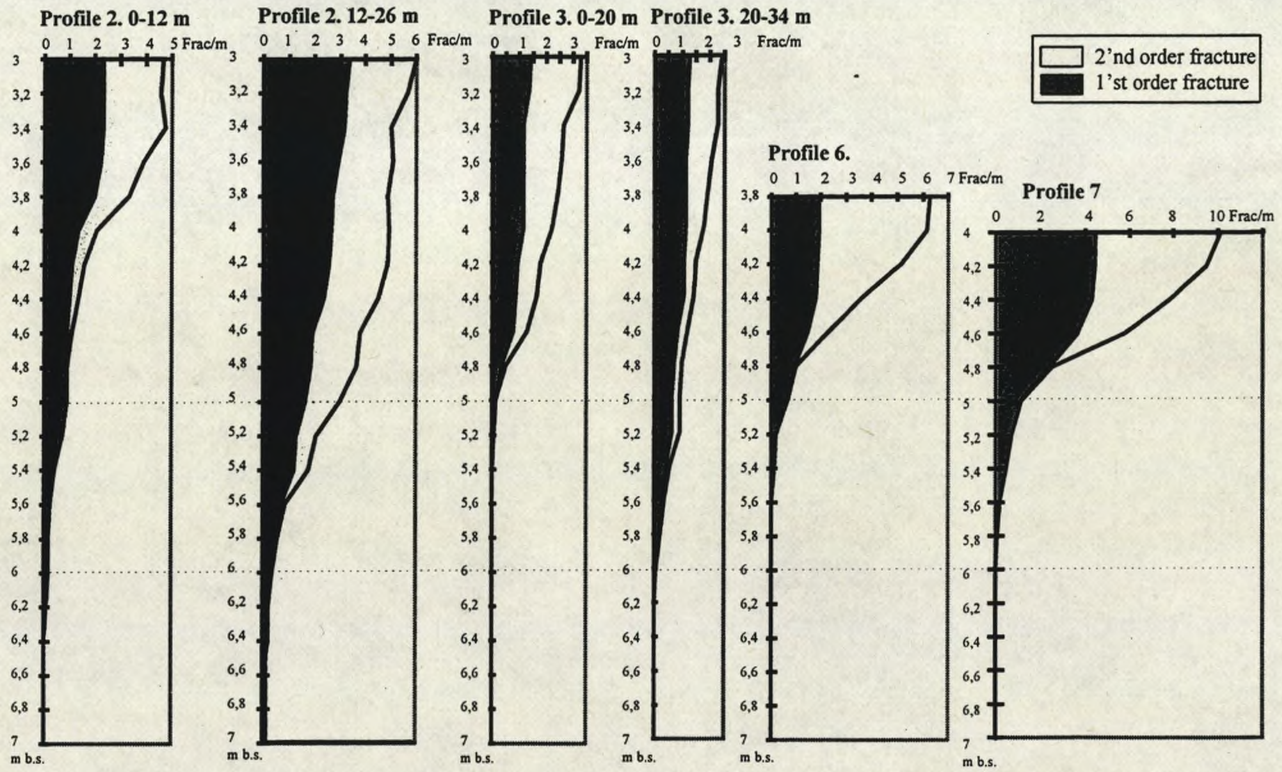

Fig. 17. fracture depth and frequency variation.

4.2.3 Fracture orientation pattern

There is no general fracture orientation in the area. Locally fractures may develop in an seemingly systematic way but regional the fracture orientation is nonsystematic. The fractures close to the depressions apparently develops in a more or less orthogonal pattern with the major fractures perpendicular or parallel to the depressions, while fractures in areas farther from the depressions show a different fracture-pattern with development of higher order polygonal systems. These areas are characterized by a larger fracture-intensity, a deeper weathering, and formation of a kind of "columnar clay". The 1'st order fractures forms 1'st order columns approximately 40 cm wide, which again are truncated by 2'nd order fractures forming 2'nd order columns typically 4-6 cm wide.

4.2.4 Fracture precipitation

The fractures are from the surface to between 1,5 and 3 m b.s. characterized by a weathered surface with a light gray cover and often a thin network of roots or root-canals on the surface. The gray cover consist most likely of clay with reduced iron. This cover is in the uppermost part associated with a bleached halo penetrating up to 2 cm into the matrix on both sides of the fracture. The light gray color has a sharp transition into the red-brown oxidized matrix. Roots penetrating the matrix have the same zonation or "halo" just in a "ring" structure, thus giving the uppermost part of the lithology a characteristic pattern with light-gray stripes and spots in a red brown matrix. The zonation becomes gradually weaker towards depth and below approximately 3 m the last light gray zones disappeared giving place to only the red brown oxidized zonation as illustrated on fig. 18.
and finally this zonation disappeared depending on the size of the fracture between 3 and 7 m b.s.

The different zonations gives an overall gradually color change from light grayish brown in the upper 1,5 m to grayish brown from 1,5 to 3 m b.s. to dark grayish brown below 3 m.

