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Volcanic Facies and Eruption Styles in the Cretaceous Buffalo Head Hills Kimberlites, Alberta, Canada

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Introduction

From 1997 to 2003, thirty-eight kimberlites were discovered in the Buffalo Head Hills (BHH) area by a joint venture consisting of Ashton Mining of Canada, Alberta Energy Corporation (now Encana), and Pure Gold Minerals (Figure 1). These discoveries were made largely through geophysical interpretation of magnetic, electromagnetic, and gravity data, with most kimberlites under up to 127 meters of cover excepting at five localities (Skelton et al., 2003). The limited outcrop, coupled with the rapid rate of discovery and assessment rate led to a limited amount of drilling on some bodies, with much of the drill core consumed for diamond testing. However at the time of this study a selection of continuous drill core for six kimberlites – K6, K11, K252, K281, K296, and K300 was available. A geological assessment of these six kimberlites in core and thin section was undertaken to assess the mechanisms of kimberlite eruption and deposition in this region, as well as to document the uniquely preserved volcanic features of these bodies. Nearly 2,000 meters of core from 16 drill holes was directly examined, with drill logs for processed core also reviewed in the course of the study. From these data an idealized geological model for the BHH kimberlites has been fashioned, and some speculation on their eruptive process is put forth.

Volcanic Geology of BHH Kimberlites

Initial assessment of the BHH kimberlites identified their volcaniclastic nature (Carlson et al., 1999), but in detail a wide variety of volcaniclastic rocks are present. K6 drill core represents a crater to crater edge/extra crater environment, infilled mainly by pyroclastic fall, with discrete surge events. The pyroclastic fall is poorly sorted and massive with rare accretionary pyroclasts and bomb sags. The lack of pyroclast abrasion suggests a primary pyroclastic origin. The pyroclastic surge is better sorted, fine grained, and well bedded, with high angle bedding typical of surge deposition. The depletion of fines suggests elutriation in a volcanic column, supported by the presence of accretionary pyroclasts formed through the subaerial mixing of ash vapor and fluid.

Kimberlite 11 consists of intra-crater fill as pyroclastic fall, with material from earlier in the eruption being recycled in into subsequent eruptions. The earlier pyroclastic fall consists of fresh olivine phenocrysts

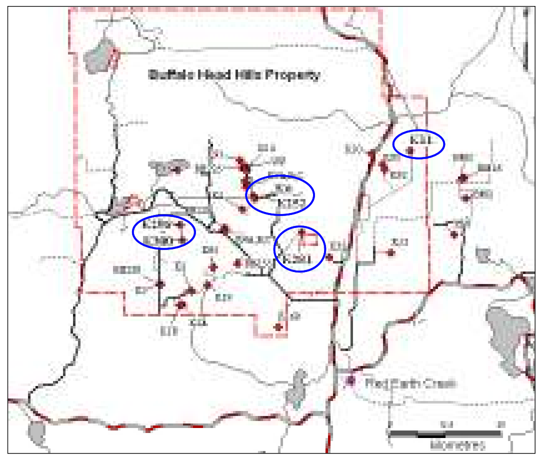

Figure 1: Location map for the Buffalo Head Hills kimberlites, with bodies of this study encircled in blue.

with fluidal single phase juvenile pyroclasts in a serpentine matrix. The later pyroclastic fall contains olivine altered to serpentine in a carbonate rich matrix that also contains multiphase, juvenile pyroclasts with ragged, broken margins, suggesting that this lithofacies has recorded multiple eruption events.

K252 is the most complex kimberlite, with multiple layers of pyroclastic and reworked kimberlite separated by intervals of concordant mudstone. The kimberlite layers represent discrete kimberlite depositional events, separated by deposition of marine muds in an extra-crater environment. Three lithofacies are present; reworked pyroclastic kimberlite, accretionary pyroclast rich kimberlite, and gradational accretionary pyroclast-rich to reworked kimberlite. The reworked kimberlite is well sorted, lacks juvenile and accretionary pyroclasts, and has distinct bedding with abraded olivine grains. The accretionary pyroclast rich fall deposits have a bimodal clast population with cm-sized accretionary pyroclasts, mm-sized olivine crystals and interstitial juvenile pyroclasts.

