Preservation of a Remobilized Scoria Cone Facies: North West Bay, NZ

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ABSTRACT: Exposed scoriaceous units along the shore platform of North West Bay, Banks Peninsula have been analyzed in detail, using physical descriptions and field photographs, to investigate how these deposits function in relation to a typical scoria cone facies. Photo interpretation of a headwall to the northeast of North West Bay deposits was useful for comparison and definition of different eruptive phases of the cone. Scoria cone deposits have been studied at other areas on Banks Peninsula, but deposits at North West Bay are unique because they display features of significant remobilization of material. Stratigraphic columns based on field data and observations were created at four locations along the shore platform of North West Bay in order to understand the processes behind scoria cone construction and subsequent degradation. The stratigraphic columns and overall well preservation of the deposits at North West Bay suggest a cone sector collapse due to a sudden violent eruption. Dip angle and direction of bedding packages at North West Bay, as well as the headwall to the northeast, suggest the vent of the cone is located to the northeast of the shore platform and southwest of the headwall. This cone is an expression of typical Akaroa volcanism, but displays significantly different facies distributions over the area.

INTRODUCTION

Previously unrecognized scoria deposits on the flank of Akaroa Volcano in North West Bay, Banks Peninsula are well exposed on the shore platform and headwall to the northeast (Fig. 1). The incredible preservation of these scoria deposits, which are surrounded and buried by younger lava flows originating from the Akaroa volcano, reflects the processes behind the growth of the scoria cone and subsequent degradation. The initial geometries of scoria cones are remarkably similar, and the expected proximal, medial, and distal facies becomes increasingly less dense and less welded with distance from the original vent (Fig. 2, Schmincke, 2004). During cone formation and subsequent degradation, various processes can shape a scoria cone’s morphology. Scoria cone degradation can remobilize and redeposit material, and ultimately change the post-eruptive morphometry of the cone. Syn- and post-eruption remobilization plays
an important role in the mass redistribution of material over very short periods, and syn-eruptive
collapse of a growing cone can cause unconformities in its deposits (Wood, 1980; Houghton and
Schminke, 1989; Hooper et al., 1998). Described scoria cone facies in the literature (Johnston et
al., 1997; Schminke, 2004) are helpful in comparing expected variations within facies to those
seen at North West Bay, and to determine if a remobilization event has occurred.

This study aims to gain a deeper understanding of the how the deposits at North West
Bay function in relation to typical scoria deposits, and what processes cause proximal and medial
welded facies to remobilize syn- or post-eruption. It is significant in understanding the
complexity and potential variations behind scoria cone growth and development, as well as
adding to previous knowledge of the entire Akaroa volcanic complex. This area is ideal for
studying the remobilization and degradation of scoria cone deposits because deposits here are
incredibly well preserved.

**GEOLOGIC SETTING**

Banks Peninsula formed primarily from Miocene-aged volcanism of two large intraplate
volcanoes – the Lyttelton Volcano (11.0-9.7 Ma) to the northwest and the Akaroa Volcano (9.3-8
Ma) to the southeast (Sewell, 1988; Ring and Hampton, 2012). The majority of Banks Peninsula
is comprised of the Akaroa Volcanic group with lava flows radiating around Akaroa Harbour
forming the bulk of the central/southeastern portion of the peninsula.

The Akaroa volcano contains a series of flank scoria cones that largely reflect previous
surface morphology and are therefore useful in understanding the eruptive history of these
extinct volcanic systems (Hampton and Cole, 2009). Extensive lateral dike injections of hawaiite
magma away from the central conduit resulted in the wide and numerous distributions of scoria
cones on Banks Peninsula. Although scoria cones have been analyzed throughout the entirety of
Banks Peninsula, the most comprehensive study to date was conducted by Johnston et al. (1997).
Authors defined four distinct lithofacies for scoria deposits on Banks Peninsula based on clast
size, shape, and degree of welding: (1) ash-rich deposits; (2) non-flattened scoria deposits; (3)
mixed scoria deposits; and (4) densely welded scoria deposits. Variations within and between
lithofacies suggest that there were distinct phases of Hawaiite-type fire fountaining (responsible
for the welded spatter deposits) as well as Strombolian eruptions (responsible for the non-
flattened scoria deposits) (Johnston et al., 1997).
METHODS

Fieldwork was conducted along the shore platform at North West Bay (Fig. 3), where the textural and physical properties of the scoria deposits were noted along the 4 primary faces. Data was collected using the iPad application GeoFieldbook (Malinconico et al., 2013) in addition to a traditional field notebook. Field methods included:

(1) Measuring and describing clast size and shape
(2) Determining the aspect ratios of bombs (flattened and non-flattened), welded material, and ash/lapilli
(3) Approximating layer thickness
(4) Taking strike and dip measurements where bedding was discernable
(5) Documenting the vertical and lateral facies variations at each of the four locations, as well as along the entire shore platform.