Fracture surface cover

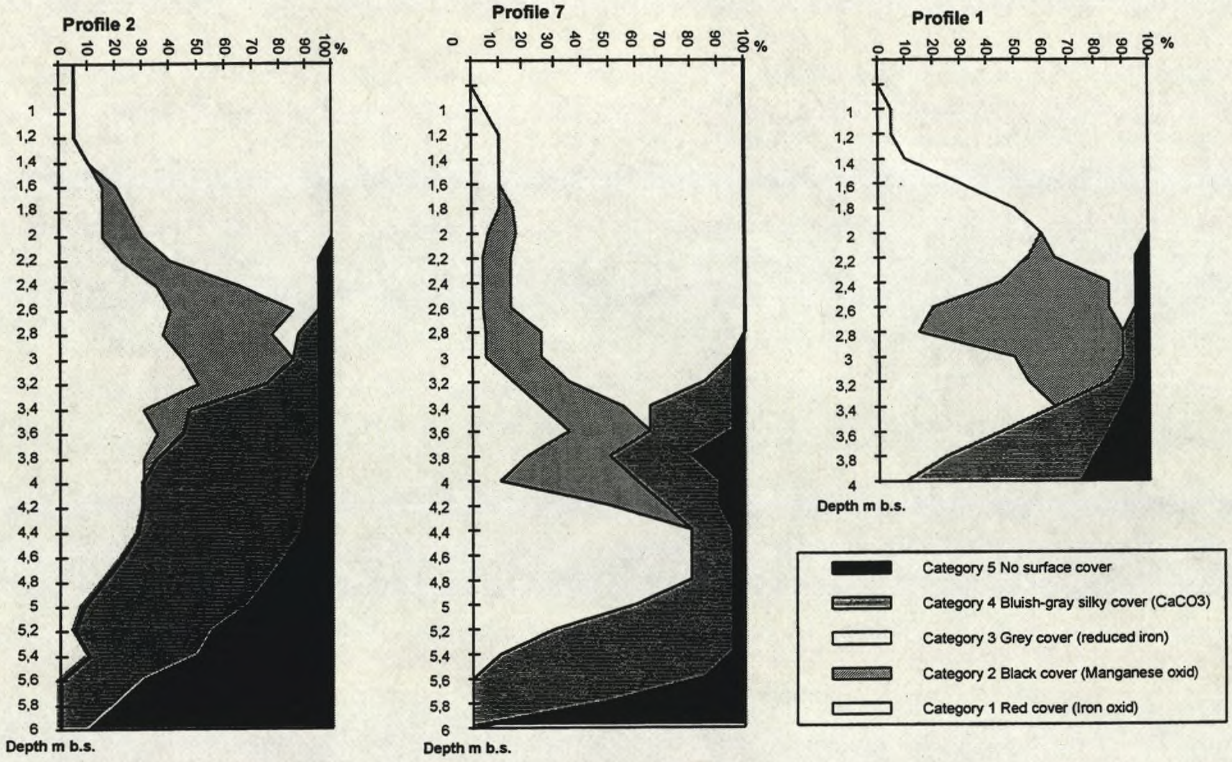

Fig. 18. Fracture surface cover measured on single 1'st order fractures in profile 1, 2 and 7. The magnitude of the different kind of surface covers is a qualitative evaluation made in both the field and from photographs.

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APPENDIX A

Fracture spacing and intensity

profile 1

Fracture data												
Profile 1. 1-3 m b.s.								Fracture spacing			Fracture i	
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr.freq tot
100	5	85	15	2	3	5	10,0	5,6	3,11	0,10	0,18	0,32
100	15	85	15	0	0	0	0,0	0,0	0,00	0,00	0,00	0,00
100	25	75	15	0	2	2	0,0	9,7	9,66	0,00	0,10	0,10
100	35	65	15	2	3	5	9,1	5,1	2,83	0,11	0,20	0,35
100	45	55	15	4	1	5	3,3	16,4	2,56	0,31	0,06	0,39
100	55	45	15	6	3	9	1,8	4,0	1,19	0,55	0,25	0,84
100	65	35	15	0	1	1	0,0	11,5	11,47	0,00	0,09	0,09
100	75	25	15	3	1	4	2,4	8,5	1,69	0,42	0,12	0,59
100	85	15	15	2	1	3	2,6	5,2	1,46	0,39	0,19	0,69
100	95	5	15	1	1	2	1,7	1,7	0,87	0,57	0,57	1,15
100	105	5	15	3	1	4	0,5	1,7	0,35	2,04	0,57	2,87
100	115	15	15	1	2	3	5,2	2,6	1,46	0,19	0,39	0,69
100	125	25	15	0	2	2	0,0	4,2	4,23	0,00	0,24	0,24
100	135	35	15	5	2	7	1,8	5,7	1,25	0,56	0,17	0,80
100	145	45	15	6	5	11	1,8	2,2	0,97	0,55	0,45	1,03
100	155	55	15	4	0	4	3,3	0,0	3,28	0,31	0,00	0,31
100	165	65	15	0	1	1	0,0	18,1	18,13	0,00	0,06	0,06
100	175	75	15	2	0	2	9,7	0,0	9,66	0,10	0,00	0,10
Sum				41	29	70				6,20	3,64	10,60
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
100	10	90	15	2	3	5	10,00	5,63	3,13	0,10	0,18	0,32
100	30	70	15	2	5	7	9,40	2,94	2,06	0,11	0,34	0,49
100	50	50	15	10	4	14	1,16	3,06	0,82	0,86	0,33	1,21
100	70	30	15	3	2	5	2,81	5,00	1,56	0,36	0,20	0,64
100	90	10	15	3	2	5	0,98	1,74	0,54	1,02	0,58	1,84
100	110	10	15	4	3	7	0,69	0,98	0,38	1,44	1,02	2,63
100	130	30	15	5	4	9	1,56	2,00	0,84	0,64	0,50	1,19
100	150	50	15	10	5	15	1,16	2,39	0,77	0,86	0,42	1,30
100	170	70	15	2	1	3	9,40	18,79	5,29	0,11	0,05	0,19
				41	29	70				5,50	3,62	9,81

Fracture data												
Profile 2. 3 m b.s.							**Fracture spacing**			**Fracture intensity**		
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
102	5	83	26	1	3	4	34,41	9,68	6,88	0,03	0,10	0,15
102	15	87	26	4	8	12	6,92	3,30	2,18	0,14	0,30	0,46
102	25	77	26	2	2	4	16,89	16,89	6,76	0,06	0,06	0,15
102	35	67	26	3	5	8	8,97	4,99	3,04	0,11	0,20	0,33
102	45	57	26	6	4	10	3,74	5,81	2,20	0,27	0,17	0,45
102	55	47	26	5	5	10	3,96	3,96	1,92	0,25	0,25	0,52
102	65	37	26	3	2	5	5,87	10,43	3,26	0,17	0,10	0,31
102	75	27	26	2	2	4	7,87	7,87	3,15	0,13	0,13	0,32
102	85	17	26	3	2	5	2,85	5,07	1,58	0,35	0,20	0,63
102	95	7	26	3	1	4	1,19	4,22	0,84	0,84	0,24	1,18
102	105	3	26	1	2	3	1,81	0,91	0,51	0,55	1,10	1,96
102	115	13	26	6	3	9	1,00	2,19	0,66	1,00	0,46	1,52
102	125	23	26	4	3	7	2,71	3,81	1,48	0,37	0,26	0,67
102	135	33	26	4	6	10	3,78	2,43	1,43	0,26	0,41	0,70
102	145	43	26	5	5	10	3,69	3,69	1,79	0,27	0,27	0,56
102	155	53	26	6	5	11	3,56	4,33	1,90	0,28	0,23	0,53
102	165	63	26	3	4	7	8,69	6,18	3,38	0,12	0,16	0,30
102	175	73	26	3	3	6	9,32	9,32	4,26	0,11	0,11	0,23
Sum				64	65	129				5,31	4,75	10,96
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
102	10	88	26	5	11	16	5,41	2,38	1,63	0,18	0,42	0,61
102	30	72	26	5	7	12	5,15	3,61	2,08	0,19	0,28	0,48
102	50	52	26	11	9	20	1,88	2,30	1,03	0,53	0,43	0,97
102	70	32	26	5	4	9	2,87	3,67	1,55	0,35	0,27	0,65
102	90	12	26	6	3	9	0,93	2,03	0,61	1,08	0,49	1,64
102	110	8	26	7	5	12	0,53	0,75	0,30	1,90	1,33	3,29
102	130	28	26	8	9	17	1,55	1,37	0,72	0,65	0,73	1,39
102	150	48	26	11	10	21	1,77	1,95	0,92	0,56	0,51	1,08
102	170	68	26	6	7	13	4,13	3,52	1,87	0,24	0,28	0,54
				64	65	129				5,69	4,75	10,66

Fracture data

Profile 2. 5 m b.s.

