Geological Survey of Canada

CURRENT RESEARCH
2003-A5

Preliminary drilling results from the Pemberton Valley, British Columbia

K.A. Simpson, M.V. Stasiuk, J.J. Clague, S.G. Evans, and P. Friele

2003

Natural Resources Canada
Ressources naturelles Canada

Canada

CURRENT RESEARCH

ISSN 1701-4387
Catalogue No. M44-2003/A5E-IN
ISBN 0-662-33300-4

A copy of this publication is also available for reference by depository libraries across Canada through access to the Depository Services Program's website at http://dsp-psd.pwgsc.gc.ca

A free digital download of this publication is available from the Geological Survey of Canada Bookstore web site:

http://gsc.nrcan.gc.ca/bookstore/

Click on Free Download.

Authors' addresses

K.A. Simpson (ksimpson@nrcan.gc.ca)
Geological Survey of Canada
605 Robson Street, Suite 101
Vancouver, British Columbia V6B 5J3

M.V. Stasiuk (lstasiuk@nrcan.gc.ca)
Geological Survey of Canada
3303 - 33rd Street North West
Calgary, Alberta T2L 2A7

J.J. Clague (jclague@sfu.ca)
Dept. of Earth Sciences
Simon Fraser University
8888 University Drive
Burnaby, British Columbia V5A 1S6

S.G. Evans (evans@nrcan.gc.ca)
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

P. Friele (dupuis@mntn.net)
Ascaphus Consulting, Box 612
Squamish, British Columbia V0N 3G0

Publication approved by GSC Pacific, Vancouver

Preliminary drilling results from the Pemberton Valley, British Columbia

K.A. Simpson, M.V. Stasiuk, J.J. Clague, S.G. Evans, and P. Friele

Simpson, K.A., Stasiuk, M.V., Clague, J.J., Evans, S.G., and Friele, P., 2003: Preliminary drilling results from the Pemberton Valley, British Columbia; Geological Survey of Canada, Current Research 2003-A5, 6 p.

Abstract: The Mount Meager volcanic complex experiences frequent landslides and is a potentially active volcano that last erupted 2350 years ago. The combination of loose, altered volcanic material and steep topography is thought to be responsible for the significant landslide hazard. Sediments obtained from drilling in the Pemberton Valley record both landslide events and volcanic eruptions from the Mount Meager volcanic complex over the past 6500 years. Three major debris-flow deposits were identified, ranging from 0.6 to 8 m in thickness. Two of the debris-flow deposits were dated at approximately 2600 and 6200 years ago. The third debris-flow deposit is inferred to be approximately 4000 years old. The remainder of the drill-core sediments record typical meandering-river-valley sedimentation. Long-term sedimentation rates for the Pemberton Valley range from 1 to 7 mm per year. This paper is intended as an update for the Pemberton Valley landowners, rather than as a detailed scientific communication.

Résumé : Le complexe volcanique de Mount Meager, un volcan potentiellement actif dont la dernière éruption remonte à 2 350 ans, est le lieu de fréquents glissements de terrain. On croit que c'est la présence d'accumulations meubles de matériaux volcaniques altérés combinée à une topographie abrupte qui sont responsables du risque important de glissement de terrain. Les sédiments prélevés lors de travaux de forage dans la vallée Pemberton rendent compte à la fois de glissements de terrain et d'éruptions volcaniques survenus au cours des 6 500 dernières années dans le complexe volcanique de Mount Meager. Trois principaux dépôts de coulée de débris d'une épaisseur variant de 0,6 à 8 m ont été identifiés. Deux de ces dépôts de coulée de débris remontent à environ 2 600 et 6 200 ans. On suppose que le troisième dépôt de coulée de débris date d'environ 4 000 ans. Les autres sédiments obtenus par carottage témoignent d'une sédimentation typique de vallée fluviale sinueuse. Les taux de sédimentation à long terme dans la vallée Pemberton varient entre 1 et 7 mm par année. Le présent document se veut une mise à jour destinée aux propriétaires fonciers de la vallée Pemberton, plutôt qu'une communication scientifique détaillée.