Four stratigraphic columns (Figs. 4-7) were created at the four distinct locations that were representative of both lateral and vertical change along the shore platform. Due to its inaccessible location, photo documentation was used as the primary data collection method for mapping the headland to the north of North West Bay. These photos were then used to categorize the various sections and their corresponding facies based on the visible trends and textures. Data collection through field mapping and photo analysis of this scoria cone made it possible to identify the distinct lithofacies present and to ultimately determine the erosional and degradational evolution of the scoria cone.

SCORIA CONE LITHOFACIES

Typical scoria cones have expected proximal, medial, and distal facies that usually only vary slightly. Scoria cone facies proposed by Schminke (2004) and Johnston et al. (1997) were used in comparing facies observed at North West Bay with classic scoria cone facies.

**Proximal Facies:** These facies consist of almost entirely densely welded material due to proximity to the vent. Spatter deposits and agglutinates are found here.

**Medial Facies:** These facies consist of nonflattened scoria deposits and mixed scoria deposits. The nonflattened deposits have bedded to massive clast-supported bombs. Mixed scoria deposits have flattened and nonflattened bombs in an ash/lapilli matrix. This facies is defined as having over 20% flattened bombs and no welded material.
**Distal Facies:** These facies consist of ash-rich deposits with lapilli and few isolated bombs. These deposits are usually bedded.

**RESULTS AND INTERPRETATION**

**North West Bay Stratigraphy**

Scoria deposits, lava flows, ash layers, and dike planes were observed on the shore platform. Four stratigraphic columns (Figs. 4-7) showed the lateral change working from southwest to northeast along the shore platform. Pie charts indicate the ratio of flattened bombs, nonflattened bombs, welded material, and ash/lapilli.

The stratigraphic column at Location 1 (Fig. 4) is at the south end of the shore platform and the most distal to the vent region. Overall, it fits into the mixed scoria deposit facies, but it also contained welded spatter fragments (Fig. 8A) as well as vesicular fuseform bombs. Bombs are in a purple-red fine ash to granule matrix. Bombs sizes here range from 17 cm to 70 cm in width. This location contains the highest proportion of flattened bombs out of all four locations on the shore platform (55% flattened bombs).

The stratigraphic column at Location 2 (Fig. 5) shows an equal proportion of flattened bombs, nonflattened bombs, welded material, and ash/lapilli. There was no dominant facies category that the deposit at this location fit into. A lava flow overtops the primary ash-supported unit. This 1 meter-thick ash-rich layer displays reverse grading (Fig. 8B) due to slope instability at the time of deposition that caused large clasts to roll over smaller clasts. A small dyke intersects the clast-supported unit under the ash-rich layer.

The stratigraphic column at Location 3 (Fig. 6) is a mixed scoria deposit with few spatter clasts (Fig. 8D), bedded welded scoria, and clast-supported horizons. Two large pyroxene crystals preserved in roughly in their original crystal habit (Fig. 8C), suggest that this material stayed together while moving downslope. There are four dark grey dyke planes intersecting the scoriaceous deposits at this location.

The stratigraphic column at Location 4 (Fig. 7) is the most proximal location to the vent. It contains approximately equal proportions of flattened bombs, nonflattened bombs, welded material, and ash/lapilli. A large welded scoria block (2 by 2 m) was observed in one clast-rich layer (Fig. 8E), and it fell between two aligned bedding packages indicating that this block may have slipped from upslope after other material was deposited.
Overall, these deposits exhibit many features that deviate from expected scoria cone deposits. Locations 1 and 4, the furthest and closest deposits from the original vent of the cone, display a high degree of welded material, while Location 2 has no welded material. If material were in its original depositional state, the highest amount of welded material would fall at Location 4 and there would be very little, if any, at other locations. With that being said, there would still not be a large amount of welded material at this location. Bedding orientations are consistent throughout the shore platform. Clasts were aligned in similar bedding packages at Locations 1, 2 and 4 (Fig. 9). While material was being remobilized downslope following cone instability, it was not reworked much allowing material to remain in consistent beds.

