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Large lateral ramps in the Eocene Valkyr shear zone: extensional ductile faulting controlled by plutonism in southern British Columbia: Discussion

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INTRODUCTION

Simony and Carr (1997) give an excellent description of the three-dimensional geometry and the development of the Valkyr shear zone, British Columbia. There are two aims of this discussion. First, to suggest that the Valkyr extensional shear zone, as described by Simony and Carr (1997), is compatible with recent descriptions of the geometry and development of oversteps along normal fault zones. The second aim is to suggest that the common usage of interpretations from thrust systems to describe extensional faults, as carried out by both Gibbs (1984) and by Simony and Carr (1997), can be misleading.

LATERAL RAMPS AND RELAY RAMPS

Simony and Carr (1997) describe the Eocene Valkyr shear zone as being a down-to-the-east extensional shear zone, which defines the outer limit of the Valhalla core complex. It has a width of ≈500 m, a maximum displacement of 15–20 km, formed with a low-angle of dip, and has a 2.5 km high south-facing lateral ramp. A *lateral ramp* is defined by Butler (1982) as a ramp that strikes parallel to the transport direction, characterised by dominantly strike-slip deformation. Simony and Carr (1997, fig. 7) show the lateral ramp as having been formed by the linkage of two overstepping segments of the shear zone which were originally unconnected. The position of the overstep and the subsequent ramp was controlled by Middle Jurassic and Palaeocene to Eocene plutons.

A *relay ramp* is an area of reorientation, e.g. of bedding, between two normal faults which overstep in map view and which dip in the same direction. Larsen (1988) states that relay ramps occur between listric faults, Peacock and Sanderson (1991, 1994) suggest they can also form along unconnected planar faults, while Huggins *et al.* (1995) show the faults can branch upwards from a single fault. Relay ramps are often breached by faults which connect the overstepping fault segments, eventually forming a single fault with an along-strike bend (e.g. Peacock and Sanderson, 1994, fig. 10). Previously described relay ramps are within brittle normal fault systems and within sedimentary rocks. There seems no geometric or rheological reason, however, why structures with similar geometries cannot form lower in the crust, between extensional shear zones and within metamorphic rocks.

THE USE OF THRUST AND NORMAL FAULT TERMINOLOGY TO INTERPRET NORMAL FAULTS

Simony and Carr (1997, p. 769) comment on the direct comparison between normal and thrust faults made by Gibbs (1984), and suggest that the lateral ramp along the Valkyr extensional shear zone is analogous to a lateral ramp along a thrust. Such an analogue may be misleading, as it may be possible to reinterpret the Valkyr shear zone as being a lower-crustal breached relay ramp. Such a model is illustrated in Fig. 1. The two originally isolated segments of the Valkyr shear zone were connected to form the "lateral ramp" (Simony and Carr, 1997, fig. 7) in a similar way to the breaching of a relay ramp to form an along-strike bend within a normal fault zone (Peacock and Sanderson, 1994, fig. 3). Simony and Carr (1997, fig. 6) show that the regional foliation strike is approximately N–S, with the foliation having an average WNW-strike around the ramp. This variation in strike may have been

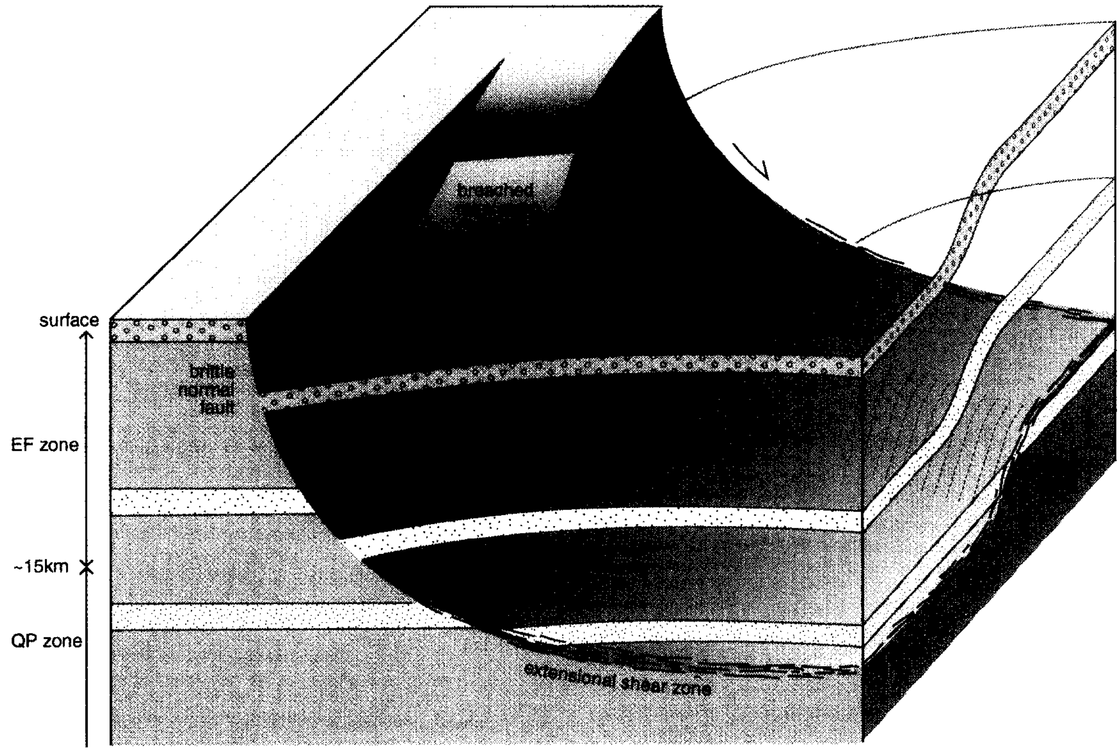

Fig. 1. Block diagram of a model for a *lateral ramp* along an extensional shear zone, involving a relay ramp at higher crustal levels. A *relay ramp* is an area of reorientation between two normal faults which overstep in map view and which dip in the same direction (Larsen, 1988; Peacock and Sanderson, 1991, fig. 9; Peacock and Sanderson, 1994, fig. 1). Such a model may be applicable to the Valkyr shear zone, which is described by Simony and Carr (1997). The lateral ramp visible in strike-section would correspond with the Arrow Lake and Murphy Creek ramps (Simony and Carr, 1997, figs 5 and 7). The 'brittle–ductile' transition occurs at the boundary between faulting (EF) and quasi-plastic (QP) zones (Sibson, 1989), at depths of ≈ 15 km.

caused by rotation of the foliation within a relay ramp (cf. Peacock and Sanderson, 1991, fig. 9).

The interpretation illustrated in Fig. 1 is a three-dimensional equivalent of the link between lower-crustal shear zones and upper-crustal brittle faults described by Ramsay (1980). This interpretation of the Valkyr shear zone also suggests that segmentation is as important for shear zones as it is for brittle normal faults.

Although relay ramps have been described from normal fault systems (e.g. Larsen, 1988), and similar structures have been described from strike-slip fault zones (Peacock and Sanderson, 1995), there have been no detailed descriptions of analogous structures at oversteps along thrust faults in map view. It may, therefore, be more productive to interpret the geometries of extensional shear zones using modern interpretations of normal fault systems, which are based on detailed field observations (e.g. Peacock and Sanderson, 1991) and on three-dimensional seismic data (e.g. Huggins *et al.*, 1995), rather than use thrust terminology.

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