25. THE LAKE HAZEN FAULT ZONE, ELLESMERE ISLAND: A TRANSPRESSIONAL UPTHRUST?

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Abstract

Observations on well-exposed sections of the Lake Hazen fault zone around the head of Tanquary Fiord, northern Ellesmere Island, suggest a model of development involving basement upthrusts controlled by tectonic transpression, with a small amount of dextral strike-slip. Large displacements, whether strike-slip or dip-slip, need not be invoked.

Résumé

Des observations le long de sections bien exposées de la zone faillée de Lake Hazen, près du sommet du fjord Tanquary dans le nord de l'île Ellesmere, suggèrent un modèle de formation comprenant des soulèvements du socle rocheux contrôlés par la transpression tectonique, avec de petits rejets horizontaux vers la droite. Il n'est pas nécessaire de faire appel aux déplacements importants, qu'ils soient horizontaux ou verticaux.

Introduction

The Lake Hazen fault zone trends east-northeast across northern Ellesmere Island (Fig. 25.1). It is traceable for almost 400 km from Hare Fiord in the west via Tanquary Fiord and Lake Hazen to the coast of the Lincoln Sea near Alert, and in its eastern part forms the southern margin of the Grantland Mountains (Christie, 1964; Nassichuk and Christie, 1969; Trettin, 1971; Trettin et al., 1972; Miall, 1979). It consists of a series of en echelon reverse faults, which cut both the lower Paleozoic sediments of the Hazen Trough, deformed by the mid-Paleozoic Ellesmerian orogeny, and their upper Paleozoic-Mesozoic cover of Sverdrup Basin sediments. Locally faults affect the early Tertiary Eureka Sound Formation (Miall, 1979). The fault deformation is ascribed to the main phase of the Eurekan orogeny (post-middle Eocene, pre-early Miocene: Trettin and Balkwill, 1979).

The dip-slip component of displacement on the faults is upwards on the north side and Nassichuk and Christie (1969, p. 24) described them as "steep, north-dipping mountain front thrusts", bordering the Grantland Uplift with an estimated vertical displacement of 1-2 km. Subsequent workers have generally accepted this interpretation, but recently larger displacements have been proposed, as is currently fashionable. Håkansson and Pedersen (1982) have erected a mobilistic model for northern Ellesmere Island and North Greenland in which several hundred kilometres of strike-slip displacement are proposed on the Lake Hazen fault zone and its supposed continuation in North Greenland, the Harder Fjord fault zone (Higgins et al., 1981). Since stratigraphic and structural features can be matched across the Harder Fjord fault zone without the necessity for any strike-slip displacement (authors' observations), and since the Tanquary structural high (Nassichuk and Christie, 1969; Wilson, 1976) crosses the Lake Hazen fault zone with a few kilometres offset only (Fig. 25.1), this interpretation can be ruled out. More serious consideration must be given to the thin-skinned model of Osadetz (1982), as this is based on fieldwork in the vicinity of Tanquary Fiord and Ekblaw Lake. He proposed that the component faults of the Lake Hazen fault zone are low-angled thrusts, rooting in a décollement near the base of the Grant Land Formation and having dip-slip displacement of many tens of kilometres.

An invitation to join the GSC party based at Tanquary Fiord in 1982 enabled the authors to map selected parts of the Lake Hazen fault zone in more detail than had been previously possible, with a view to deciding between the thin-skinned and upthrust interpretations. Observations were made on four well-exposed sections in the fault zone around the head of Tanquary Fiord: east of Bent Glacier; between Rollrock Lake and Ekblaw Lake; at Mount Timmia; and at Mount Thompson (Fig. 25.1). This paper is a preliminary report on our findings which, in our view, support a model which involves upthrusts associated with limited dextral transpression.

