Bull Volcanol (1999) 60:489–507

ORIGINAL PAPER

C. J. Hickson · J. K. Russell · M. V. Stasiuk

Volcanology of the 2350 B.P. Eruption of Mount Meager Volcanic Complex, British Columbia, Canada: implications for Hazards from Eruptions in Topographically Complex Terrain[1]

Received: 20 January 1998 / Accepted: 29 September 1998

Abstract The Pebble Creek Formation (previously known as the Bridge River Assemblage) comprises the eruptive products of a 2350 calendar year B.P. eruption of the Mount Meager volcanic complex and two rock avalanche deposits. Volcanic rocks of the Pebble Creek Formation are the youngest known volcanic rocks of this complex. They are dacitic in composition and contain phenocrysts of plagioclase, orthopyroxene, amphibole, biotite and minor oxides in a glassy groundmass. The eruption was episodic, and the formation comprises fallout pumice (Bridge River tephra), pyroclastic flows, lahars and a lava flow. It also includes a unique form of welded block and ash breccia derived from collapsing fronts of the lava flow. This Merapi-type breccia dammed the Lillooet River. Collapse of the dam triggered a flood that flowed down the Lillooet Valley. The flood had an estimated total volume of 10^9 m^3 and inundated the Lillooet Valley to a depth of at least 30 m above the paleo-valley floor 5.5 km downstream of the blockage. Rock avalanches comprising mainly blocks of Plinth Assemblage volcanic rocks (an older formation making up part of the Mount Meager volcanic complex) underlie and overlie the primary volcanic units of the Formation. Both rock avalanches are unrelated to the 2350 B.P. eruption, although the post-eruption avalanche may have its origins in the over-steepened slopes created by the explosive phase of the eruption. Much of the stratigraphic complexity evident in the Pebble Creek Formation results from deposition in a narrow, steep-sided mountain valley containing a major river.

Key words Mount Meager · Volcanic stratigraphy · Pyroclastic flow · Lahar · Avalanche · Petrography · Geochemistry

Introduction

Overview and purpose

The Mount Meager complex is the site of the most recent major explosive volcanic activity in British Columbia (Hickson 1994). This activity produced a diverse sequence of volcanic deposits, well exposed in the bluffs along the Lillooet River (Fig. 1), that are herein defined as the Pebble Creek Formation. The primary volcanic deposits are dacitic in composition and include dissected remnants of fallout pumice, pyroclastic flows, welded breccias, flood deposits (lahars) and a lava flow. The eruption was so energetic that thin, very fine-grained, distal deposits of tephra have been identified in Alberta, 530 km from the vent (Nasmith et al. 1967; Westgate and Dreimanis 1967). An unusual, thick apron of welded vitrophyric breccia may represent the explosive collapse of an early lava dome or lava flow front (e.g., Francis et al. 1974; Bardintzeff 1984; Nakada 1993).

This paper describes the physical aspects of these deposits: their distribution, relationships, nature and hazards. We summarize and review pertinent field, petrographic and chemical data (Nasmith et al. 1967; Anderson 1975; Read 1977a, b; Stasiuk and Russell 1989, 1990; Evans 1992; Ke 1992; Stasiuk et al. 1996), reconstruct the sequence of events that produced these volcanic deposits, and explain several enigmatic, if not unique, pyroclastic deposits. This complex volcanic assemblage provides an excellent example of the hazards resulting from cyclic deposition of Merapi-type deposits

[1] Geological Survey of Canada Contribution Number 1997224

Editorial responsibility: D. A. Swanson

C. J. Hickson (✉)
Geological Survey of Canada, #101–605 Robson Street, Vancouver, British Columbia, V6B 5J3
E-mail: chickson@gsc.nrcan.gc.ca, Fax: (604) 666-7507

J. K. Russell
Department of Geological Sciences, University of British Columbia, 6339 Stores Road, Vancouver, B. C. V6T 1Z4