							Fracture spacing			**Fracture intensity**		
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
102	5	83	22	1	1	2	29,11	29,11	14,56	0,03	0,03	0,07
102	15	87	22	4	2	6	29,29	14,65	3,77	0,03	0,07	0,27
102	25	77	22	1	2	3	28,58	14,29	8,04	0,03	0,07	0,12
102	35	67	22	1	1	2	27,00	27,00	13,50	0,04	0,04	0,07
102	45	57	22	0	1	1	0,00	24,60	24,60	0,00	0,04	0,04
102	55	47	22	1	0	1	21,45	0,00	21,45	0,05	0,00	0,05
102	65	37	22	1	1	2	17,65	17,65	8,83	0,06	0,06	0,11
102	75	27	22	1	0	1	13,32	0,00	13,32	0,08	0,00	0,08
102	85	17	22	3	3	6	2,41	2,41	1,10	0,41	0,41	0,91
102	95	7	22	2	0	2	1,79	3,57	1,79	0,56	0,28	0,56
102	105	7	22	3	1	4	3,57	3,57	0,71	0,28	0,28	1,40
102	115	13	22	2	2	4	3,30	3,30	1,32	0,30	0,30	0,76
102	125	23	22	2	1	3	5,73	11,46	3,22	0,17	0,09	0,31
102	135	33	22	1	1	2	15,98	15,98	7,99	0,06	0,06	0,13
102	145	43	22	1	0	1	20,01	0,00	20,01	0,05	0,00	0,05
102	155	53	22	1	1	2	23,43	23,43	11,71	0,04	0,04	0,09
102	165	63	22	2	1	3	13,07	26,14	7,35	0,08	0,04	0,14
102	175	73	22	0	1	1	0,00	28,05	28,05	0,00	0,04	0,04
Sum				27	19	46				2,28	1,85	5,17

Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
102	10	88	22	5	3	8	4,58	8,24	2,79	0,22	0,12	0,36
102	30	72	22	2	3	5	13,95	7,85	4,36	0,07	0,13	0,23
102	50	52	22	1	1	2	23,11	23,11	11,56	0,04	0,04	0,09
102	70	32	22	2	1	3	7,77	15,54	4,37	0,13	0,06	0,23
102	90	12	22	5	3	8	0,95	1,72	0,58	1,05	0,58	1,72
102	110	8	22	5	3	8	0,64	1,15	0,39	1,57	0,87	2,57
102	130	28	22	3	2	5	3,87	6,89	2,15	0,26	0,15	0,46
102	150	48	22	2	1	3	10,90	21,80	6,13	0,09	0,05	0,16
102	170	68	22	2	2	4	13,60	13,60	5,44	0,07	0,07	0,18
				27	19	46				3,50	2,07	6,01

Fracture data												
Profile 3. 3 m b.s.								Fracture spacing			Fracture intensity	
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
7	5	3	34	0	2	2	0,00	1,19	1,19	0,00	0,84	0,84
7	15	8	34	2	2	4	3,15	3,15	1,26	0,32	0,32	0,79
7	25	18	34	1	1	2	14,01	14,01	7,00	0,07	0,07	0,14
7	35	28	34	4	5	9	4,26	3,33	1,80	0,23	0,30	0,56
7	45	38	34	9	3	12	2,35	7,85	1,76	0,42	0,13	0,57
7	55	48	34	4	4	8	6,74	6,74	3,21	0,15	0,15	0,31
7	65	58	34	1	1	2	38,44	38,44	19,22	0,03	0,03	0,05
7	75	68	34	0	1	1	0,00	42,03	42,03	0,00	0,02	0,02
7	85	78	34	0	1	1	0,00	44,34	44,34	0,00	0,02	0,02
7	95	88	34	0	3	3	0,00	12,74	12,74	0,00	0,08	0,08
7	105	83	34	2	4	6	22,50	9,00	5,79	0,04	0,11	0,17
7	115	73	34	3	6	9	12,19	5,57	3,66	0,08	0,18	0,27
7	125	63	34	1	4	5	40,39	8,08	6,31	0,02	0,12	0,16
7	135	53	34	4	3	7	7,24	10,18	3,96	0,14	0,10	0,25
7	145	43	34	3	5	8	8,70	4,83	2,94	0,12	0,21	0,34
7	155	33	34	3	3	6	6,94	6,94	3,17	0,14	0,14	0,32
7	165	23	34	0	1	1	0,00	17,71	17,71	0,00	0,06	0,06
7	175	13	34	1	1	2	10,20	10,20	5,10	0,10	0,10	0,20
Sum				38	50	88				1,87	2,98	5,16
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
7	0-20	7	34	2	4	6	2,76	1,10	0,71	0,36	0,91	1,41
7	21-40	23	34	5	6	11	2,77	2,28	1,22	0,36	0,44	0,82
7	41-60	43	34	13	7	20	1,79	3,38	1,16	0,56	0,30	0,86
7	61-80	63	34	1	2	3	40,39	20,20	11,36	0,02	0,05	0,09
7	81-100	83	34	0	4	4	0,00	9,00	9,00	0,00	0,11	0,11
7	101-120	77	34	5	10	15	6,90	3,35	2,22	0,14	0,30	0,45
7	121-140	57	34	5	7	12	5,94	4,16	2,39	0,17	0,24	0,42
7	141-160	37	34	6	8	14	3,51	2,60	1,47	0,29	0,38	0,68
7	161-180	17	34	1	2	3	13,25	6,63	3,73	0,08	0,15	0,27
				38	50	88				1,98	2,88	5,11

