

# The Causes and Implications of Microstructures in Glacial Sediments

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The candidate confirms that the work submitted is his own  
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## Abstract

This thesis examines how microstructures in glaciogenic sediments reflect the processes forming them, and how these microstructures then affect the conditions around them, through a series of field studies, laboratory tests, models, and statistical analyses. Following literature reviews, a deformational chronology is developed for diamictos at Criccieth, North Wales, and their microstructures are used to indicate the stress, hydraulic, and environmental changes the materials have undergone. Microstructures of the lowest diamict indicate clast lodgement. The processes reflected in the microstructures of this lowest diamict are built into a quantitative model that estimates its residual strength (20 - 50 kPa) and the ice velocity during lodgement (20 - 50 m a<sup>-1</sup>). The response of sediment to glacial stress is further examined by triaxial testing of diamict from Yorkshire, and the subsequent examination of its micromorphology. Shears in the material are disrupted by clasts, and this may be responsible for work hardening seen during the tests. Fabric compression, and the development of immobilised shears or hydraulic fractures buffer pore fluid pressure to ~470 kPa. The information from previous chapters is then used to analyse other material from the Yorkshire coast. This analysis confirms the presence in the area of meltout tills that have undergone low strain, as well as providing evidence for the decoupling of the ice and sediment in this region, and the nature of drainage systems within and above the diamicts during glaciation. Overall this thesis details the processes forming three 'classic' microstructures found in glacial sediments; omnisepic fabrics, lattisepic fabrics, and melanges, and provides evidence for the processes involved in forming diamict pebbles and skelsepic fabrics. In addition this thesis details how such structures reflect coupling and decoupling processes between glaciers and their beds, and examines the manner in which microstructures affect the response of a subglacial sediment body to stress and hydraulic conditions.

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- FIGURE 6.10 VISUAL SCALE APPEARANCE OF TWO TEST SAMPLES. TEST 5; CROSS SECTION SHOWING SHEAR DIP, DRAWN DURING SECTIONING FOR THIN SECTION SAMPLES. TEST 6; SHOWING OUTER SURFACE AFTER TESTS. NOTE THE TWO DISLOCATION PLANES. -----
- FIGURE 7.1 PHOTOMICROGRAPH OF A CLAST RICH PATCH FROM SLIDE T22. UNPOLARIZED LIGHT CONDITIONS. -----
- FIGURE 7.2 A PERVASIVE LATTISEPIC FABRIC PHOTOMICROGRAPH FROM T22. CROSS POLARISED LIGHT WITH A TINT PLATE. YELLOW AREAS OF MATRIX ARE ORIENTATED IN ONE DIRECTION, BLUE AREAS ARE ALIGNED IN ANOTHER DIRECTION, ALONG WITH SOME OTHER THIN GRAINS. -----
- FIGURE 7.3 PHOTOMICROGRAPH OF CLASTS WITHIN A SHEARED FABRIC THAT HAVE DEVELOPED AN FABRIC PARALLEL TO THEIR SIDES BETWEEN THEM. UNPOLARIZED LIGHT, SLIDE T22. -----
- FIGURE 7.4 PHOTOMICROGRAPH OF CLAY/SILT CONCENTRATION AROUND A CLAST. UNPOLARIZED LIGHT, SLIDE T22. -----
- FIGURE 7.5 CRACKING IN THIN SECTION T51. NOTE THE STRAIGHTNESS OF THE CRACKING DESPITE THE HETEROGENEITY OF THE MATERIAL. UNPOLARIZED LIGHT. -----

