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The Rockslide -Debris Avalanche of the May 18, 1980, Eruption of Mount St. Helens — 10th Anniversary Perspectives

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Article abstract

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The Rockslide – Debris Avalanche of the May 18, 1980, Eruption of Mount St. Helens — 10th Anniversary Perspectives

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Summary

The massive rockslide-debris avalanche of the May 18, 1980, eruption of Mount St. Helens began with a retrogressive failure triggered by the 08:32 PDT earthquake. It depressurized the volcano's magmatic and hydrothermal system and produced a hummocky deposit with a volume of 2.5 km^3. Detailed work provides a comprehensive understanding of a previously poorly understood type of event.

The deposit consists of relatively intact pieces (block facies) of the pre-1980 mountain and mixed material (mixed facies) that is primarily rocks from the pre-1980 Mount St. Helens and the 1980 cryptodome. Travel paths of rockslide blocks are interpreted from a geologic map of the deposit. The material was fractured and dilated during the rockslide, after which grain-to-grain dispersive stress facilitated flow. During transport, the dilated material mixed but significant fine material was not produced.

Introduction

One of the most important events of the May 18, 1980, eruption of Mount St. Helens was the rockslide-debris avalanche. The rockslide was triggered by a M=5.1 earthquake at 08:32 PDT, which depressurized the volcano's magmatic and hydrothermal system, resulting in the lateral blast. Eyewitness photographs document that the rockslide began with detachment of at least three slide blocks which accelerated to a maximum of 70 $m \cdot s^{-1}$. The slide blocks broke up into smaller pieces to become a flowing debris avalanche, moving at an average rate of 35 $m \cdot s^{-1}$ (Voight, 1981; Voight *et al.*, 1983). The resulting hummocky deposit has a volume of 2.5 km^3 (Figure 1). The Mount St. Helens rockslide-debris avalanche is the largest known mass movement in historic times.

In the ten years since the eruption, detailed field, laboratory, and modelling work has provided a comprehensive understanding of a previously poorly-understood type of event. The work includes analyses of the eyewitness photographs (Voight, 1981), the stability of the pre-eruption mountain (Voight *et al.*, 1983), the geology and emplacement of the deposit (Glicken, 1986, in press-a), the stability of debris-avalanche dams formed by the deposit (Glicken *et al.*, 1989a; Glicken and Voight, In press; Meyer *et al.*, 1985; Meyer *et al.*, 1986) and microscopic characteristics of the deposit with implications for particle-particle interactions (Glicken *et al.*, 1989b). Results of the Mount St. Helens work continue to be applied to the study of volcanic debris avalanches, associated eruptions, and hazards around the world (*e.g.*, Boudon *et al.*, 1987; summarized in Siebert *et al.*, 1987).

Stability Model

A static mathematical model of the stability of the pre-eruption mountain indicates that the mountain was stable under reasonable assumptions of cohesion and water table conditions (Voight *et al.*, 1983). Reduction of cohesion, resulting primarily from intrusion of the March-May 1980 cryptodome and associated hydrothermal fluids, and dynamic loading resulting from the M=5.1 earthquake were required for failure.

Composition of the Deposit

To analyze the debris avalanche deposit, it is necessary to define terms rigorously (Glicken, in press-b). Two different kinds of particles compose the deposit: clasts, which are rocks that would not break if passed through a sieve or immersed in water (hard rocks), and debris-avalanche blocks, which are unconsolidated or semi-consolidated (relatively soft) pieces of the pre-1980 mountain transported relatively intact. The parts of the deposit composed of debris-avalanche blocks are called block facies; the parts of the deposit composed of a blended mix of rock types from the pre-1980 mountain, juvenile material (cryptodome) and, locally, material from the underlying terrain are called mixed facies (previously referred to as matrix facies; *e.g.*, Ui, 1983).

In debris-avalanche blocks (debris blocks for brevity), recognizable structures or stratigraphy preserved from the pre-eruption Mount St. Helens are locally present (Figure 2). However, the clasts within the debris blocks are shattered, so the deposit is finer grained than the comparable material of the pre-1980 mountain.