Fracture data												
Profile 6. 4 m b.s.							**Fracture spacing**			**Fracture intensity**		
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
15	5	12	14	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00
15	15	2	14	1	1	2	0,65	0,65	0,33	1,54	1,54	3,07
15	25	8	14	3	0	3	0,73	0,00	0,73	1,37	0,00	1,37
15	35	18	14	6	1	7	0,74	5,77	0,63	1,35	0,17	1,59
15	45	28	14	3	2	5	2,46	4,38	1,37	0,41	0,23	0,73
15	55	38	14	2	1	3	5,75	11,49	3,23	0,17	0,09	0,31
15	65	48	14	1	1	2	13,87	13,87	13,87	0,07	0,07	0,07
15	75	58	14	1	0	1	15,83	0,00	0,00	0,06	0,00	0,00
15	85	68	14	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00
15	95	78	14	0	2	2	0,00	9,13	9,13	0,00	0,11	0,11
15	105	88	14	2	1	3	9,33	18,66	5,25	0,11	0,05	0,19
15	115	82	14	2	3	5	9,24	5,20	2,89	0,11	0,19	0,35
15	125	72	14	4	0	4	3,55	0,00	3,55	0,28	0,00	0,28
15	135	62	14	3	0	3	4,64	0,00	4,64	0,22	0,00	0,22
15	145	52	14	1	0	1	14,71	0,00	14,71	0,07	0,00	0,07
15	155	42	14	0	1	1	0,00	12,49	12,49	0,00	0,08	0,08
15	165	32	14	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00
15	175	22	14	0	1	1	0,00	6,99	6,99	0,00	0,14	0,14
Sum				29	14	43				5,75	2,67	8,57
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
15	10	5	14	1	1	2	1,63	1,63	0,81	0,61	0,61	1,23
15	30	15	14	9	1	10	0,41	4,83	0,37	2,45	0,21	2,73
15	50	35	14	5	3	8	1,67	3,01	1,02	0,60	0,33	0,98
15	70	55	14	2	1	3	7,65	15,29	4,30	0,13	0,07	0,23
15	90	75	14	0	2	2	0,00	9,02	9,02	0,00	0,11	0,11
15	110	85	14	4	4	8	3,72	3,72	1,77	0,27	0,27	0,56
15	130	65	14	7	0	7	1,85	0,00	1,85	0,54	0,00	0,54
15	150	45	14	1	1	2	13,20	13,20	6,60	0,08	0,08	0,15
15	170	25	14	0	1	1	0,00	7,89	7,89	0,00	0,13	0,13
				29	14	43				4,68	1,80	6,67

Fracture data												
Profile 7. 4 m b.s.								**Fracture spacing**			**Fracture intensity**	
Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
100	5	85	6	0	4	5	0,00	1,59	1,25	0,00	0,63	0,80
100	15	85	6	2	4	7	3,98	1,59	0,87	0,25	0,63	1,15
100	25	75	6	3	4	6	2,17	1,55	0,99	0,46	0,65	1,01
100	35	65	6	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00
100	45	55	6	6	2	8	0,84	3,28	0,62	1,19	0,31	1,60
100	55	45	6	2	2	4	2,83	2,83	1,13	0,35	0,35	0,88
100	65	35	6	3	1	4	1,29	4,59	0,92	0,77	0,22	1,09
100	75	25	6	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00
100	85	15	6	0	2	2	0,00	1,04	1,04	0,00	0,97	0,97
100	95	5	6	0	1	1	0,00	0,70	0,70	0,00	1,43	1,43
100	105	5	6	0	1	0	0,00	0,70	0,00	0,00	0,00	0,00
100	115	15	6	1	0	1	2,07	0,00	0,00	0,48	0,00	0,00
100	125	25	6	2	1	4	1,69	3,38	0,68	0,59	0,30	1,48
100	135	35	6	2	2	3	2,29	4,59	1,29	0,44	0,22	0,77
100	145	45	6	1	1	2	5,66	5,66	2,83	0,18	0,18	0,35
100	155	55	6	0	1	1	0,00	6,55	6,55	0,00	0,15	0,15
100	165	65	6	0	3	4	0,00	2,04	1,45	0,00	0,49	0,69
100	175	75	6	0	3	3	0,00	2,17	2,17	0,00	0,46	0,46
Sum				22	32	55				4,71	6,97	12,84

Strike W	Strike Fr.	Angle A-B	Length W	N 1'st	N 2'nd	N tot	Sp. N 1'st	Sp. N 2'nd	Sp. N tot	Fr. freq 1	Fr. freq 2	Fr. freq tot
100	10	90	6	2	8	10	4,00	0,76	0,61	0,25	1,31	1,65
100	30	70	6	3	4	7	2,11	1,50	0,82	0,47	0,67	1,22
100	50	50	6	8	4	12	0,58	1,23	0,39	1,71	0,82	2,59
100	70	30	6	3	1	4	1,13	4,00	0,80	0,89	0,25	1,25
100	90	10	6	0	3	3	0,00	0,39	0,39	0,00	2,56	2,56
100	110	10	6	1	1	2	1,39	1,39	0,69	0,72	0,72	1,44
100	130	30	6	4	3	7	0,80	1,13	0,44	1,25	0,89	2,29
100	150	50	6	1	2	3	6,13	3,06	1,72	0,16	0,33	0,58
100	170	70	6	0	6	6	0,00	0,97	0,97	0,00	1,03	1,03
sum				22	32	54				5,46	8,57	14,61

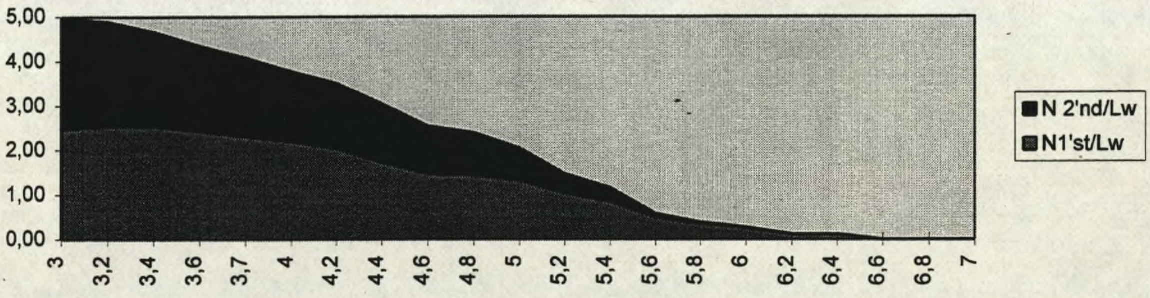
APPENDIX B

Fracture frequency and vertical variation

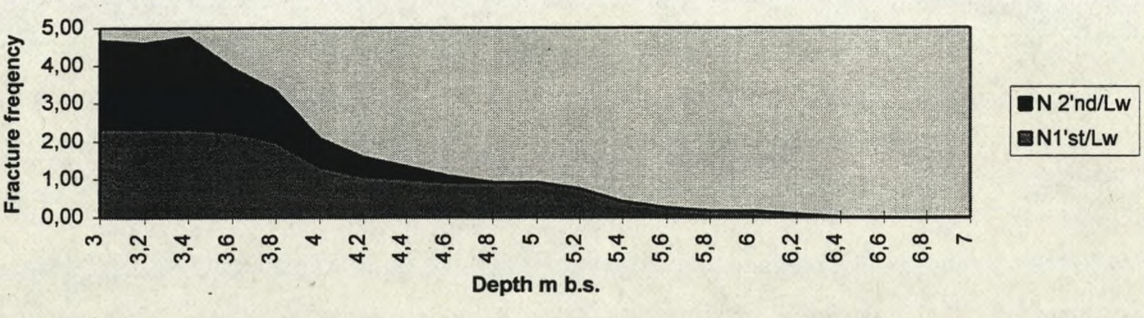
Profile 2.

