A polar paradise: the glaciation of South Victoria Land, Antarctica
Lloyd Davies, M.T.

Citation for published version (APA):
Lloyd Davies, M. T. (2004). A polar paradise: the glaciation of South Victoria Land, Antarctica Amsterdam: UvA

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CHAPTER 10: CONCLUSION

1.1 Methods employed

The collection of micromorphology samples in the field is a time-consuming and sensitive operation usually requiring mammoth or Kubiena sample tins. However, this study has demonstrated that clast rich and friable diamicts may be sampled without use of the conventional tins on the condition that they are pre-impregnated in the field as soon as possible. This is done by following the technique described in chapter 3, which is effective, cheap, safe and simple. Secondly, when sampling semi-lithified sediments, an angle grinder may be employed to rapidly extract mammoth or Kubiena tin sized blocks for micromorphological analysis. The thin sections derived from this field method demonstrated no appreciable damage when viewed under the microscope. From our experience the cost of such an angle grinder (~€2,000, including additional cutting blades) as a medium to long term investment is well worth the time gained in the field; especially in polar or mountainous regions where poor weather can make short shrift of a field season.

Micromorphology is shown to be an effective tool in distinguishing between different glacial diamicts, and providing insight as to the processes responsible for their formation. Examples taken from chapters 6, 7 and 9 are provided below.

In chapter 6 a deposit attributed to formation by a cold-based glacier has been described by Atkins et al., (2002) as a ‘sandstone and siltstone breccia’, and later informally termed a till (Lloyd Davies et al., chapter 5). However, micromorphology has added two important aspects that are less obvious in the field: (1) the style of cold-based subglacial deformation is planar and brittle and (2) the tectomicts (tills) have experienced substantial post-depositional change.

In chapter 7, it was demonstrated that non-glacigenic sediments, glacial diamicts and tills exist side by side along the relatively small terminus of Taylor Glacier in the Dry Valleys. One might argue that this could be achieved by standard field work, but micromorphology permits additional insight into those processes accountable for the sediment texture and
structure, which in turn facilitates discrimination between the sediments. One example is the glacilacustrine deposit of thin section C.911. Here the laminae demonstrate micro-scale boudinaging, folding and kinking plasmic fabric, pointing towards extensional and compressional deformation. Even though the deposits may still have been regarded as glacilacustrine in the field, an inference regarding the nature of its deformation would have gone unnoticed to the naked eye.

In chapter 9, micromorphology supported field observations, in being able to distinguish between the subglacially deformed tillite wedge thin sections and those taken from within clastic dykes. Additionally, it provided an ‘in situ’ view as to the nature of clastic dyke sedimentology. Clastic dykes are themselves considered Water Escape Structures (WESs) but the fact that they contain a range of diverse micro-WESs and micro-deformation structures allows improved understanding as to the processes responsible for their formation. For example, if the clastic dyke sediments were subjected to particle size analysis, the three dimensional geometry and structure of the micro-WESs would be lost and by examining the properties of single sized fractions the overview and nature of grading within the micro-WESs might be misrepresented.

However, as with many techniques they have the potential to cause more harm than good if used in isolation or if one were to approach glacial geology from purely a micromorphological viewpoint. Therefore, field observations, particle size analysis and clay mineralogy supported micromorphology throughout this study. It was found that the prevailing particle size fraction(s) was also prominent in the local bedrock geology in the case of the Allan Hills or debris-rich basal ice in Taylor Glacier. The clay fraction is low in the Manhaul tectomite, in all but two samples that were found upon mudstone/lithified clay bedrock. This suggests that cold-based tectomite (till) particle size is directly determined by the glacially overridden parent material. In contrast the Sirius Group derived clastic dyke sediments and tillite wedge, from the same locality as the Manhaul tectomite (till), demonstrate a relatively high clay fraction (>10%; Passchier, 2002). This indicates the increased significance of comminution and abrasion in temperate-based ice masses. A high carbonate content was found in several thin sections from the Taylor Glacier study, thus explaining their poor plasmic fabric development. The clay mineralogy of the Manhaul tectomite (till) and Sirius Group tillite, both from Allan Hills,
demonstrated the occurrence of the relatively rare swelling mica. As this is also reported in the local bedrock geology of the Allan Hills (Ballance, 1977), a local provenance origin for both deposits is plausible. Furthermore, the clay mineralogy supported a diagenetic opposed to deformational interpretation for the skelsepic plasmic fabric found in the Manhaul tectomict (till).

1.2 'Take-home' points from the chapters

Chapter 3 concludes that a clast rich, friable diamict may be pre-impregnated in the polarfield, with no significant alteration to the sample when viewed in thin section. The materials are easily obtained and safe if used with adequate ventilation. The rate of induration appears related to ambient temperature, meaning that the colder the conditions the slower the rate of hardening. The fact that this method is successful in the polarfield means that it is also most likely applicable to other warmer environments where rate of hardening would be more rapid.