Bent Glacier

In the vicinity of Bent Glacier on the north side of Tanquary Fiord (Fig. 25.1), the published 1:250 000 scale geological map (Thorsteinsson and Trettin, 1971) shows several fault-bounded wedges of Sverdrup Basin sediments in fault contact with lower Paleozoic Grant Land Formation to the north. A section across the Bent Glacier fault zone is shown in Figure 25.2a. The main fault is clearly exposed east of Bent Glacier and dips north at 35-53°, with Grant Land Formation in the hanging wall. The footwall is composed of Carboniferous-Permian limestones of the Nansen Formation inclined a little more steeply than the fault and probably inverted, in a slice or 'horse' which has a maximum thickness of 300 m. The Nansen is in fault contact with sandstones and shales of the Triassic-Jurassic Heiberg Formation (mainly Fosheim Member with dolerite sills), which is clearly inverted, dipping northwest at 45°, and forms a wedge with a maximum thickness of about 800 m. Another poorly exposed reverse fault separates the Heiberg Formation from Mesozoic formations in the steeply inverted limb of a southward verging asymmetric syncline. From a consideration of the altitude of the mid-Paleozoic unconformity north and south of the fault zone, the vertical displacement is estimated to be 3.5 km.

Rollrock Lake and Ekblaw Lake

A branch of the Lake Hazen fault zone runs along the north side of Rollrock valley (Fig. 25.1) as shown on the maps by Nassichuk and Christie (1969) and Wilson (1976).

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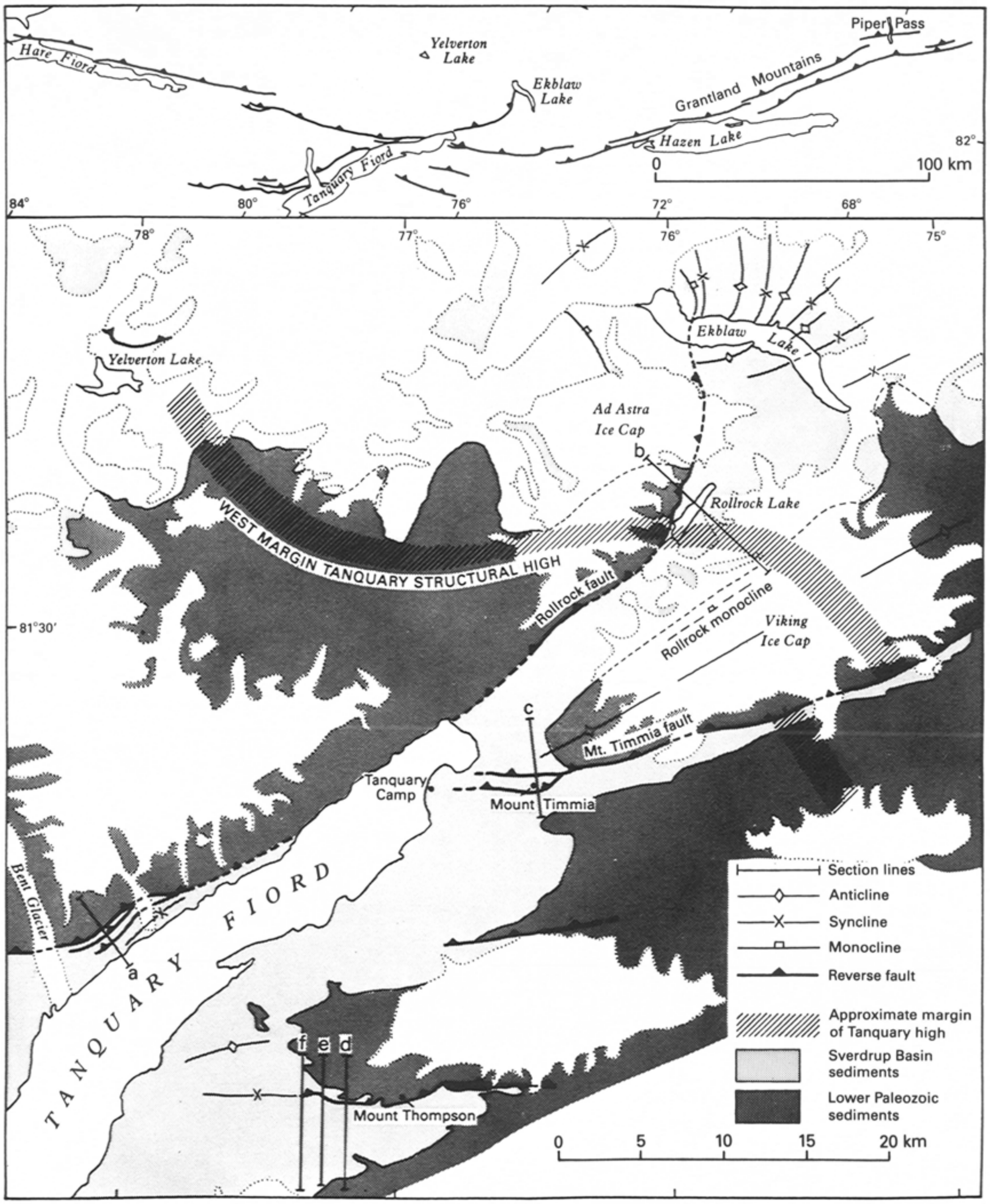