The eastern half of the deposit is composed almost entirely of block facies (Figures 1 and 4), while the western part consists of primarily mixed facies with some debris

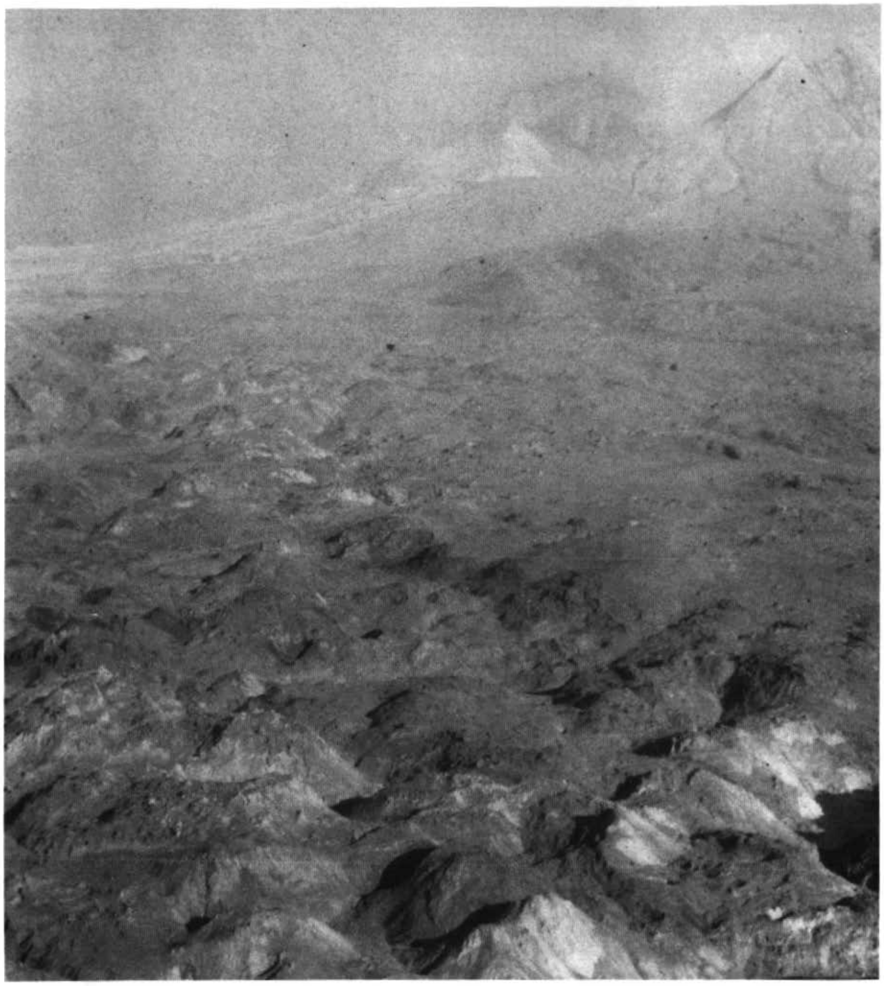

Figure 1 *Photograph of May 18, 1980, debris avalanche deposit, with Mount St. Helens in the background. Photograph taken summer 1980, before fluvial erosion. Note correlation of light and dark rocks of debris blocks in deposit with rocks of the crater wall.*

Figure 2 *Canyon of North Fork Toutle River in 1984, showing debris block with preserved, faulted, lava flow stratigraphy. Debris-avalanche deposit is covered by blast deposit. Canyon is 50 m deep.*

blocks (Figure 4). The block facies is divided into five lithologic units based on rock types of the pre-eruption Mount St. Helens. The juvenile material in the mixed facies indicates that the mixed facies was derived from the explosions of the cryptodome as well as from disaggregation and mixing of debris blocks.

Relationship of Slide Blocks to Debris Avalanche Deposit

The geologic cross-section of the pre-eruption mountain, with the slide blocks superimposed (Figure 3), together with the geologic map of the deposit (Figure 4) can be used to interpret the travel paths of the three slide blocks. Slide block I was a simple slide, triggered by the earthquake, and was deposited in Spirit Lake, on the ridge just north of the mountain, and flowed as a debris avalanche down the valley of the North Fork Toutle River. The exploding cryptodome burst through slide block II to produce the "blast surge" (Fisher *et al.*, 1987) that travelled faster than, and overtook, slide block I; the remainder of slide block II travelled down the valley, pushing slide block I into the margins of the valley. Slide block III failed as the cryptodome was still exploding. The continuing explosions disrupted large segments of the moving slide block, breaking it into debris blocks, and disaggregating debris blocks. Exploding fragments of juvenile dacite of the cryptodome mixed with the disaggregating blocks. Slide block III, therefore, consisted of a travelling mass of debris blocks engulfed by, and intermixed with, disaggregated, mixed material. The denser parts of slide block III were deposited as block facies in the eastern part of the North Fork Toutle River valley, while most of the disaggregated, mixed parts continued to flow westward to produce the bulk of the mixed facies of the western part of the deposit. The cryptodome continued to depressurize after slide block