- FIGURE 7.6 CRACK ORIENTATIONS FOR THE CRACKING IN THE THIN SECTIONS PREPARED FROM THE TEST SAMPLES. MEASUREMENTS WERE TAKEN IN THE RANGE  $90^{\circ}$  TO  $270^{\circ}$ , AND THE RESULTS ARE CATEGORISED IN  $10^{\circ}$  BINS. -----
- FIGURE 8.1 A) MAP OF LOCATIONS DISCUSSED IN THE TEXT. B) LOCATION OF SITES ON THE EAST YORKSHIRE COAST DISCUSSED IN THE TEXT. SAMPLE SITES DISCUSSED IN THIS CHAPTER ARE IN ITALICS. -----
- FIGURE 8.2 SHEAR EXTENDED CHALK MATERIAL AT HORNSEA, EAST YORKSHIRE COAST. RULED DIVISIONS ARE 10 CM. -----
- FIGURE 8.3 SEDIMENT SEQUENCE AT FILEY BRIGG, EAST YORKSHIRE COAST. COMPOUND SEQUENCE FOR THE WHOLE BRIGG AREA FROM EVANS ET AL., 1995, ALSO SHOWING THE POSITIONS OF THEIR S.E.M. THIN SECTION SAMPLES 2.7.6, 3.7.6 AND 8.7.6. SEQUENCE ON RIGHT IS THE STRATIGRAPHY AT THE SAMPLE SITE DISCUSSED IN THIS CHAPTER WITH HEIGHTS OF SAMPLES (FB1 TO 6) (AFTER AN ORIGINAL DIAGRAM BY S.CHURCH, 1996, UNPUB.). -----
- FIGURE 8.4 PHOTOGRAPH OF FILEY BRIGG SHOWING SAMPLING SITE. -----
- FIGURE 8.5 SKETCH OF THE TWO DIMENSIONAL FORM OF THE SAMPLED SEDIMENTS. -----
- FIGURE 8.6 PHOTOMICROGRAPH OF A CLAY BODY FROM SAMPLE FB6A SHOWING LOW STRAIN DEFORMATION. UNPOLARIZED LIGHT CONDITIONS. -----
- FIGURE 8.7 POTENTIAL SMALL SCALE 'MASS MOVEMENT' DEPOSIT. NOTE HOW THE CLAYS ARE FOLDED AROUND AN AREA THAT MIGHT HAVE 'FLOWED' INTO THEM IN A SEMI-COHERENT MASS. SAMPLE FB6A, UNPOLARIZED LIGHT CONDITIONS. -----
- FIGURE 8.8 PHOTOMICROGRAPHS OF CLAY BANDS SHOWING OVERPRINTING. A) SAMPLE FB6A. B) SAMPLE FB4A. PICTURE TAKEN UNDER CROSS POLARIZED LIGHT WITH A TINT PLATE. -----
- FIGURE 8.9 PHOTOMICROGRAPH OF CLAY BAND FROM SAMPLE FB5A. NOTE THAT THE INTERNAL FABRIC OF THE CLAY HAS NOT BEEN OVERPRINTED AFTER THE BAND'S DEFORMATION. -----
- FIGURE 8.10 HYPOTHETICAL SHEAR STRESS - EFFECTIVE PRESSURE PATHS ACCOUNTING FOR THE MICROSTRUCTURES OBSERVED IN THE UPPER PART OF THE SEQUENCE AT FILEY BRIGG, EAST YORKSHIRE COAST. MAIN DIAGRAM SHOWS THE SUGGESTED RHEOLOGIES OF THE MATERIAL. THE INSET DIAGRAMS ARE PATHS WHICH MAY HAVE PRODUCED THE STRAIN EVIDENCE PRESENTED IN THE TEXT. A AND B ARE THE STARTING CONDITIONS FOR THE MATERIAL WITH THE INCONSISTENT FABRIC AND ELSEWHERE RESPECTIVELY. C AND D ARE THEIR RESPECTIVE FINAL CONDITIONS. -----
- FIGURE 8.11 SEDIMENT SEQUENCE AT DIMLINGTON HIGH GROUND, EAST YORKSHIRE COAST. INSET SHOWS THE POSITION OF THE SAMPLE SITE AT THE SCALE OF CATT AND PENNY'S (1966) SURVEY OF THE AREA (THOUGH NOTE THAT THE AREA'S STRUCTURE HAS CHANGED BECAUSE OF COASTAL RETREAT). -
- FIGURE 8.12 PHOTOGRAPH OF THE SEDIMENTS SAMPLED AT THE BOUNDARY BETWEEN THE SKIPSEA TILL AND THE BASEMENT TILL AT DIMLINGTON HIGH GROUND, EAST YORKSHIRE COAST. OPEN ENDED SAMPLE BOXES ARE IN THE APPROXIMATE SAMPLE POSITIONS. -----
- FIGURE 8.13 FREQUENCY OF DIP ANGLES FOUND IN DSK2. THIS SLIDE CONTAINED THE ONLY SDF ORIENTATION FOR WHICH THERE WAS UNCERTAINTY AS TO WHETHER THE FABRIC WAS ALIGNED OR RANDOM ON THE BASIS OF A VISUAL INTERPRETATION OF FREQUENCY DATA. THE FABRICS APPEAR TO BE IN TWO DIRECTIONS, HOWEVER, THE FABRICS ARE RANDOM IN THE NORTH-SOUTH PLAIN AS SEEN IN DSK3. THIS FIGURE IS REFERRED TO WITHIN TABLE 8.4. -----
- FIGURE 8.14 PHOTOMICROGRAPH OF CLEAN SAND LENSES IN SAMPLE DSK7. UNPOLARIZED LIGHT CONDITIONS. -----
- FIGURE 8.15 PHOTOMICROGRAPH OF SHEAR 'A' AT THE TOP OF BASEMENT TILL. THE ORIENTATION OF THE SHEARED FABRIC GIVES IT A GREEN COLOUR. SAMPLE DSK6, UNDER CROSS POLARIZED LIGHT WITH A TINT PLATE. -----
- FIGURE 8.16 PHOTOMICROGRAPH OF DIAMICT PEBBLES IN THE SANDS AND DIAMICT AT THE TOP OF THE BASEMENT TILL UNDER THE DIMLINGTON SILTS. SAMPLE DS9, UNDER UNPOLARIZED LIGHT CONDITIONS. -----
- FIGURE 8.17 PHOTOMICROGRAPH OF SLIDE DSK6, SHOWING THE BASEMENT TILL. NOTE THE DISCRETE SHEARS AND PATCHES OF SHEAR ALIGNED MATERIAL. CROSS POLARIZED LIGHT CONDITIONS WITH A TINT PLATE. -----
- FIGURE 8.18 SEDIMENT SEQUENCE AT REIGHTON SANDS, EAST YORKSHIRE COAST. THE VISIBLE SEQUENCE STARTS AT ~25 M O.D. LITHOFACIES A) GREY DIAMICT. B) BROWN DIAMICT. C) CHALK GRAVEL. D) FAINTLY LAMINATED SANDS. E) MASSIVE SHELLS AND SANDS. -----
- FIGURE 8.19 PHOTOGRAPH OF THE SAMPLE SITE AT REIGHTON SANDS. -----
- FIGURE 8.20 PHOTOMICROGRAPH OF FABRIC FOLLOWING THE SANDS AT BASE OF LITHOFACIES A, THE LONG AXES OF THE LONG DARK GRAINS FOLLOW THE GENERAL FABRIC DIRECTION. SAMPLE F1A, UNDER CROSS POLARIZED LIGHT WITH A TINT PLATE. -----
- FIGURE 8.21 POTENTIAL FLUID-FLOW / DEFORMATION HISTORY FOR LITHOFACIES A. -----