INTRODUCTION

This article summarizes the results of a recent drilling program in the Pemberton Valley. It is intentionally brief, as it is an update for Pemberton Valley landowners, local government officials, and other interested members of the public, and is not intended to serve the technical and scientific community. Complete scientific results of this study will be presented in a technical journal publication at a later date. This report illustrates to the scientific community the type of information provided as an update to local communities during this type of research project in an effort to keep them informed and engaged.

In 2002, the Geological Survey of Canada initiated a multidisciplinary research project in the Mount Meager/Pemberton area. This project aims to identify, assess and compile the landslide and volcanic hazards of the Mount Meager volcanic complex. The complex is a potentially active volcano that last erupted ~2350 years ago (Clague et al., 1995; Leonard, 1995) and has one of the highest frequencies of landslides in Canada. The landslide activity makes the complex a natural laboratory where research results can lead to reduced landslide risk in other parts of Canada. The results will also help people in the Pemberton area to make informed decisions concerning land-use planning in the coming decades.

A drilling program was undertaken in March 2002 in an effort to understand the geological history of the Pemberton Valley over the past 6000 years. The program aimed to identify the extent of large debris-flow/flood events associated either with past volcanic eruptions or with landslides from the Mount Meager volcanic complex. Understanding these past events aids in determining the potential debris-flow hazard in the Pemberton Valley, should future eruptions or large landslides take place.

VOLCANIC ERUPTIONS AND LANDSLIDES

The Mount Meager volcanic complex is a potentially active volcano. Although there have been no eruptions in historic time from the complex, we know from other volcanoes that during an eruption, the melting of snow and ice can result in the formation of bouldery mudflows or debris flows. Erupted deposits may also dam river valleys. During the last eruption of Mount Meager, 2350 years ago, volcanic material filled the Lillooet River valley to a height of 100 m, impounding a temporary lake upstream of this natural dam (Hickson et al., 1999). The dam eventually failed catastrophically, releasing a huge volume of water and debris into the Lillooet River and flooding the valley downstream. The vestige of the dam remains where the Lillooet River flows over cliffs of young volcanic rock at Keyhole falls.

Volcanoes do not have to erupt to cause natural disasters. During eruptions, volcanoes produce abundant loose material that accumulates on steep slopes. This material can be easily moved downslope during times of heavy rainfall or intense snowmelt. In addition, hotsprings and fumaroles (gas vents) are common on volcanoes. These geothermal phenomena can alter or change the minerals in the rock, which can lead to further weakening of the slopes. Large landslides in the Mount Meager area occur at a frequency of three to eight years. Few areas of comparable size in Canada have this frequency of slope failure. The steep topography, coupled with the large volumes of loose, altered volcanic material, is thought to be responsible for the significant landslide hazard at Mount Meager.

A secondary hazard of landslides is that like erupted volcanic deposits, they can block river valleys, producing natural dams and forming temporary lakes that flood the valley floor upstream of the dam (Clague and Evans, 1994). Landslide dams are unstable and if the dam fails suddenly, the lake catastrophically drains in an outburst flood event. These floods can cause far-reaching destruction downstream.

The main goals of the drilling program were to recognize buried sedimentary deposits created by these sorts of catastrophic events, to determine their downstream effects, and to determine how often they have occurred in the recent geological past. This information can be used for predicting future events.

LILLOOET RIVER

River systems are continually changing in terms of the river's path, width, depth and the volume of water it carries. The lower part of the Lillooet River was a meandering-type river before dykes were built to control flooding. A meandering river has one main channel that migrates, or 'meanders', sideways across the valley as sediment fills in the main channel. Most of the time (under normal stream flow conditions), the river is confined to the main channel, sedimentation rates are fairly regular, and changes in the river system are relatively gradual.

During times of flooding, the river overflows its banks and flows out of the main channel onto the floodplain, depositing clay, silt and fine sand. Since floodplains may be free of water for years or decades, they are generally vegetated when floods happen, and plants become inundated with water and sediment.

In the event of a landslide or volcanic eruption, the river system can be disrupted when huge amounts of sediment are added to the system, essentially producing instantaneous debris flows. Debris flows travel at great speeds and can deposit several metres of sediment within minutes to hours. Debris-flow deposits are generally a poorly sorted mixture of sediment ranging from clay to large boulders. These are easily recognised in drill core. Trees and plants are also common in debris flow deposits. It can take years for a river system to re-establish itself after such a catastrophic event.