Kimberlite K281 consists of thick alternating pyroclastic fall and well-sorted pyroclastic surge deposits in an intra to extra crater environment. Spectacular accretionary pyroclasts indicate continued recirculation in an active volcanic column, with preservation of delicate rims on some clasts indicating an absence of resedimentation.

Within-crater deposition is also indicated for K296, dominated by pyroclastic fall, a crater rim sequence dominated by pyroclastic surge, and later infilling of the crater by reworked pyroclastic material likely derived from a tuff ring. Broken olivine grains and a general absence of any juvenile or accretionary pyroclasts characterize the reworked material. The surge lithofacies is normally graded, finely laminated and cross-bedded kimberlite, with fluidal juvenile pyroclasts and discrete olivine crystals forming alternating coarser and finer beds between foresets. The crater filling pyroclastic fall deposits is more massive and unsorted but with a similar clast population to the surge deposits.

Kimberlite K300 has a lithofacies consistent with deposition of basal pyroclastic fall, followed by surge deposits, and with reworked kimberlite at the top. The pyroclastic surge and fall have similar clast populations but with better sorting and bedding in the surge deposit. The reworked volcaniclastic kimberlite has no juvenile or accretionary pyroclasts, is very well sorted, and enriched in both olivine crystals and mantle garnet with respect to other deposits.

Geologic data collected from these six BHH kimberlites indicate individually different but collectively similar geometries and features, that allow for synthesis of an idealized single BHH kimberlite volcano. All of the kimberlites share a broadly similar eruptive style, with a crater and a surrounding tuff ring, as well as thin extra crater deposits. Pyroclastic fall and surge are the two volcanic depositional mechanisms, with hydraulic reworking of kimberlite from erosion of tephra cones and/or extra crater fall and surge deposits.

New geochronology demonstrates that two pulses of BHH kimberlite volcanism occurred at 88-81 Ma and 64-60 Ma, with early BHH magmatism confirmed in the present study by the K11 and K252 kimberlites dated at 84.8+/-0.9 and 81.3+/-2.3 Ma, respectively (Eccles et al., 2008). Early BHH magmatism was coeval with Turonian to Santonian marine mudstone deposition as indicated by palynological data (Sweet et al. in prep., cited in Eccles et al., 2008). The eruptive and depositional mechanisms recorded in the BHH kimberlites are generally similar to the Fort a la Corne (FalC) kimberlite province, located ~700 kilometers east-southeast in central Saskatchewan. Although the FalC kimberlite magmatism is older at 104-95 Ma (Heaman et al., 2004), pyroclastic, surge, and large volumes of extra crater kimberlite are interstratified with early Cretaceous (Albian) continental to shallow marine clastic deposits (Zonneveld et al., 2006).

The idealized BHH kimberlite is geometrically similar to a maar-style volcano, defined as a vertical-walled volcanic crater of explosive origin surrounded by a low rim of ejecta and filled with water. Maar volcanism is often associated with phreatomagmatism, in which ascending magmas explosively react with shallow groundwater or near-surface waters. Common