Figure 25.1. *Sketch map of the area around the head of Tanquary Fiord showing main structural elements, and location of the cross-sections of Figure 25.2. The west boundary of the Tanquary structural high coincides approximately with the erosional limit of the Upper Carboniferous-Lower Permian Belcher Channel Formation, which here unconformably overlies the lower Paleozoic basement. Farther east, the basement is overlain in some areas by the Upper Triassic-Lower Jurassic Heiberg Formation and in others by a thin Lower Permian Sabine Bay Formation, in turn overlain by the Heiberg. The limit has been adapted from the preliminary geological map by Mayr et al. (1982), but our interpretation involves projection across several large areas of non-exposure. Inset at top shows en echelon elements of Lake Hazen Fault Zone.*

Osadetz (1982) has shown that towards Ekblaw Lake this fault trace swings from northwest to north. The fault is best exposed on the north side of Rollrock Lake (Fig. 25.3), while at Ekblaw Lake it dies out into a monocline. We therefore refer to it here as the 'Rollrock fault', rather than the 'Ekblaw Lake thrust', the term introduced by Osadetz (1982).

At Rollrock Lake the main reverse fault, dipping northwest at angles between 30° and 62°, carries lower Paleozoic rocks in the hanging wall (Grant Land Formation) and climbs up-sequence into the Sverdrup Basin cover, which here on the Tanquary structural high consists of Heiberg Formation resting directly on Grant Land Formation (Figs. 25.2b, 25.3). The Sverdrup basin sequence in the footwall consists of Permo-Carboniferous to Cretaceous sediments preserved in a conspicuous monocline, which has a maximum limb dip of 70°. The fault cuts up-sequence through late Jurassic and Cretaceous sediments. Interposed between the lower and upper plates is a 'horse' of Heiberg Formation, and again, as at Bent Glacier, this is inclined to the northwest and inverted. The vertical displacement on the fault zone in this area is estimated to be about 2.5 km.

The fault swings northwards beneath the Ad Astra Ice Cap and reappears to cross the west end of Ekblaw Lake. Osadetz (1982) showed his 'Ekblaw Lake thrust' terminating here against a fault which displaces it above the present erosion level. Our mapping indicates that stratigraphic separation on the Rollrock fault diminishes northwards and on the northern side of Ekblaw Lake it dies out into the vertical limb of a north-northwest trending monocline. The displacement is also taken up on a further monocline some 6 km to the west, and the series of open folds mapped by Osadetz to the east, which are responsible for the spectacular inverted topography north of Ekblaw Lake.