Fracture depth Variation below 3 m.

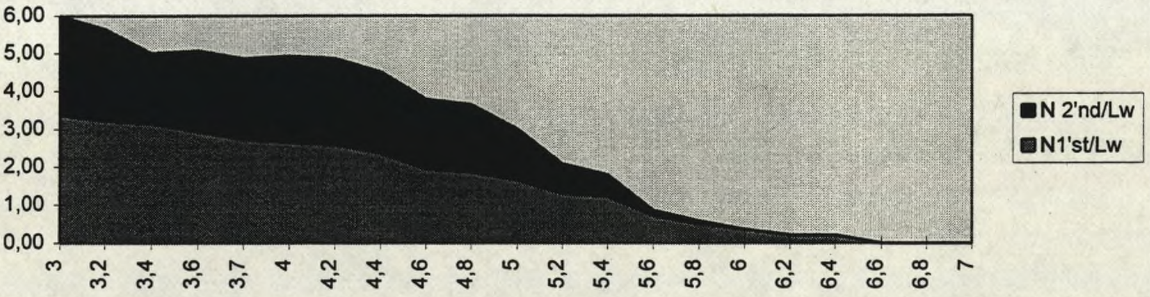
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	26	64	65	129	3	2,46	2,50	4,96
3,2	26	66	61	127	3,2	2,54	2,35	4,88
3,4	26	66	55	121	3,4	2,54	2,12	4,65
3,6	26	63	50	113	3,6	2,42	1,92	4,35
3,7	26	60	46	106	3,7	2,31	1,77	4,08
4	26	57	41	98	4	2,19	1,58	3,77
4,2	26	53	38	91	4,2	2,04	1,46	3,50
4,4	26	45	34	79	4,4	1,73	1,31	3,04
4,6	26	38	28	66	4,6	1,46	1,08	2,54
4,8	26	37	25	62	4,8	1,42	0,96	2,38
5	26	34	19	53	5	1,31	0,73	2,04
5,2	26	27	11	38	5,2	1,04	0,42	1,46
5,4	26	22	8	30	5,4	0,85	0,31	1,15
5,6	26	13	2	15	5,6	0,50	0,08	0,58
5,8	26	9	1	10	5,8	0,35	0,04	0,38
6	26	7	0	7	6	0,27	0,00	0,27
6,2	26	3	0	3	6,2	0,12	0,00	0,12
6,4	26	3	0	3	6,4	0,12	0,00	0,12
6,6	26	0	0	0	6,6	0,00	0,00	0,00
6,8	26	0	0	0	6,8	0,00	0,00	0,00
7	26	0	0	0	7	0,00	0,00	0,00



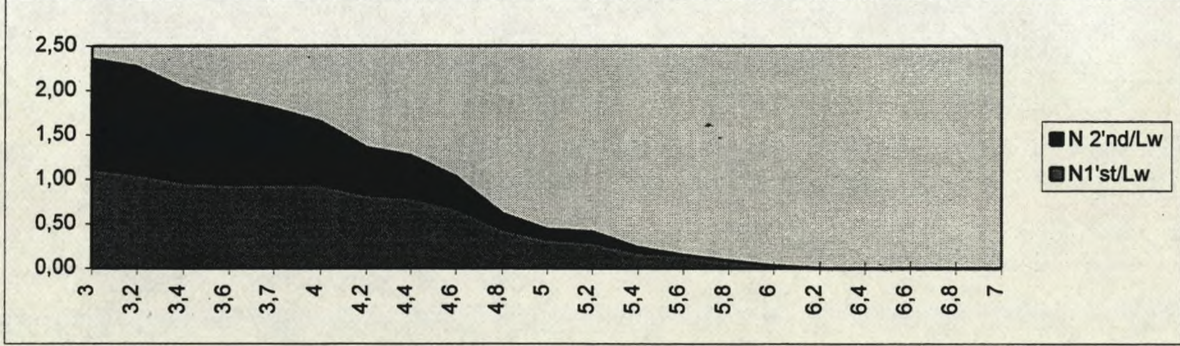
Profile 2. 0-12 m								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	12	28	28	56	3	2,33	2,33	4,67
3,2	12	28	27	55	3,2	2,33	2,25	4,58
3,4	12	28	29	57	3,4	2,33	2,42	4,75
3,6	12	27	20	47	3,6	2,25	1,67	3,92
3,8	12	24	16	40	3,8	2,00	1,33	3,33
4	12	16	9	25	4	1,33	0,75	2,08
4,2	12	13	6	19	4,2	1,08	0,50	1,58
4,4	12	12	4	16	4,4	1,00	0,33	1,33
4,6	12	11	2	13	4,6	0,92	0,17	1,08
4,8	12	11	0	11	4,8	0,92	0,00	0,92
5	12	11	0	11	5	0,92	0,00	0,92
5,2	12	9	0	9	5,2	0,75	0,00	0,75
5,4	12	5	0	5	5,4	0,42	0,00	0,42
5,6	12	3	0	3	5,6	0,25	0,00	0,25
5,8	12	2	0	2	5,8	0,17	0,00	0,17
6	12	2	0	2	6	0,17	0,00	0,17
6,2	12	1	0	1	6,2	0,08	0,00	0,08
6,4	12	0	0	0	6,4	0,00	0,00	0,00
6,6	12	0	0	0	6,6	0,00	0,00	0,00
6,8	12	0	0	0	6,8	0,00	0,00	0,00
7	12	0	0	0	7	0,00	0,00	0,00