**Headwall**

The headwall to the northeast of the shore platform consists mostly of massive, vertically jointed lavas dipping southeast. Three distinct red ash layers can be traced throughout the headwall and suggest that there was more than one phase of eruption, which was not evident in North West Bay deposits. On the western portion of the headwall (Fig. 9A), there was a horizontal alignment of scoria deposits. Deposits towards the central portion of the headwall (Fig. 9B) are dominated by massive lava flows overlying scoriaceous deposits. The top of the eastern portion of the headwall contains a lava flow completely surrounded by scoriaceous material, which indicates these were both deposited during the same episode of eruption. Radially jointed portions near the top of the western portion of the headwall fall under a channel, which indicates that thinner Hawaite lava was flowing during the last eruptive phase.

A previous study of the headwall (Shirley, 2012) concluded that there were at least two phases of eruption of this cone and the vent of this cone must have been further out to sea because massive lava and scoria are uniformly distributed. It was also concluded that there were two source vents in the region, but I did not find evidence to support this in deposits at North West Bay. Based on the dips of deposits at the headwall and North West Bay (northeast and southwest, respectively), the inferred original vent is to the northeast of North West Bay and falls above the middle portion of the headwall (Fig. 11).
DISCUSSION

The scoria cone facies at North West Bay suggest that proximal and medial material was transported downslope to the base of the cone during the eruption due to a cone collapse. The headwall records deposits of an initial Strombolian eruption and a final Hawaiian eruption, while initial distal deposits at North West Bay were eroded to the sea. Strombolian-style eruptions produce coarse grained and vesicular pyroclasts and are associated with low magma flux rate. Hawaiian-style eruptions, on the other hand, are more violent and have a significantly higher magma flux rate and deposit coarser material. A change in eruption style from Strombolian to Hawaiian can cause lava to be emitted from the base of the cone (‘rafting’) and trigger a cone sector collapse (Nemeth et al., 2011). With such a violent burst, the cone becomes oversteepened and the slope angle becomes higher than the angle of repose aiding in this collapse (Sigurdsson, 2000; Valentine et al., 2005).

When the southwestern flank collapsed, material was removed from the vent and proceeded downslope to the North West Bay area. Due to the high preservation of material in this area, it is likely that the cone did not continue growing after this last eruptive phase. Even though scoria cones are said to have similar facies distributions, there have been many studies on other cones around the world that suggest scoria cone morphology is more complex than previously thought (Nemeth et al., 2011; Valentine et al., 2005; Riggs, 2008). Sector collapse of scoria cones is recognized as a common process, however the remobilized scoriaceous facies are not well preserved in cones.

CONCLUSION

Scoria deposits at North West Bay exhibit physical characteristics of proximal and medial facies at a distal location on the cone. A collapse in the southwestern flank of this scoria cone caused proximal and medial material to be remobilized downslope while preserving original bedding orientations. In contrast, deposits on the headwall were preserved over multiple eruptive phases. Additional research is necessary to further define the mechanisms behind a syn-eruptive cone sector collapse and to determine if this process is preserved at any other scoria deposits on Banks Peninsula.
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REFERENCES


APPENDIX OF FIGURES

**Figure 1:** Location map of entire research area.

![Location map of entire research area](image)

Top right: Banks Peninsula, NZ, with field area highlighted

Left: Field analysis at North West Bay (A, see figure 2), and photo analysis at headwall (B, see figure 4)

**Figure 2:** Model of typical scoria cone with defining locations of proximal, medial, and distal facies (Schminke, 2004).

![Model of typical scoria cone with defining locations](image)

**Figure 3:** Field analysis of North West Bay deposits. Stratigraphic logs created at each of the four locations shown.

![Field analysis of North West Bay deposits](image)
Figure 4: Stratigraphic log and material ratios of Location 1.

Figure 5: Stratigraphic log and material ratios of Location 2.
Figure 6: Stratigraphic log and material ratios of Location 3.

Figure 7: Stratigraphic log and material ratios of Location 4.
Figure 8: Features indicating remobilized beds; (A) welded spatter fragment at Location 1; (B) inversely graded bed at Location 2; (C) matrix with large pyroxene crystals at Location 3; (D) spatter clast at Location 3; (E) large welded scoria block within clast-rich layer at Location 4.
Figure 9: Clast alignment within bedding packages at Locations 1, 2, and 4. Beds dip to the southwest.
Figure 10: Photo analysis of the headwall. (A) shows the horizontally layered scoria of the western portion of the headwall. (B) defines the massive lava flow and underlying scoriaceous deposits of the central portion, and (C) is a close-up of the vertically jointed lava.

Figure 11: Inferred vent region of original cone (top photo) and extension of proximal, medial, and distal locations. (Bottom) cross section of scoria cone progression of facies.