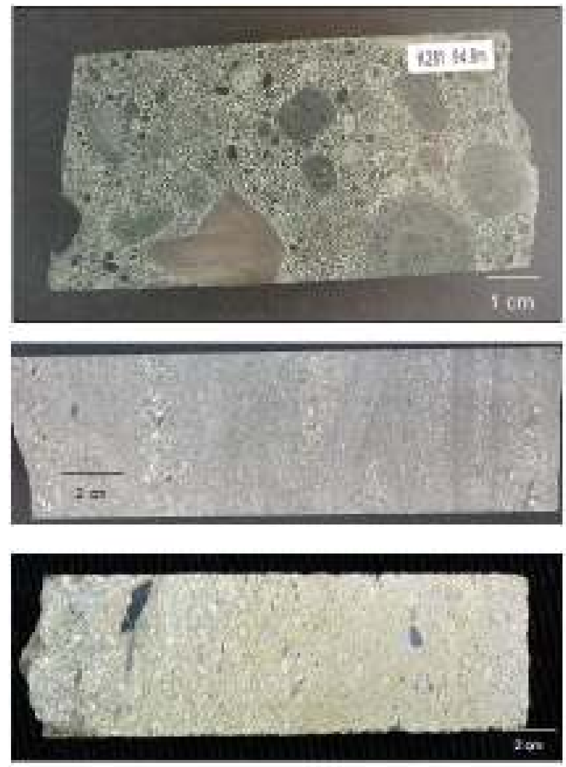

Figure 2: (top) Concentric accretionary pyroclast in pyroclastic fall from K281; (middle) coarse olivines between foresets in pyroclastic surge from K296; (bottom) well-sorted olivine in reworked volcaniclastic kimberlite from K300.

accretionary pyroclasts and surge deposits in the BHH kimberlites indicate that water played a major role in their eruption, but these observations alone cannot reconcile whether magmatic water or groundwater played the more important role. Considering the extremely high water contents inferred for kimberlite, it is inevitable that both sources were involved. Any model for kimberlite volcanism in the BHH region must consider and include both of these sources.

Conclusions

Geologic assessment of drill core and related data from select BHH kimberlites indicates that their eruptive and depositional processes are consistent with those observed for volcanoes in general. Classic examples of pyroclastic airfall and surge deposits are recognized in the BHH drill core. Accretionary pyroclasts are common and the fragmentation of these and olivine crystals records reworking of much of the initial ejecta.

BHH kimberlites of this study likely represent the waning end of an 88-81 Ma pulse of magmatism, although only two kimberlites in this study have been successfully dated. The kimberlites erupted contemporaneously with marine, near-shore deposits of the Cretaceous inland sea. Geometrically the BHH kimberlites resemble maar-type volcanoes, and it is likely that both magmatic and groundwater or near-surface waters contributed to the eruptive process.

References

Boyer, L.P. 2005. Kimberlite volcanic facies and eruption in the Buffalo Head Hills, Alberta. M.Sc. Thesis, Mineral Deposit Research Unit, University of British Columbia, Vancouver, B.C.

Carlson, S.M., Hillier, W.D., Hood, C.T., Pryde, R.P. and Skelton, D.N. 1999. The Buffalo Hills kimberlites: a newly discovered diamondiferous kimberlite province in north-central Alberta, Canada. Proc. 7th Int. Kimberlite Conf., Volume 1. pp. 109-116.

Eccles, D.R., Creaser, R.A., Heaman, L.M. and Ward, J. 2008. Rb-Sr and U-Pb geochronology and setting of the Buffalo Head Hills kimberlite field, northern Alberta. Canadian J. Earth Sci., in press.

Heaman, L.M., Kjarsgaard, B.A. and Creaser, R.A. 2004. The temporal evolution of North American kimberlites. Lithos, 76, 377-397.

Skelton, D., Clements, B., McCandless, T.E., Hood, C., Aulbach, S., Davies, R., and Boyer, L.P. 2003. The Buffalo Head Hills kimberlite province, Alberta. In Slave Province and North Alberta Field Trip Guidebook, B.A. Kjarsgaard, (Ed.), Geol. Surv. Canada Misc. Pub. G-293.

Zonneveld, J.P., Kjarsgaard, B.A., Harvey, S.E. and McNeil, D. 2006. Accomodation space and kimberlite edifice preservation: implications for volcanological models of Fort a la Corne kimberlites. Extended Abstract. 2006 Kimberlite Emplacement Workshop, Saskatoon, Saskatchewan, 3p.