Mount Timmia

A main branch of the Lake Hazen fault zone passes through Mount Timmia, northeast of Tanquary Camp at the head of Tanquary Fiord (Fig. 25.1), and was first shown on the map by Nassichuk and Christie (1969). Osadetz (1982) mapped a single thrust here, inclined at about 15°, and regarded this as important evidence in favour of a thin-skinned interpretation for the fault zone. Our more detailed mapping shows there to be, in fact, two reverse faults at Mount Timmia (Fig. 25.2c). The main fault, which east of

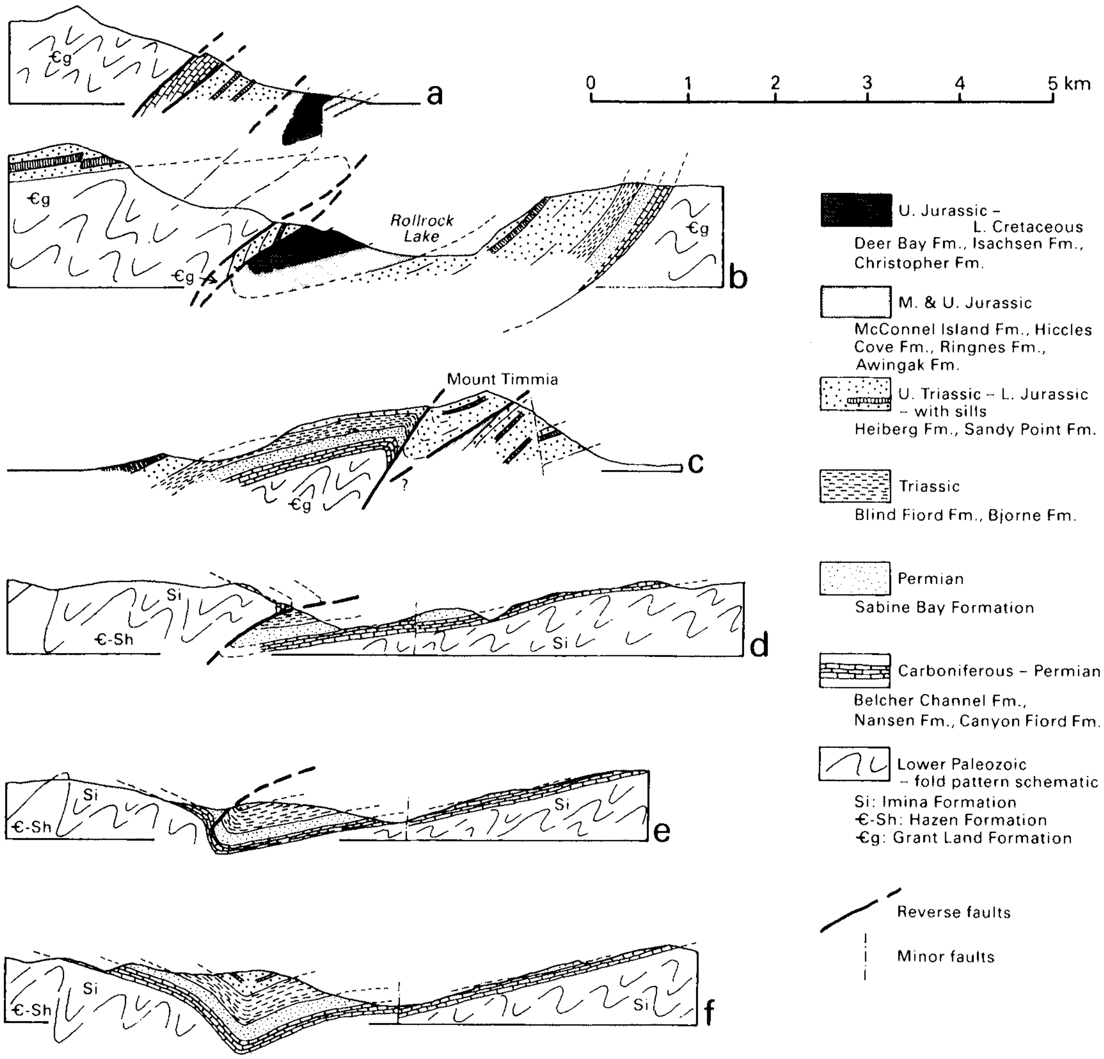

Figure 25.2. Sketch cross-sections (see Fig. 25.1 for location): (a) East of Bent Glacier; (b) Rollrock Lake; (c) Mount Timmia; (d), (e) and (f) Mount Thompson.