M. V. Stasiuk
Department of Geology, University of Lancaster, Great Britain

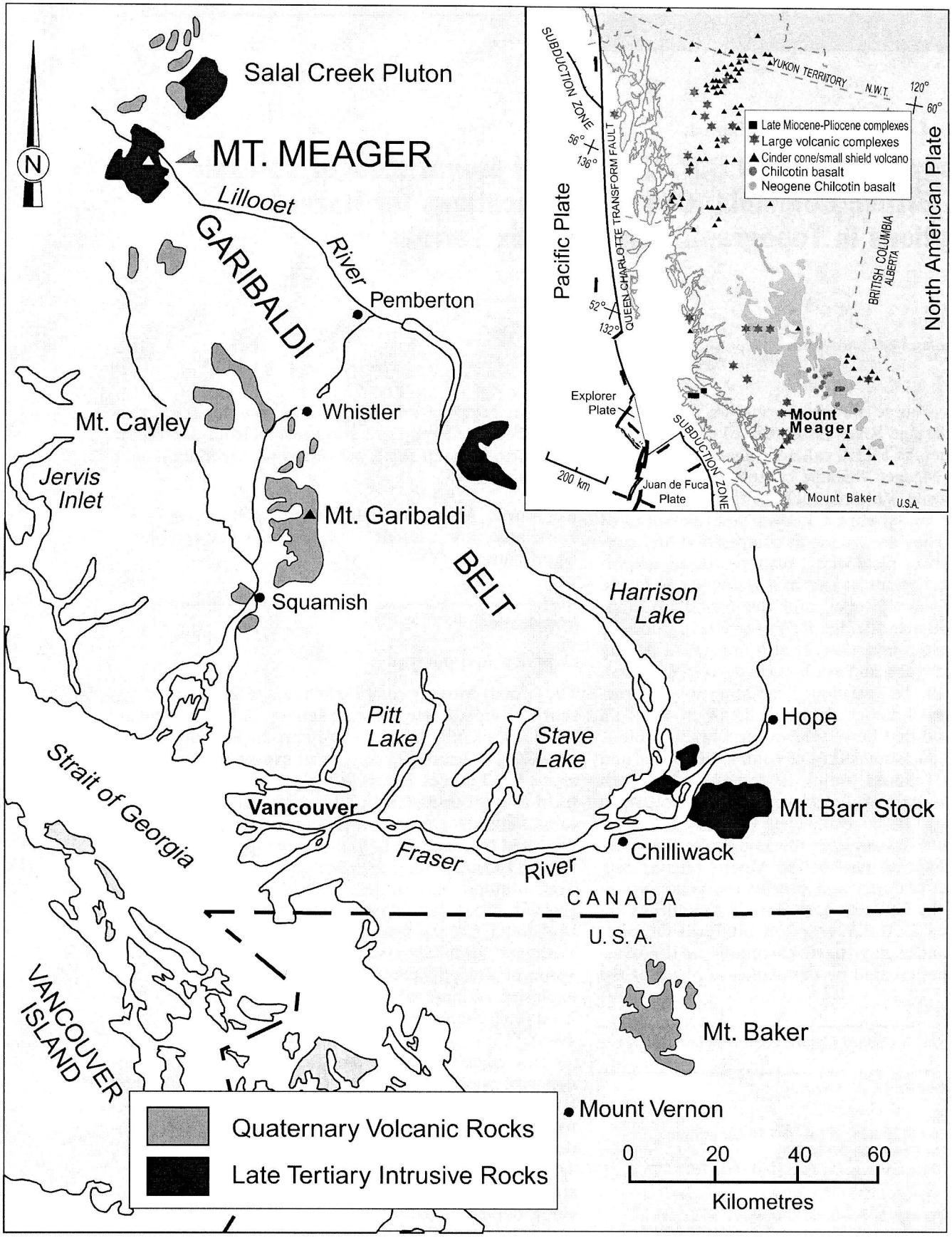


Fig. 1 Location of Mount Meager volcanic complex and the Garibaldi volcanic belt. Inset map shows Quaternary volcanoes in the Canadian Cordillera and adjacent areas of the United States (modified from Hickson 1994)

in rugged mountain valleys. Our work demonstrates that volcanic activity at Mount Meager blocked the Lillooet River, setting the stage for catastrophic failure of the upper part of the formation and resulted in an massive outburst flood.

Geological background

The Mount Meager complex is part of the Garibaldi volcanic belt (Fig. 1), the northernmost segment of the Cascade magmatic arc (Green et al. 1988; Guffanti and Weaver 1988; Read 1990; Sherrod and Smith 1990; Hickson 1994), which includes Mount Baker and Glacier Peak in Washington. Quaternary volcanism along the Cascade magmatic arc is related to subduction of the Juan de Fuca plate beneath North America (Fig. 1 inset; Green et al. 1988; Rohr et al. 1996).