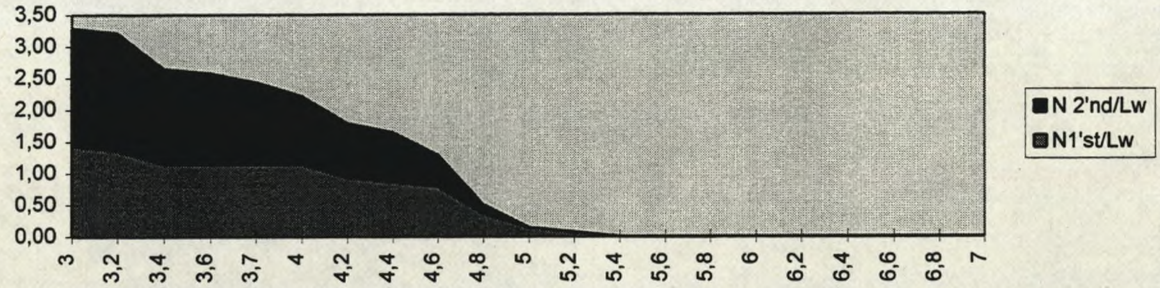
Profile 2b. 12 - 26 m								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	14	47	37	38	3	3,36	2,64	6,00
3,2	14	45	34	34	3,2	3,21	2,43	5,64
3,4	14	44	26	26	3,4	3,14	1,86	5,00
3,6	14	41	30	30	3,6	2,93	2,14	5,07
3,7	14	38	30	30	3,7	2,71	2,14	4,86
4	14	37	32	32	4	2,64	2,29	4,93
4,2	14	36	32	22	4,2	2,57	2,29	4,86
4,4	14	33	30	10	4,4	2,36	2,14	4,50
4,6	14	27	26	6	4,6	1,93	1,86	3,79
4,8	14	26	25	5	4,8	1,86	1,79	3,64
5	14	23	19	3	5	1,64	1,36	3,00
5,2	14	18	11	1	5,2	1,29	0,79	2,07
5,4	14	17	8	0	5,4	1,21	0,57	1,79
5,6	14	10	2	0	5,6	0,71	0,14	0,86
5,8	14	7	1	0	5,8	0,50	0,07	0,57
6	14	5	0	0	6	0,36	0,00	0,36
6,2	14	3	0	0	6,2	0,21	0,00	0,21
6,4	14	3	0	0	6,4	0,21	0,00	0,21
6,6	14	0	0	0	6,6	0,00	0,00	0,00
6,8	14	0	0	0	6,8	0,00	0,00	0,00
7	14	0	0	0	7	0,00	0,00	0,00



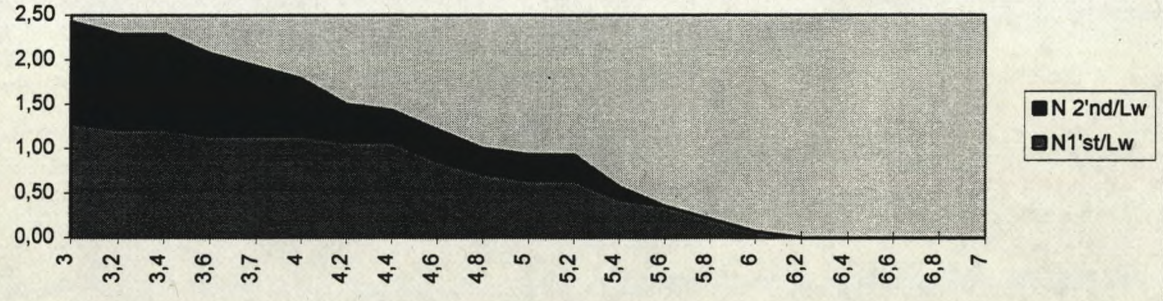
Profile 3.								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	34	38	42	80	3	1,12	1,24	2,35
3,2	34	36	41	77	3,2	1,06	1,21	2,26
3,4	34	33	36	69	3,4	0,97	1,06	2,03
3,6	34	32	33	65	3,6	0,94	0,97	1,91
3,7	34	32	29	61	3,7	0,94	0,85	1,79
4	34	32	24	56	4	0,94	0,71	1,65
4,2	34	28	18	46	4,2	0,82	0,53	1,35
4,4	34	27	16	43	4,4	0,79	0,47	1,26
4,6	34	23	12	35	4,6	0,68	0,35	1,03
4,8	34	15	6	21	4,8	0,44	0,18	0,62
5	34	11	4	15	5	0,32	0,12	0,44
5,2	34	10	4	14	5,2	0,29	0,12	0,41
5,4	34	6	2	8	5,4	0,18	0,06	0,24
5,6	34	5	0	5	5,6	0,15	0,00	0,15
5,8	34	3	0	3	5,8	0,09	0,00	0,09
6	34	1	0	1	6	0,03	0,00	0,03
6,2	34	0	0	0	6,2	0,00	0,00	0,00
6,4	34	0	0	0	6,4	0,00	0,00	0,00
6,6	34	0	0	0	6,6	0,00	0,00	0,00
6,8	34	0	0	0	6,8	0,00	0,00	0,00
7	34	0	0	0	7	0,00	0,00	0,00



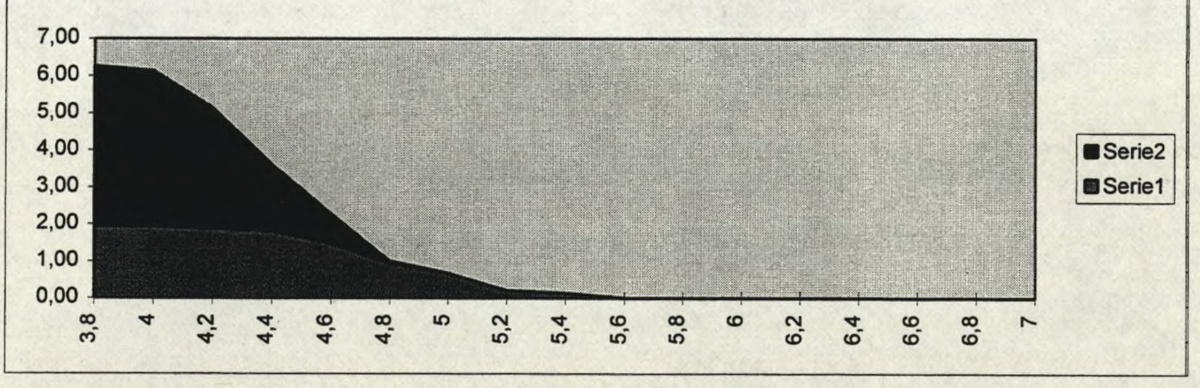
Profile 3a. 0 - 20 m								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	14	20	26	46	3	1,43	1,86	3,29
3,2	14	19	26	45	3,2	1,36	1,86	3,21
3,4	14	16	21	37	3,4	1,14	1,50	2,64
3,6	14	16	20	36	3,6	1,14	1,43	2,57
3,7	14	16	18	34	3,7	1,14	1,29	2,43
4	14	16	15	31	4	1,14	1,07	2,21
4,2	14	13	12	25	4,2	0,93	0,86	1,79
4,4	14	12	11	23	4,4	0,86	0,79	1,64
4,6	14	11	7	18	4,6	0,79	0,50	1,29
4,8	14	5	2	7	4,8	0,36	0,14	0,50
5	14	2	0	2	5	0,14	0,00	0,14
5,2	14	1	0	1	5,2	0,07	0,00	0,07
5,4	14	0	0	0	5,4	0,00	0,00	0,00
5,6	14	0	0	0	5,6	0,00	0,00	0,00
5,8	14	0	0	0	5,8	0,00	0,00	0,00
6	14	0	0	0	6	0,00	0,00	0,00
6,2	14	0	0	0	6,2	0,00	0,00	0,00
6,4	14	0	0	0	6,4	0,00	0,00	0,00
6,6	14	0	0	0	6,6	0,00	0,00	0,00
6,8	14	0	0	0	6,8	0,00	0,00	0,00
7	14	0	0	0	7	0,00	0,00	0,00