Chapter 4 is a review chapter that sets the scene regarding the growing evidence for cold-based glacial activity. Such evidence concerns cold-based glacial entrainment, ductile and brittle subglacial sediment deformation, thrust-block moraine formation, erosion, deposition and glacitectonism of lithified bedrock. The range of observations come from South Victoria Land only, suggesting they may also be found in other (high elevation) regions in Antarctica so to add more weight to the case for cold-based glacial activity. Chapter 4 concludes that the existing assumption regarding cold-based glacial inactivity should be abandoned. This, in particular, has implications for modelling ice sheet dynamics (cf Näslund et al., 2000, 2003) or automatically equating glacially modified landscapes to temperate-based glaciers only.

Chapter 5 documents first hand evidence for cold-based glacial advance during the Last Glacial Maximum (LGM) in the Allan Hills. In particular, evidence is provided for cold-based subglacial erosion, deposition and glacitectonism, with the latter being the most conspicuous. The chapter also speculate as to the low preservation potential of these cold-based features upon climatic amelioration, explaining their ‘perceived absence’ in the Pleistocene record.
Chapter 6 concludes that the Manhaul Bay Glacier is capable of producing a locally derived tectomic (till), by subglacial deformation. The till demonstrates a glaciectonic rather than sedimentary signature and is thus termed a tectomic following the recommendation of van der Meer et al., 2003a. The planar (brittle) mode of deformation is acutely different to that observed in temperate tills due to its low clay and (presumably) water content. All samples analysed are susceptible to water facilitated post-depositional changes in polar, arid environments. This has implications regarding their preservation potential, especially under wetter regimes.

Chapter 7 concludes that Taylor Glacier terminus should not be regarded as one of the classical sublimation till sites. In contrast, ~≤100μm thick clay coated grains observed in thin section are proposed as indicative for meltout till that has subsequently experienced wet flow in contemporary ice-marginal environments. The sedimentary regime at Taylor Glacier terminus is dynamic, with proglacial lacustrine deposits, aeolian fines, meltout till (including that subjected to syn- and/or post-depositional wet sediment flow) all being observed. Many of the sediments at Taylor Glacier terminus have a high salt and carbonate content.

Chapter 8 concludes that fracturing is the first stage in subglacial (temperate) bedrock tectonism, and its density is related to bedrock competency and thickness. The fractures also move from a vertical to oblique orientation in the direction of former ice-flow. All of the sandstone strata overlying brecciated coal or carbonaceous siltstone are not in situ but have been laterally displaced and used as the deforming tool. Moreover, bedrock glaciectonism contributes significantly to local till production, but without direct glacial ice contact. In a generalized sense the former ice sheet(s) that deposited the Sirius Group at Allan Hills flowed from the south(west) to north(east) and were warm-based.

Chapter 9 reports the first time finding of clastic dykes and tillite wedges in Antarctica, and that they were formed subglacially, close to an ice mass margin. This was most likely during the over-riding of a Neogene temperate East Antarctic Ice Sheet (EAIS), which was experiencing huge amounts of subglacial meltwater. The scale of the EAIS is directly comparable with former Pleistocene ice masses. All of the examined clastic dykes contain micro-WESs formed by a hydrostatic pressure gradient and not a velocity gradient, and express evidence for deformation. The tillite
Wedge and clastic dyke thin sections have a number of micro-structures in common with subglacial tills and flow deposits. However, the combination of extensive, diverse micro-WESs with large, isolated rotational features, grain lineations and a laminar, imbricate fabric could be tentatively regarded as diagnostic for clastic dyke sediments examined in thin section. Finally, caution must be exercised when assessing clastic dyke strike in section view, as it was noted they tend to spread laterally.

1.3 The last word

In studying the contemporary glacial environments of South Victoria Land, Antarctica, a significant amount of information has been obtained in relation to its glacial nature and history. Evidence is presented for cold-based glacial activity in a relatively small area of Antarctica. It is hoped that future research will uncover further evidence for cold-based glacial dynamics across the ice free regions of the continent. As the 'classic sublimation till' site of Taylor Glacier terminus is challenged, in one of the most arid and cold places on Earth, its current existence on our planet must be questioned. Glacitectonised bedrock and clastic dykes related to former glaciations that deposited the Sirius Group in the Allan Hills, demonstrate a warmer, wetter and dynamic past in Antarctica.

The timing of this is still an ongoing debate. However, all the above findings confirm that the Antarctic is a dynamic and changing environment. The more we understand its history, the better the profile of the continent's nature and character. In this way a 'ground truth' is provided, that improves our predictions regarding inevitable climatic and environmental change, and in turn supplements a framework for environmental stewardship.