The Mount Meager volcanic complex (2645 m asl) is 150 km north of Vancouver in the southern Coast Mountains, between the Lillooet River and Meager Creek (Fig. 2). The Quaternary volcanic complex overlies a basement of plutonic and metamorphic rocks. As originally mapped by Read (1977a, b), the Mount Meager volcanic complex includes peripheral coeval basaltic lava flows and pyroclastic deposits, central overlapping piles of andesite lava flows, dacite domes and flows, and pyroclastic units (Fig. 2). Read (1977a, b) subdivided the complex into a number of assemblages: the Devastator; Pylon; Job; Capricorn; Plinth; Mosaic; and the Bridge River Assemblage. Read (1977a, b) demonstrated that the most recent phase of volcanic activity was the eruption and deposition of the Bridge River Assemblage. The "Bridge River" designation was based on correlation with ash beds first described near Bridge River, British Columbia, and referred to as Bridge River tephra (e.g., Drysdale 1916; Stevenson 1947; Nasmith et al. 1967; Westgate and Dreimanis 1967). We have renamed this unit of postglacial volcanic deposits as the Pebble Creek Formation due to the prior usage of the term Bridge River Complex (Gabrielse and Yorath 1991) for Paleozoic rocks north of the volcanic complex.

Radiometric ages on volcanic rocks of the Mount Meager volcanic complex range from 2.2 Ma (K-Ar) to 2350 B.P. (radiocarbon) (Read 1977a, b; Evans 1992). The most recent dating by Clague et al. (1995) and Leonard (1995) indicates that the youngest eruption is about 2350 calendar years old. The vent for the most recent eruption is no longer exposed but was located by Read (1977a, b) on the amphitheatre-like northeastern shoulder of Plinth Peak at an elevation of about 1500 m, 1000 m above the floor of the Lillooet Valley (Fig. 3).

Petrographic characteristics

The vent of the 2350 B.P. eruption is in a col surrounded by steep cliffs comprising units of the Plinth