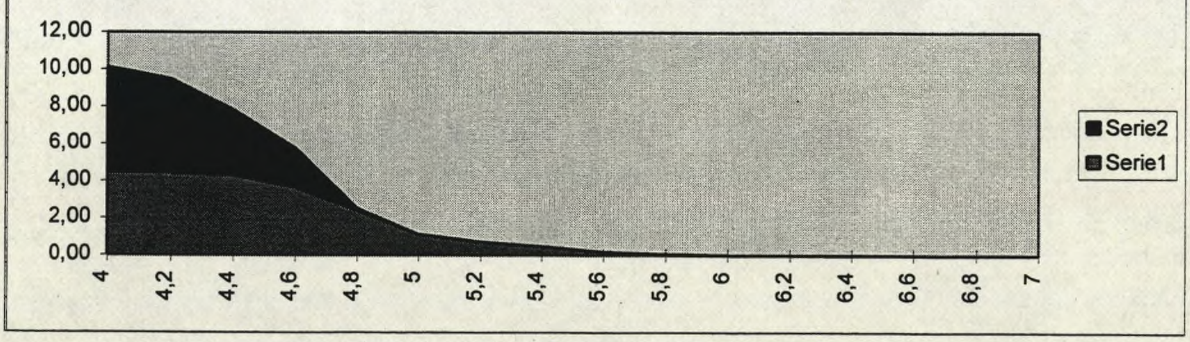
Profile 3b. 20-34 m								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	14	18	16	38	3	1,29	1,14	2,43
3,2	14	17	15	34	3,2	1,21	1,07	2,29
3,4	14	17	15	26	3,4	1,21	1,07	2,29
3,6	14	16	13	30	3,6	1,14	0,93	2,07
3,7	14	16	11	30	3,7	1,14	0,79	1,93
4	14	16	9	32	4	1,14	0,64	1,79
4,2	14	15	6	22	4,2	1,07	0,43	1,50
4,4	14	15	5	10	4,4	1,07	0,36	1,43
4,6	14	12	5	6	4,6	0,86	0,36	1,21
4,8	14	10	4	5	4,8	0,71	0,29	1,00
5	14	9	4	3	5	0,64	0,29	0,93
5,2	14	9	4	1	5,2	0,64	0,29	0,93
5,4	14	6	2	0	5,4	0,43	0,14	0,57
5,6	14	5	0	0	5,6	0,36	0,00	0,36
5,8	14	3	0	0	5,8	0,21	0,00	0,21
6	14	1	0	0	6	0,07	0,00	0,07
6,2	14	0	0	0	6,2	0,00	0,00	0,00
6,4	14	0	0	0	6,4	0,00	0,00	0,00
6,6	14	0	0	0	6,6	0,00	0,00	0,00
6,8	14	0	0	0	6,8	0,00	0,00	0,00
7	14	0	0	0	7	0,00	0,00	0,00



Profile 6								
Fracture depth Variation below 3 m.								
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	15	no data	no data	no data	no data	no data	no data	no data
3,2	15	no data	no data	no data	no data	no data	no data	no data
3,4	15	no data	no data	no data	no data	no data	no data	no data
3,6	15	no data	no data	no data	no data	no data	no data	no data
3,8	15	29	65	94	3,8	1,93	4,33	6,27
4	15	29	63	92	4	1,93	4,20	6,13
4,2	15	28	49	77	4,2	1,87	3,27	5,13
4,4	15	27	27	54	4,4	1,80	1,80	3,60
4,6	15	22	12	34	4,6	1,47	0,80	2,27
4,8	15	14	1	15	4,8	0,93	0,07	1,00
5	15	10	0	10	5	0,67	0,00	0,67
5,2	15	3	0	3	5,2	0,20	0,00	0,20
5,4	15	2	0	2	5,4	0,13	0,00	0,13
5,6	15	0	0	0	5,6	0,00	0,00	0,00
5,8	15	0	0	0	5,8	0,00	0,00	0,00
6	15	0	0	0	6	0,00	0,00	0,00
6,2	15	0	0	0	6,2	0,00	0,00	0,00
6,4	15	0	0	0	6,4	0,00	0,00	0,00
6,6	15	0	0	0	6,6	0,00	0,00	0,00
6,8	15	0	0	0	6,8	0,00	0,00	0,00
7	15	0	0	0	7	0,00	0,00	0,00



Profile 7								
Fracture depth Variation below 3 m.					**Fracture depth Variation below 3 m.**			
Depth m b	Lw	N 1'st	N 2'nd	N 1'st+2'n	Depth m b	N1'st/Lw	N 2'nd/Lw	Ntot/Lw
3	17	no data	no data	no data	no data	no data	no data	no data
3,2	17	no data	no data	no data	no data	no data	no data	no data
3,4	17	no data	no data	no data	no data	no data	no data	no data
3,6	17	no data	no data	no data	no data	no data	no data	no data
3,7	17	no data	no data	no data	no data	no data	no data	no data
4	17	76	96	172	4	4,47	5,65	10,12
4,2	17	75	86	161	4,2	4,41	5,06	9,47
4,4	17	73	60	133	4,4	4,29	3,53	7,82
4,6	17	62	36	98	4,6	3,65	2,12	5,76
4,8	17	41	2	43	4,8	2,41	0,12	2,53
5	17	19	0	19	5	1,12	0,00	1,12
5,2	17	12	0	12	5,2	0,71	0,00	0,71
5,4	17	8	0	8	5,4	0,47	0,00	0,47
5,6	17	3	0	3	5,6	0,18	0,00	0,18
5,8	17	1	0	1	5,8	0,06	0,00	0,06
6	17	0	0	0	6	0,00	0,00	0,00
6,2	17	0	0	0	6,2	0,00	0,00	0,00
6,4	17	0	0	0	6,4	0,00	0,00	0,00
6,6	17	0	0	0	6,6	0,00	0,00	0,00
6,8	17	0	0	0	6,8	0,00	0,00	0,00
7	17	0	0	0	7	0,00	0,00	0,00