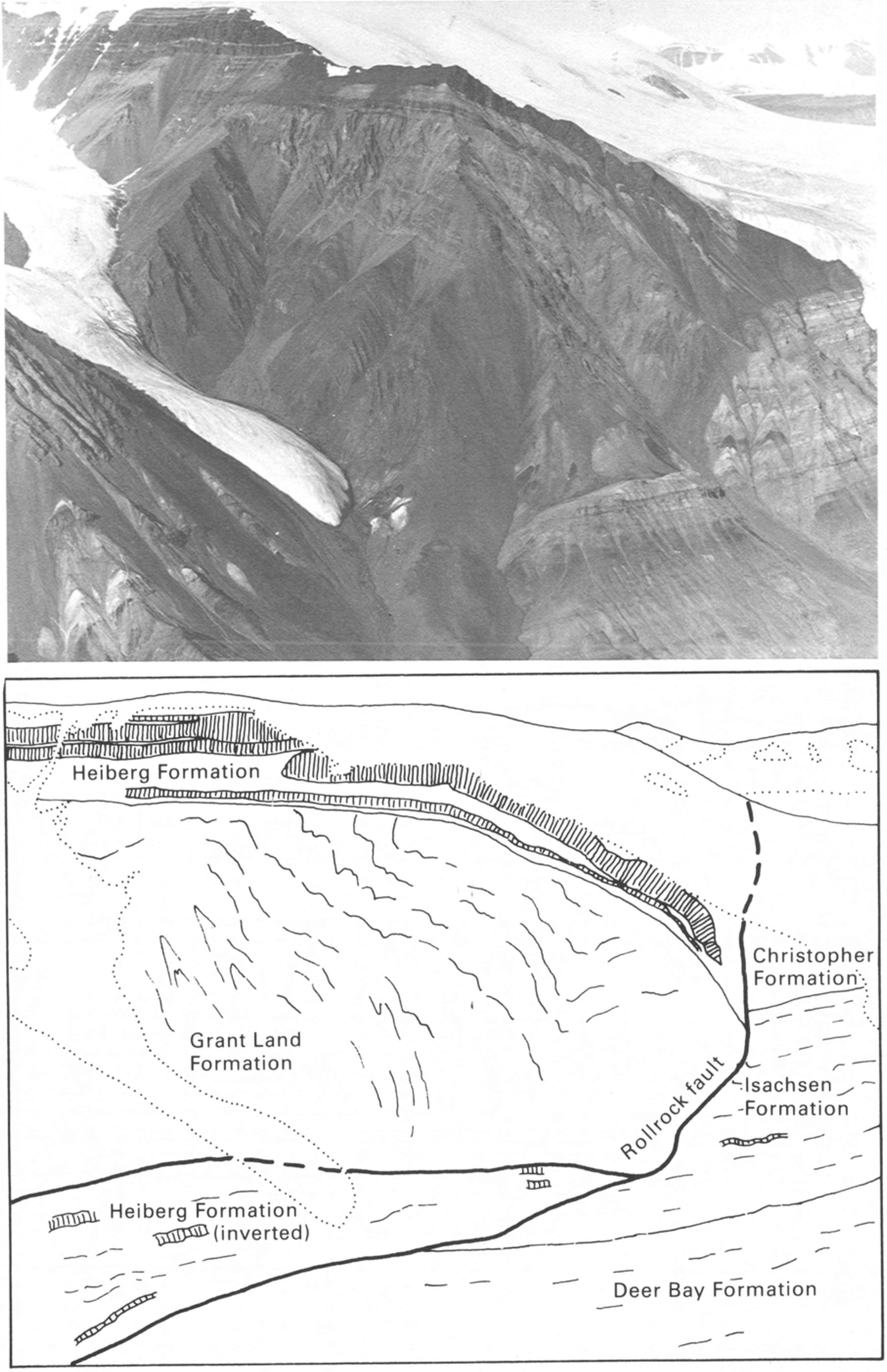

Figure 25.3. *The Rollrock fault north of Rollrock Lake. Folded Grant Land Formation and unconformably overlying Heiberg Formation in the hanging wall are faulted against Mesozoic formations in the footwall. Note wedge of inverted Heiberg Formation at left – see also Figure 25.2b.*

Mount Timmia emplaces lower Paleozoic Grant Land Formation over Sverdrup Basin cover, climbs westward into the cover in the hanging wall and bifurcates into northern and southern branches, which are inclined northwards at 55° and 35° respectively (Fig. 25.2c). The southern branch cuts down-sequence locally in the footwall.

Mount Thompson

Sixteen kilometres south of Tanquary Camp, the 1:250 000 scale geological map by Thorsteinsson and Trettin (1971) shows a reverse fault in the Mount Thompson area passing westwards into a major syncline in Sverdrup Basin sediments. Our detailed mapping confirms this basic interpretation.

The fault plane dips north at low angles of 20-25°, subparallel to the bedding of the sediments in the footwall, and along strike follows the same stratigraphical level for 7 km before cutting rapidly up-sequence in the hanging wall to die out in the steep common limb of an east-west trending fold pair. Three cross-sections of the structure in the transition from reverse fault to fold are shown in Figure 25.2d, e, f.

Discussion

Osadetz (1982) stated that the thrust faults in the Tanquary Fiord – Ekblaw Lake area generally dip at angles of less than 15°, and this appears to be one of the reasons for his adoption of a thin-skinned interpretation for the Lake Hazen fault zone. We do not