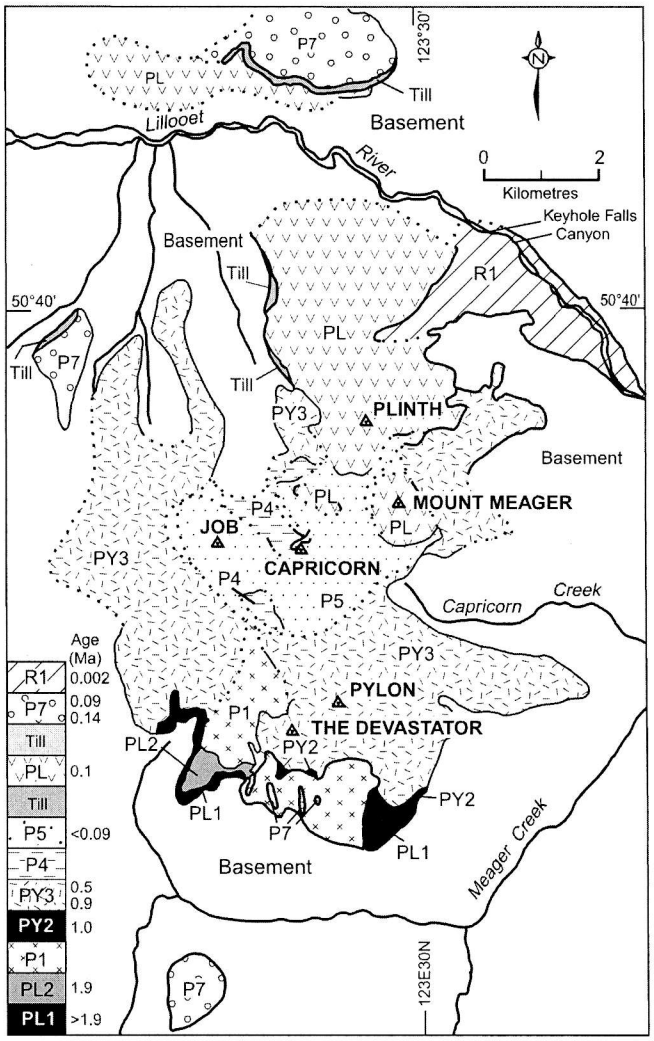
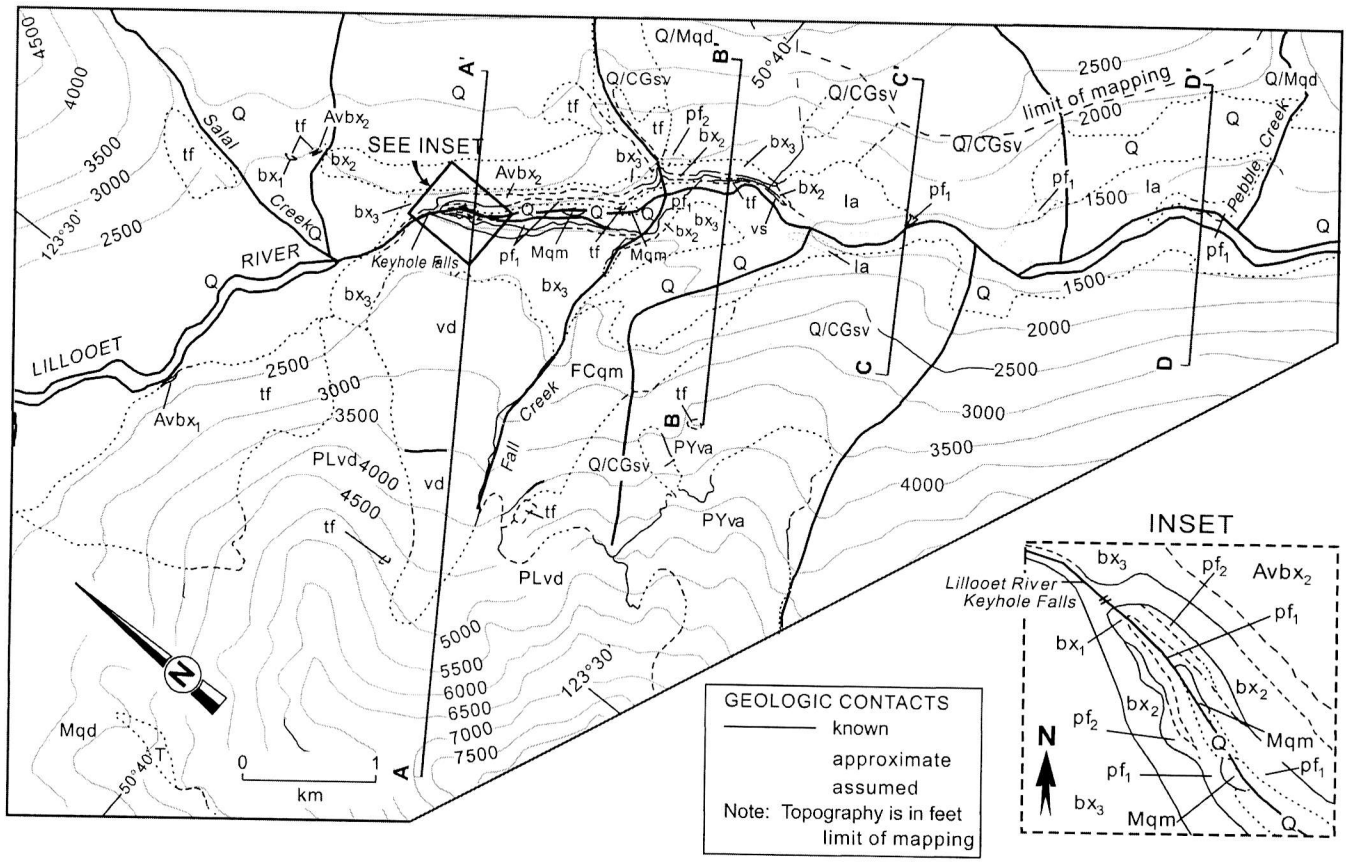


Fig. 2 Geological map showing the distribution and age of volcanic rocks of the Mount Meager volcanic complex (Read 1977b; modified from Read 1990): *PL1,* basal breccia; *PL2,* porphyritic dacite; *P1,* The Devastator Assemblage; *PY2* and *PY3,* Pylon Assemblage; *P4,* Job Assemblage; *P5,* Capricorn Assemblage; *PL,* Plinth Assemblage; *P7,* Mosaic Assemblage; *R1,* dacitic deposits of the Pebble Creek Formation

Assemblage (Plvd) (Fig. 2 unit PL; Fig. 3, unit Plvd; Read 1977a, b; Evans 1992). Although volcanic rocks of the Plinth and Pebble Creek Formations have a number of mineralogical and chemical similarities, they can be distinguished petrographically (Table 1). These petrologic differences are critical to sorting out the source and origin of some of the stratigraphic units.