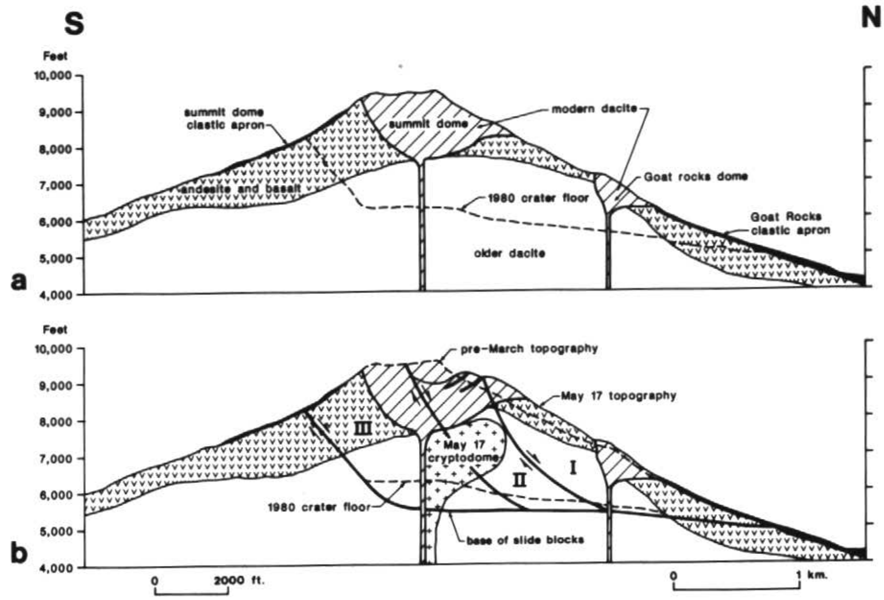

Figure 3 *N-S cross-section of Mount St. Helens just before eruption, showing slide blocks I, II, and III visible in eyewitness photographs. Geology of pre-1980 eruption mountain from C.A. Hopson, summarized in Glicken (1986, in press-a).*