wish to discuss here each point on which our respective interpretations differ, but it is necessary to emphasize that our direct observations of the fault planes show them to have extremely variable and commonly steep inclinations. As described briefly above, and shown in Figure 25.2, the main faults at Bent Glacier are inclined at 35-55°, at Rollrock Lake 30-62°, at Mount Timmia 35-55°, and only at Mount Thompson can a thrust fault be traced for an appreciable distance with a rather uniform dip of less than 25°. East of the Tanquary Fiord area, a dip of 60° was observed on a part of the Lake Hazen fault zone east of Piper Pass (Fig. 25.4), and this concurs with the report by Miall (1979) that the main thrust fault is steeply dipping to near vertical between Lake Hazen and Piper Pass (Fig. 25.1).

Our overwhelming impression is that when one or both walls of the faults are in Sverdrup Basin cover rocks then the inclination is variable, commonly steep as a fault cuts up-section or follows a surface in steeply inclined strata, but locally following gently inclined bedding in certain units (particularly the Fosheim Member of the Heiberg Formation). When entirely within previously folded lower Paleozoic rocks the faults are difficult to discern, but when visible or inferred from aerial photographs, they appear to cross pronounced topography with little deflection, suggestion steep inclinations (H.P. Trettin, personal communication). A few direct observations of fault traces in Grant Land Formation indicate dips in excess of 60°, and we infer that the faults could well steepen with depth, as required by an upthrust interpretation.