FIGURE 8.22 PHOTOMICROGRAPH OF THE MELANGE OF DIAMICT, SILTS AND CLAYS THAT MAKES UP LITHOFACIES B WHICH APPEARS TO BE A DIAMICT ON AN OUTCROP SCALE. SAMPLE F5A, UNDER UNPOLARIZED LIGHT CONDITIONS. -----

FIGURE 9.1 SUMMARY OF THE MAIN CONCLUSIONS ON THE ORIGIN OF MICROSTRUCTURES IN THIS THESIS. FOR FURTHER INFORMATION, SEE THE FOLLOWING CHAPTERS; A) CHAPTER SEVEN, B) CHAPTERS SEVEN AND EIGHT, C) CHAPTER FOUR, D) CHAPTER EIGHT, E) CHAPTERS SEVEN AND EIGHT, F) CHAPTER EIGHT. -----

FIGURE 9.2 SUMMARY OF THE MAIN CONCLUSIONS ON THE PROCESSES ACTING AT THE ICE-SEDIMENT INTERFACE AND BELOW. FOR FURTHER INFORMATION, SEE THE FOLLOWING CHAPTERS; A) CHAPTER EIGHT, B) CHAPTER FIVE, C) CHAPTER EIGHT, D) CHAPTERS SIX, SEVEN AND EIGHT, E) CHAPTERS SIX, SEVEN AND EIGHT, F) CHAPTERS SIX AND SEVEN.-----