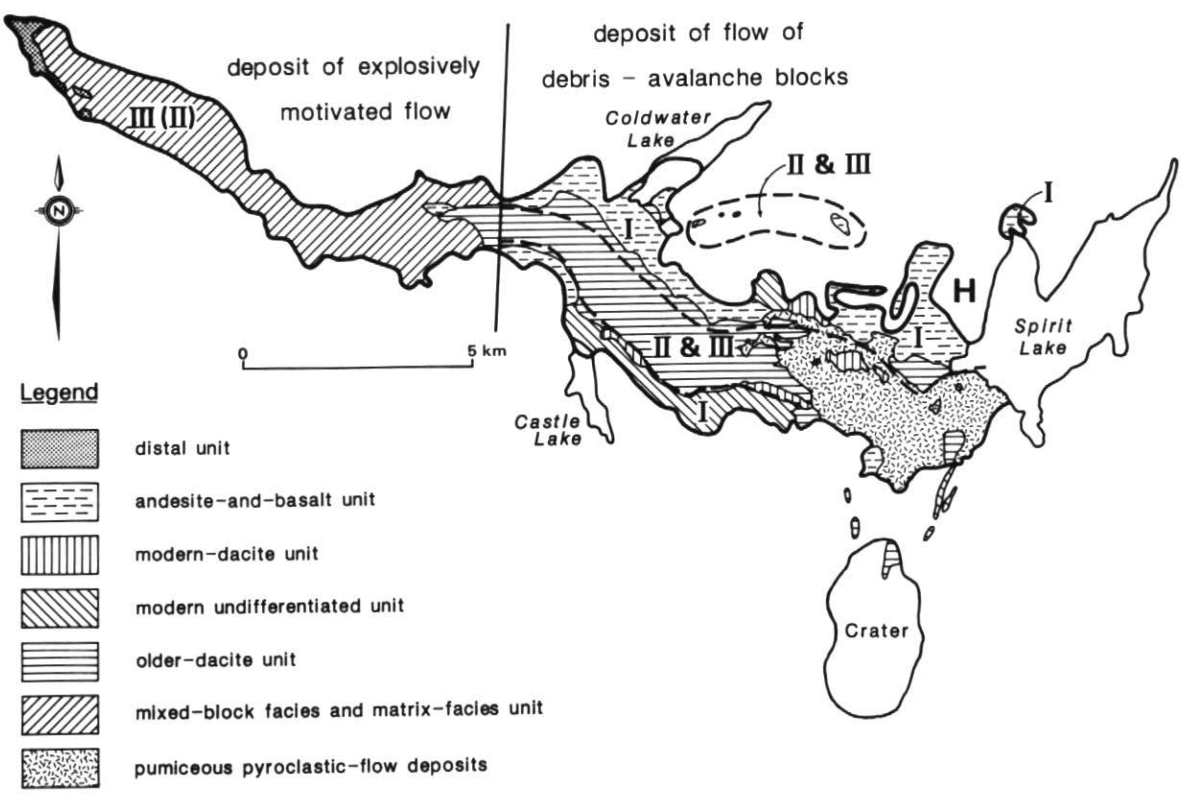

Figure 4 *Generalized map of debris avalanche deposit. Interpretations of resting places of slide blocks shown by roman numerals. III (II) indicates primarily slide block III with subordinate volume of slide block II. Generalized from 1:12,000 map of Glicken (1986).* ***H*** *stands for Harrys Ridge.*

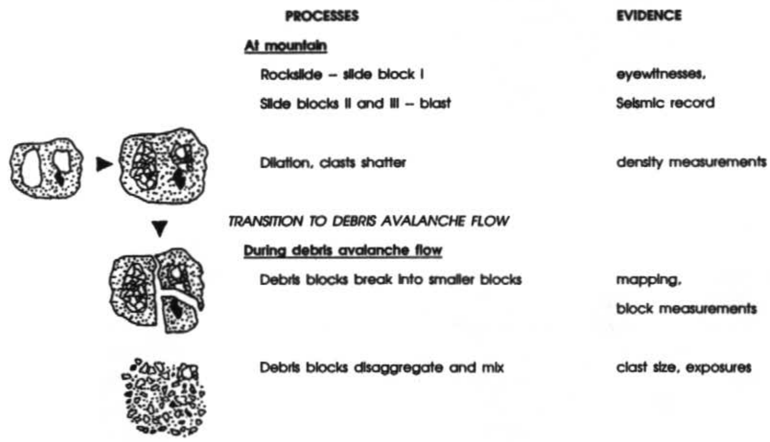

Figure 5 *Summary of sedimentary processes in rockslide-debris avalanche transport.*

III left the crater (minutes after 08:32 PDT), resulting in a juvenile dacite-rich pyroclastic flow deposit that rests on top of the debris-avalanche deposit as far as 20 km from the crater (Criswell, 1987). After deposition, major lahars were produced by dewatering of water-saturated parts of the debris-avalanche deposit.

Sedimentary Processes

Sedimentary processes of the rockslide-debris avalanche (how the material moved, broke up, and was deposited) are summarized in Figure 5. The mean density of the pre-1980 cone was determined by laboratory specific gravity measurements of individual clasts and in-place sand-cone density to be about 20% greater than the mean density of the avalanche deposit measured by the sand-cone density technique (Glicken, 1986, in press-a). The density of the deposit does not decrease with distance, suggesting that debris blocks were fractured and dilated at the mountain, rather than during transport.

Recent work (Komorowski *et al.*, in prep.) shows that waves of compression and rarefaction propagated from the base of the moving rockslide fractured and dilated the material. The material remained dilated because of grain-to-grain dispersive stress, which facilitated flow. The fracturing resulted in jigsaw cracks that are visible at the micron scale in SEM images (Glicken *et al.*, 1989b), but, unlike other debris avalanches, are rarely seen in exposures in the field. Various grain-size parameters show that during transport, the dilated material mixed together, but significant amounts of fine material were not produced.

Conclusions

Mount St. Helens provided a serendipitous confluence of pre-eruption studies, observations and photographs made during the early moments of sliding of the rockslide blocks, and an opportunity to recognize and analyze each specific component of the debris-avalanche deposit. Each has been vital in gaining an understanding of the mechanisms of failure, transport, and deposition of the immense rockslide-debris avalanche of May 18, 1980. The processes are more common at volcanoes than had been realized previously, and application of the work of Mount St. Helens contributes to improved assessments of hazards at volcanoes throughout the world.

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