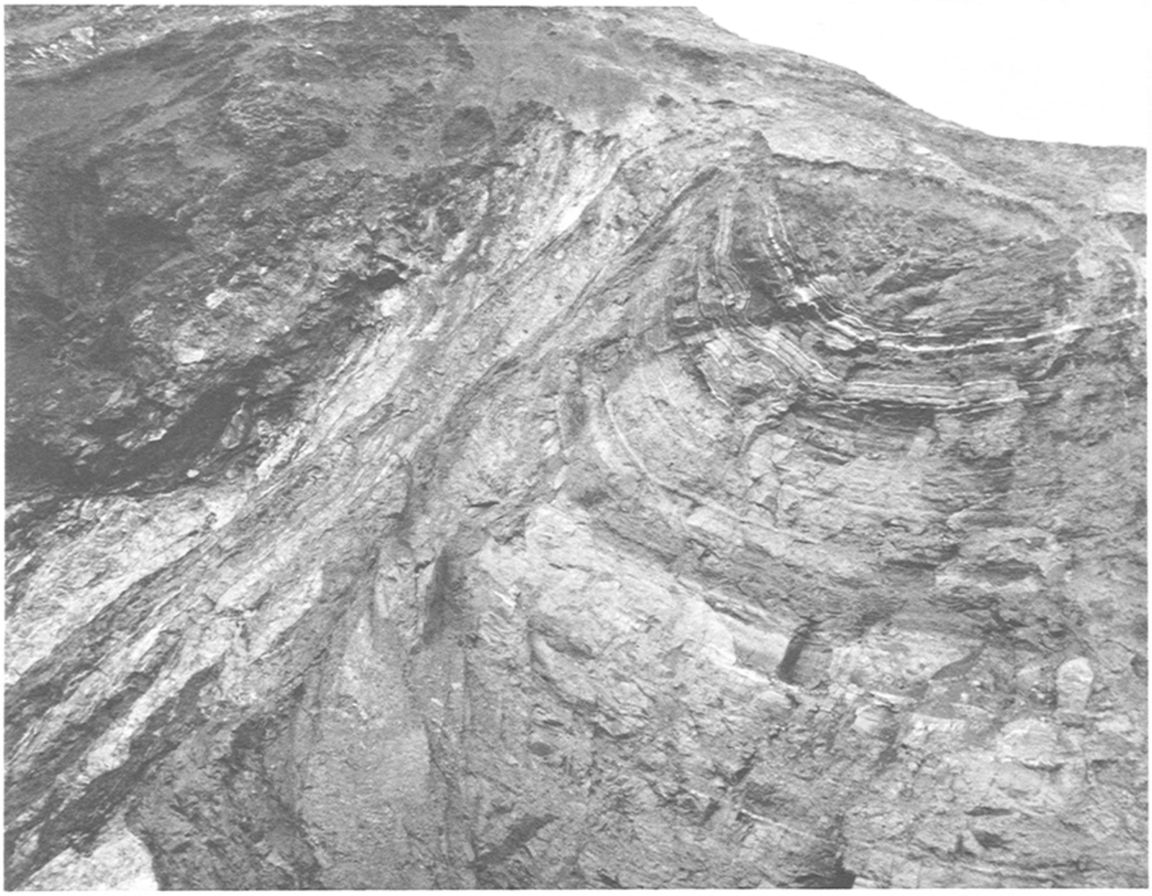

Figure 25.4. *Part of the Lake Hazen fault zone east of the southern end of Piper Pass. The fault plane dips northwards at 60°. Grant Land Formation in the hanging wall is faulted against Permian sandstones (Trold Fiord Formation).*