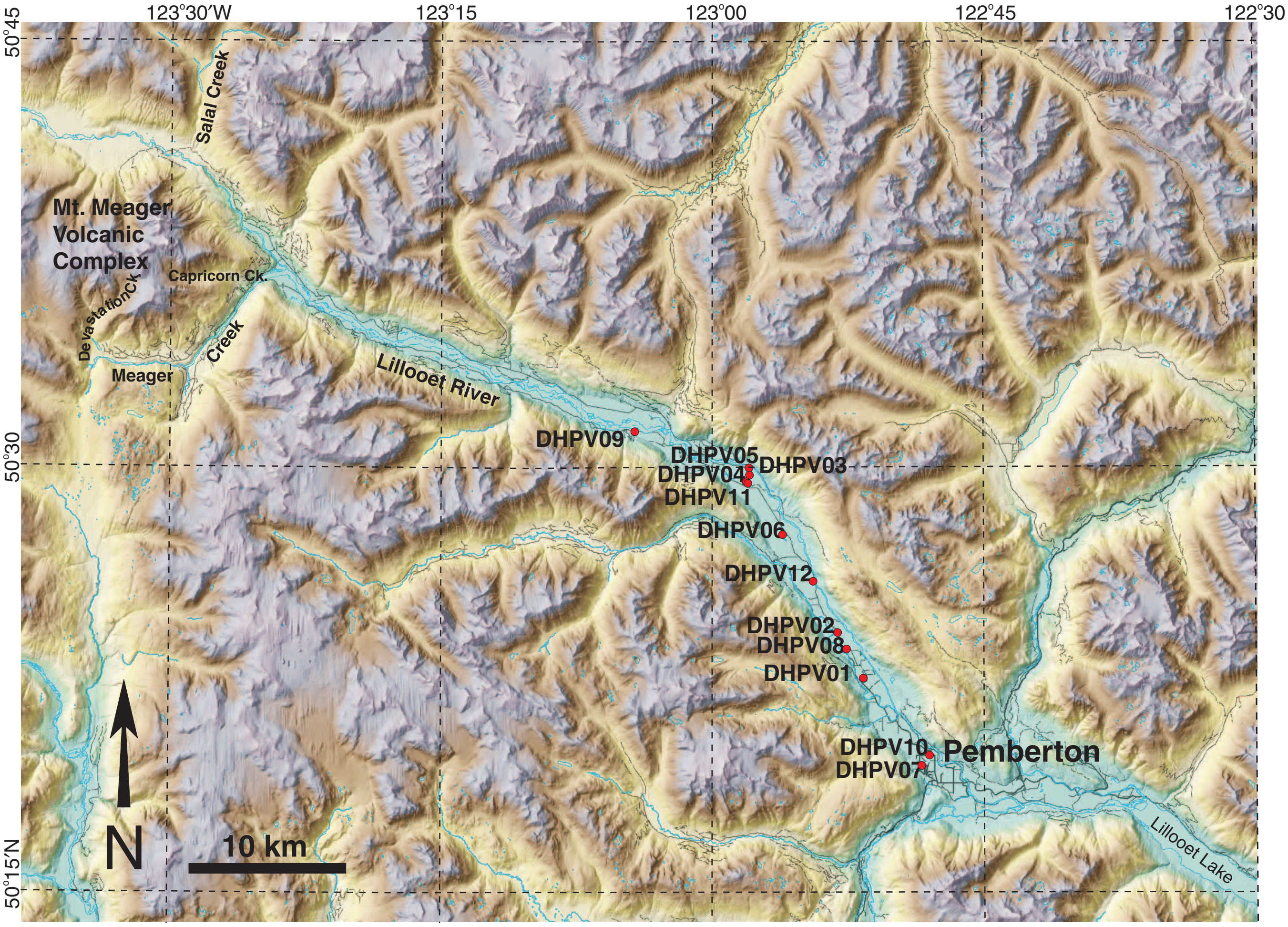

Figure 1. *Location of the 12 holes drilled in the Pemberton Valley.*

DRILLING PROGRAM

Twelve holes were drilled in the Pemberton Valley between March 14 and 29, 2002 (Fig. 1, 2). Holes ranged in depth from 10.95 to 38.71 m. One hundred and sixty samples were taken for further analyses. Drill core from all holes is being stored at the Geological Survey of Canada warehouse in Vancouver.