In outcrop, rocks of the Plinth Assemblage are massive, dense, light to dark grey, and commonly red weathering. In thin section, the rocks are highly porphyritic; plagioclase dominates the phenocryst assemblage, but biotite and quartz are also abundant, and amphibole and clinopyroxene are also present. The groundmass is fine-grained, hyalocrystalline and microvesicular. Locally, the groundmass can be partly devitrified. The crystalline portion of the groundmass comprises crystals of plagioclase, amphibole, pyroxene and



QUATERNARY

Holocene

Q — Colluvium, alluvium, fluvial deposits

Pebble Creek Formation (PCF)

$Avbx_2$ — Plinth Avalanche deposits: Monolithologic poorly sorted, lithic breccia blocks, unconsolidated

vd — Vitrophyric, locally highly vesicular, porphyritic (plagioclase, orthopyroxene, amphibole and biotite) dacite

la — Very poorly sorted, unconsolidated, polymictic debris flow deposit containing characteristic prismatically jointed welded breccia blocks (either bx_1 or bx_2)

bx_3 — Reddish-grey, partially lithified, monolithologic, crudely bedded, matrix to clast supported breccia

bx_2 — Welded vitrophyric block and ash flow, variably welded, rare granitic clasts, unconsolidated basal breccia of lithic blocks

vs — Discontinuous, poorly sorted, crudely bedded, polymictic debris flow, subangular PCF blocks dominate; 20% subangular to subrounded granitic clasts

pf_2 — Pyroclastic flow unit; laterally discontinuous; subrounded to breadcrust-textured pumice blocks in fine-grained ash matrix; reverse grading of pumice, normal grading of lithic clasts, no charred wood

bx_1 — Welded vitrophyric block and ash flow; less intensely welded than bx_2

pf_1 — Pyroclastic flow unit; laterally continuous; subrounded breadcrust-textured pumice blocks in fine-grained ash matrix; reverse grading of pumice, normal grading of lithic clasts, abundant charred wood

tf — Fallout tephra unit: well sorted grey-buff pumice lapilli and blocks; accessory pinkish-grey welded ignimbrite, accidental sparse granite and Plinth Assemblage clasts, rare rounded granite clasts; upper portions substantially reworked;

$Avbx_1$ — Avalanche deposit, monolithologic Plinth Peak assemblage rocks; soil horizon developed on upper surface

Pleistocene

Plinth Assemblage

PLvd — Light to dark grey, porphyritic (plagioclase, quartz, biotite) dacite flows, breccia and ash

T — Till

PYva — Porphyritic (plagioclase + pyroxene) andesite flows, breccia and ash

TERTIARY

Miocene

Fall Creek Stock

FCqm — Biotite quartz monzonite, leucoquartz monzonite; alaskite

MESOZOIC

Cretaceous and/or Jurassic

Q/Mqm — Biotite, quartz monzonit limited outcrop

Q/Mqd — Biotite, quartz diorite; limited outcrop

Triassic (?)

Cadwallader Group

Q/CGsv — Greenstone, volcanic breccia, grey phyllite; minor greywacke; limited outcrop

Fig. 3 Geological map showing areal distribution of Pebble Creek Formation including: a) fallout pumice deposits and reworked equivalents (unit *tf*), b) pyroclastic flow deposits (units $pf_{1\&2}$), c) "Merapi-type" welded block and ash deposit (units $bx_{1,2\&3}$), d) lava flow (unit *vd*), e) hot, jointed, block flood deposits (unit *la*), and f) Plinth-dominated rock avalanche deposits (units $Avbx_{p1\&2}$) (modified from Stasiuk et al. 1996 and Read 1977b). Locations of cross-sections shown in Fig. 7 are indicated. Contours in feet: 1 foot = 0.3048 m