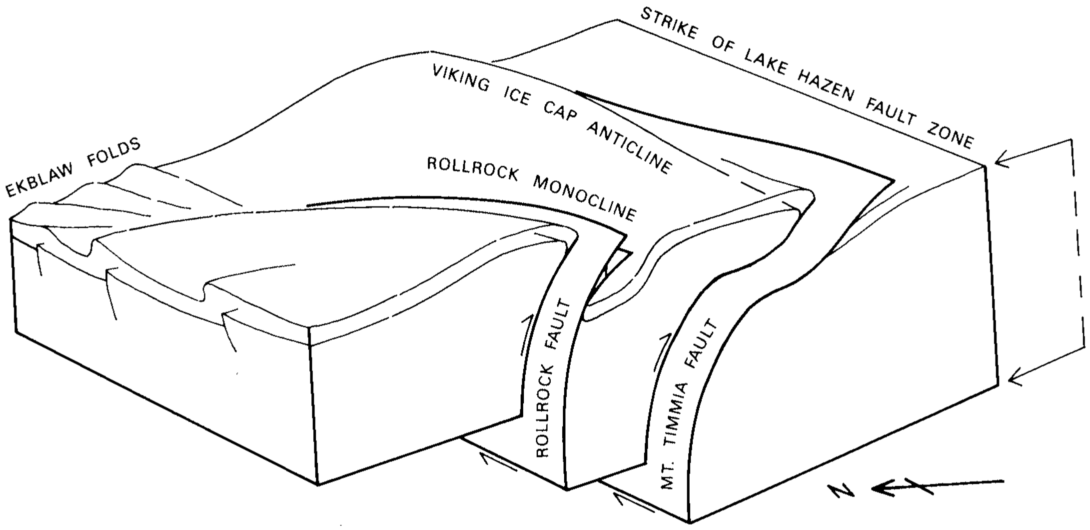

Figure 25.5. Schematic block diagram showing the geometry of the Rollrock and Mount Timmia faults, associated folds, and inferred displacements, according to a transpresssional upthrust interpretation. The Viking Ice Cap anticline and Rollrock monocline are regarded as 'roll-over' structures associated with displacement on the Mount Timmia staircase fault plane.

Substantial dip-slip displacement, in the order of tens of kilometres, is implicit in Osadetz' thin-skinned interpretation of the Lake Hazen fault zone, whereas an upthrust model can accommodate displacements of a few kilometres only. Two lines of evidence indicate that displacements are small. The whole of the fault zone is composed of en echelon dislocations (Fig. 25.1), which die out laterally and do not form a continuously interconnected network. The manner in which the faults terminate is not easy to discern when both the hanging wall and footwall are in lower Paleozoic strata. When in Sverdrup Basin cover the faults are seen to lose stratigraphic separation and pass into folds, as described above for the Mount Thompson and Rollrock faults. Displacement is transferred in this manner from one fault to the next, and clearly only a few kilometres of displacement can be so accommodated. Secondly, a simple bed-length comparison across the Rollrock and Mount Timmia faults and their associated folds indicates basement shortening of 7-8 km along a 34 km cross-strike section. The profile on which this construction is based (the front face of Fig. 25.5) lacks adequate topographic control, and there are problems connected with balancing sections across tectonic zones which involve both upthrust displacements and strike-slip, but it is clear that it is not necessary to invoke large dip-slip displacements to explain the structures.

The en echelon pattern of the individual dislocations which make up the fault zone in the Tanquary Fiord – Ekblaw Lake area suggests that a component of dextral strike-slip accompanied the upthrust displacements. Notably, the trace of the Rollrock fault curves northwards as the displacement dies out, as described above. Stratal shortening across the zone of monoclines and open folds into which the fault passes at Ekblaw Lake (Fig. 25.1) is a little more than one kilometre, indicating that a strike-slip component is present, but not great.

A model which involves basement upthrusts controlled by tectonic transpression, as developed for example by Sylvester and Smith (1976) for part of the San Andreas fault zone, can account for the observed structures and inferred displacements on the Lake Hazen fault zone in the area studied (Fig. 25.5), although in our case the displacements are relatively small. We envisage that southeast facing drape monoclines developed in the cover sequence above the upthrusts and that their steep limbs were subsequently disrupted and locally inverted by continued displacement on the reverse faults, together with footwall imbrication. The essentially monoclinal nature of the Lake Hazen fault zone seems to persist along the southern frontal scarp of the Grantland Mountains, at least as far as Piper Pass, with a thin veneer of steeply inclined cover sediments resting unconformably on the lower Paleozoic rocks and passing southeast into the Lake Hazen syncline (cf. Miall, 1979).

More detailed analysis of these structures must await preparation of a suitable topographic base map for the Rollrock Lake and Ekblaw Lake areas, which is currently in hand.

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