Drilling results

For each drillhole, a log similar to that shown in Figure 3 was produced. These logs help to illustrate the details of the drill core by presenting drillhole depth on the vertical axis and average grain size on the horizontal axis. Grain size increases (from left to right) from clay/silt (< 0.0625 mm) to sand (0.0625–2 mm) to gravel (>2 mm).

The example in Figure 3 is from the deepest drillhole, DHPV09. This hole contains all the different types of sediments that were seen in the 12 holes, although each hole is slightly different in detail. The main sediments found in the drillholes are the following:

1. Relatively well sorted (limited particle-size range) clay, silt and very fine sand — these sediments are generally deposited in low-energy environments and are interpreted to be either overbank deposits on floodplains or sediments deposited in abandoned river channels. Wood fragments, other plant tissue, and seeds are common.
2. Moderately to well sorted coarse sand, granules, and pebbles (gravel) – these sediments are deposited in moderate- to high-energy river channels.
3. Very poorly sorted deposits ranging from clay to cobbles — these sediments are deposited by flows of muddy, bouldery sediment and are interpreted to be debris flow deposits. Wood fragments and charcoal may be present in these deposits.

The sediments in the drill core record the typical changes seen in modern meandering river valleys. Coarse river gravel overlain by sand and then by clay and silt record the migration of the main river channel, decrease in water flow and eventually complete channel abandonment. Floodplain sediments

***Figure 2. A**) Drilling on Neil Vanloon's Farm (drillhole DHPV01;* see *Fig. 1). **B**) Extracting the core (drillhole DHPV11;* see *Fig. 1).*

(clay and silt) overlain by sand and then by coarse river gravel reflect the migration of the main channel into a floodplain environment.

Thick intervals of peat represent floodplains that were vegetated for long periods of time with no evidence for flooding. Intervals of laminated peat, clay, and silt represent floodplains that were inundated with floodwaters often and repeatedly over years. Plants were able to establish themselves between floods and likely died off after each flood event. Intervals of laminated clay and silt with no peat intervals may represent times when flooding was so frequent that plants were unable to establish themselves, or they may represent single large flood events.

A significant discovery in the drill core was the identification of three debris-flow deposits. These deposits may be the result of landslides from the slopes of the Mount Meager volcanic complex, or they could have formed directly from a volcanic eruption. As described previously, snow and ice melted during an eruption can mix with loose, often hot, volcanic material to produce debris flows. The debris flows can travel tens of kilometres from the source and can be extremely destructive. It is not yet known if the debris-flow deposits identified in the drill core resulted from a landslide or a volcanic eruption; however, work on this is ongoing.

The uppermost debris flow deposit was identified in seven drillholes and appears in places to be valley wide. It ranges from 2 to 4.4 m in thickness and was traced to a distance of at least 50 km from the Mount Meager volcanic complex. The thickness of the middle debris flow deposit is not known, due to poor core recovery. It is at least 0.6 m thick and was only found in hole DHPV09 (34 km downstream from the complex). The lowermost debris flow deposit is ~8 m thick and was also only found in hole DHPV09. It is likely that this unit was also valley wide, although this cannot be confirmed without further drilling.

Wood and peat can be dated using the carbon-14 method. The ages determined on these materials may be the same as those of the enclosing sediments. Average sedimentation rates can also be calculated in this way. Since organic material was only found in the floodplain deposits and the debris-flow deposits, these are the only units that were dated. The uppermost debris-flow deposit is ~2600 years old, and may be associated with the most recent volcanic eruption (~2350 years ago); however, more work is required to clarify this. The lowermost debris-flow deposit is ~6200 years old.

Average sedimentation rates in the Pemberton Valley over the last 6500 years range from 1 to 7 mm per year. These numbers can be a bit misleading since sedimentation in the valley occurs in a step-like fashion. For hundreds of years, there may be no sedimentation, but one flood or debris flow can deposit several millimetres to metres of sediment within a few days. For example, the 8 m thick debris-flow deposit was likely deposited within hours to days; thus the sedimentation rate for the year that the debris flow occurred would have been >8 m per year.