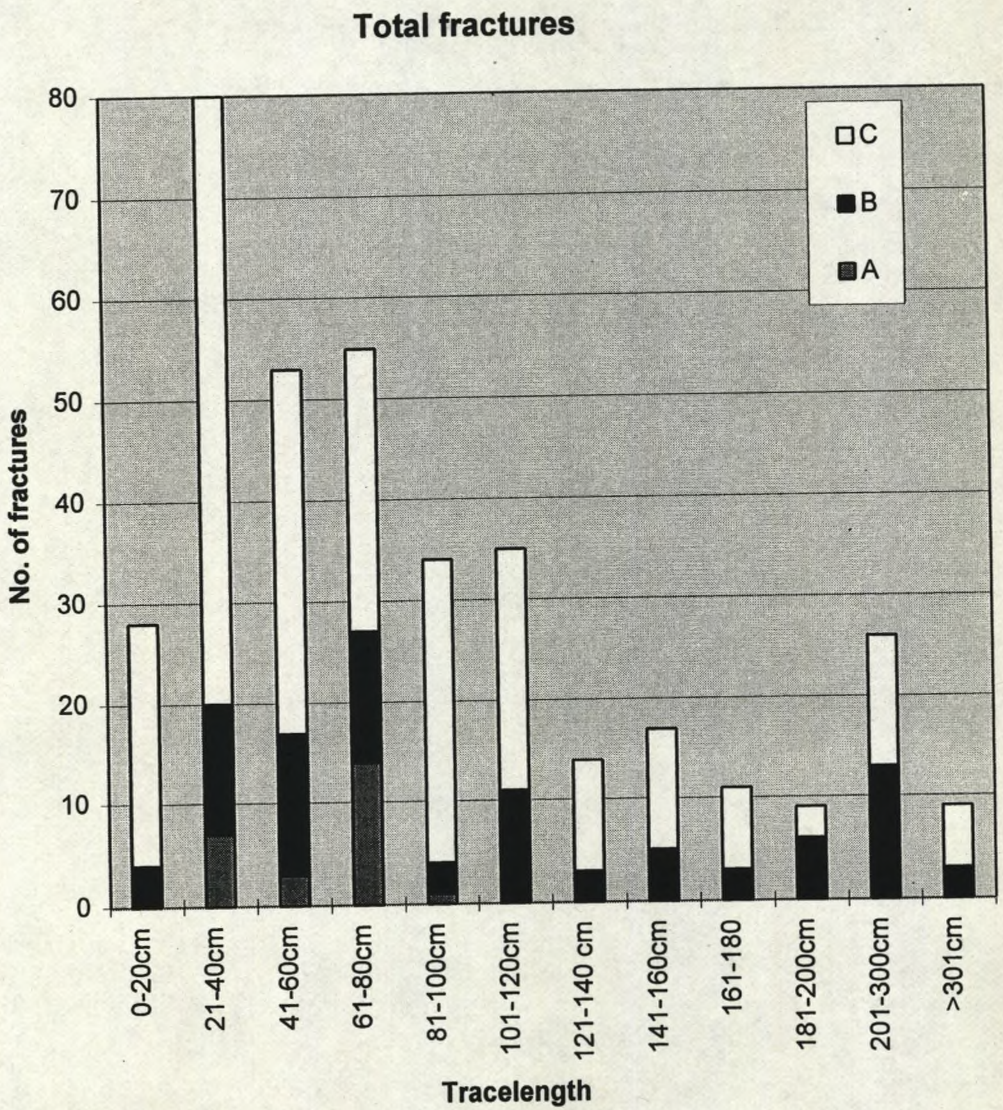


APPENDIX C

Fracture tracelength variation.

Profile 1. fracture tracelength diagram 2 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	160-180c	181-200c	201-300c	>301cm
A	0	1	1	0	0	0	0	0	0	0	0	0
B	2	6	2	0	0	2	0	0	0	0	0	0
C	6	18	8	5	6	6	1	5	1	1	1	0
Profile 2. fracture tracelength diagram 5 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	160-180c	181-200c	201-300c	>301cm
A	0	0	0	0	1	0	0	0	0	0	0	0
B	1	2	3	0	1	2	1	0	0	5	3	0
C	3	4	3	3	3	2	0	0	2	1	5	3
Profile 2. fracture tracelength diagram 3 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	160-180c	181-200c	201-300c	>301cm
A	0	0	2	0	0	0	0	0	0	0	0	0
B	0	0	1	2	0	3	0	3	1	1	2	0
C	4	8	9	7	12	3	3	1	2	0	3	3
Profile 3. fracture tracelength diagram 3 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	160-180c	181-200c	201-300c	>301cm
A	0	6	0	1	3	1	0	0	0	0	0	0
B	1	4	1	3	2	2	2	2	2	0	8	3
C	2	13	9	4	5	4	2	6	1	1	3	0
Profile 6. fracture tracelength diagram 4 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	161-180	181-200c	201-300c	>301cm
A	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	2	3	0	1	0	0	0	0	0	0
C	5	7	8	10	4	2	3	0	2	0	1	0

Profile 7. fracture tracelength diagram 4 m b.s.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	161-180	181-200c	201-300c	>301cm
A	0	0	0	0	0	0	0	0	0	0	0	0
B	0	1	5	5	0	1	0	0	0	0	0	0
C	4	10	6	9	5	7	2	0	0	0	0	0
Total fracture tracelength diagram.												
	0-20cm	21-40cm	41-60cm	61-80cm	81-100cm	101-120c	121-140 c	141-160c	161-180	181-200c	201-300c	>301cm
A	0	7	3	14	1	0	0	0	0	0	0	0
B	4	13	14	13	3	11	3	5	3	6	13	3
C	24	60	36	28	30	24	11	12	8	3	13	6


Total fractures
No. of fractures
80
70
60
50
40
30
20
10
0
C
B
A
0-20cm
21-40cm
41-60cm
61-80cm
81-100cm
101-120cm
121-140 cm
141-160cm
161-180
181-200cm
201-300cm
>301cm
Tracelength