POST-DRILLING RESULTS

Work in the Mount Meager/Pemberton area has continued with field work undertaken in July, August, and September 2002. This work included mapping in the Mount Meager volcanic complex, installing a weather station, and installing a GPS (Global Positioning System) network. Landslides at the Mount Meager volcanic complex have historically taken place during times of prolonged hot weather (high snowmelt). Intense rainfall after prolonged hot weather may also increase the landslide hazard. The weather station will help to better monitor these climatic factors. The GPS network was installed on unstable slopes in an effort to monitor and predict future landslides. Periodic resurveying of the GPS stations can detect earth movements of as little as 3 mm. Geological mapping was done at high elevations, in the source basins of historic landslides, to identify the types of deposits that have failed in the past and to try and predict areas that are likely to fail in the future.

Figure 3. *Drill log for hole DHPV09. The vertical axis shows the depth of the hole below the surface, and the horizontal axis shows the average grain size of the sediment layers.*

An effort was also made to trace the debris-flow deposits identified in the drill core upvalley to the potential source. This work is ongoing and will likely continue in the summer of 2003. Analyses are also being done on the rock fragments in the debris-flow deposits to try and correlate them with specific source areas on the Mount Meager volcanic complex.

Installation of a seismic station was postponed but will hopefully happen in 2003. This installation will include satellite telemetry, which will transmit data from both the seismic station and the weather station to scientists as they are recorded.

FUTURE LANDSLIDES AND VOLCANIC ERUPTIONS

The landslide hazard at the Mount Meager volcanic complex is high. Landslides and associated debris flows pose a threat to visitors at the nearby Meager Creek hotsprings. In an effort to minimize the potential danger to visitors, the hotsprings are periodically closed during times of hot weather or heavy rainfall, when the hazard is the greatest. Debris flows associated with landslides are a hazard downstream of the Mount Meager volcanic complex in the Pemberton Valley. The extent of this hazard is being determined.

At the present time, there are no signs of renewed volcanic activity at the Mount Meager volcanic complex; however, it is a potentially active volcano. The first signs of volcanic activity are generally abundant shallow earthquakes, which may be accompanied by changes in the temperature, vigour, or location of hotsprings and fumaroles (gas vents). These signs of renewed volcanic activity generally occur well in advance of a potential eruption. The volcanic hazard at this time is low.

CONCLUSIONS

The main results of the drilling program are the quantification of sedimentation rates, determination of the sedimentary architecture and history of the valley, and the discovery of three major debris flows that originated from the Mount Meager volcanic complex. Two of the debris-flow deposits were dated at approximately 2600 and 6200 years ago. The third debris-flow deposit has not yet been dated, but is probably about 4000 years old. These events were obviously significant, and have occurred with a frequency that is relevant to development in the valley. As the work continues in the Pemberton area, the research group will provide further updates to the community.

ACKNOWLEDGMENTS

Funding for this research was provided by the Geological Survey of Canada. We would like to thank the Pemberton Valley landowners for allowing us to drill on their properties. Lionel Jackson provided a critical review of the manuscript, and Bev Vanlier is also thanked for her final edits.

REFERENCES

Clague, J.J. and Evans, S.G.
1994: Formation and failure of natural dams in the Canadian Cordillera; Geological Survey of Canada, Bulletin 464, 35 p.

Clague, J.J., Evans, S.G., Rampton, V.N., and Woodsworth, G.J.
1995: Improved age estimates for the White River and Bridge River tephras, western Canada; Canadian Journal of Earth Sciences, v. 32, p. 1172–1179.

Hickson, C.J., Russell, J.K., and Stasiuk, M.V.
1999: Volcanology of the 2350 BP eruption of Mount Meager volcanic complex, British Columbia, Canada: implications for hazards from eruptions in topographically complex terrain; Bulletin of Volcanology, v. 60, p. 489–507.

Leonard, E.M.
1995: A varve-based calibration of the Bridge River tephra fall; Canadian Journal of Earth Sciences, v. 32, p. 2098–2102.

Geological Survey of Canada Project NH2505