



Kimberlite Volcanism on the Margin of the Lower Cretaceous Moosebar-Clearwater Seaway: Sedimentology and Volcanology of the Star Kimberlite

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Abstract

Numerous diamond-bearing kimberlites occur in the Fort à la Corne region of east-central Saskatchewan (Fig. 1). Kimberlite deposits from the Fort à la Corne area are exceptional in their completeness and include the first well-described examples of extensive extra-crater primary pyroclastic airfall kimberlite deposits (Kjarsgaard, 1995; Kjarsgaard et al., 1997, 2005; Leckie et al., 1997; Nixon and Leahy, 1997; Leahy, 1997; 2001; Zonneveld et al., 2002a,b; 2004). Many Fort à la Corne kimberlites consist primarily of extra-crater pyroclastic deposits, which are interstratified with Lower Cretaceous (Albian) strata (Fig. 2). Kimberlites occur interstratified with continental, marginal marine and shallow marine strata of the Mannville Group (Cantuar and Pense formations) and shallow to deep marine deposits of the Colorado Group (Joli Fou, Viking and Westgate Formations) (Leckie et al., 1997; Zonneveld et al., 2004).

Core drilling has been conducted on many Fort à la Corne kimberlites however most have been perforated by only a single core in an effort to quickly prioritize kimberlites with the greatest economic potential. The Star Kimberlite, which occurs at the southeastern end of the Fort à la Corne kimberlite trend (Fig. 1), is the focus of the present study. The Star kimberlite was discovered in 1996 by core drilling following aeromagnetic and ground magnetic surveys. Encouraging macro diamond results from large diameter (mini-bulk sample) drilling, and bulk sampling from underground drifts has resulted in rapid advancement of the Star project. Detailed logs of 40



historical (pre-2005) drill cores containing Cretaceous kimberlite and sedimentary rocks, coupled with new observations from the pre-feasibility core drilling and underground drifts have been integrated with whole rock major- and trace-element data and chrono-stratigraphic studies to develop comprehensive sedimentological and volcanological models for the Star kimberlite.

At least five distinct eruptive phases of kimberlite are recognized in the Star body. The oldest kimberlites at Star are widely dispersed, conformable subaerial pyroclastic kimberlite (PK) fall deposits interfingering with siliciclastic sediments of the Cantuar Formation (Fig. 2). A Cantuar feeder vent occurs in the south-central part of the Star kimberlite, and consists of coarse to very coarse-grained pyroclastic kimberlite containing common mantle xenoliths/xenocrysts. Reworked Cantuar kimberlite occurs at several horizons in both fluvial and estuarine successions. Kimberlite body geometry and the presence/thickness of extra-crater pyroclastic kimberlite in the Cantuar Formation is largely a function of fluctuations in fluvial base level and concomitant variation in available accommodation space.

Successive eruptive events occurred contemporaneous with deposition of the marginal marine upper Mannville Group (Pense Formation; Fig. 2). Pense-equivalent kimberlite occurs over a wide area in the northern, central and eastern parts of the Star kimberlite. Kimberlites within the Pense Formation consist primarily of subaerial and marine fall deposits and are characterized by a 10 – 20 m thick basal eruptive sequence of exceptionally coarse-grained PK with abundant mantle xenoliths/xenocrysts. Fine- to medium-grained cross-stratified kimberlitic (olivine dominated) sandstone in this interval reflects reworking of these airfall deposits during a regional marine transgression.

The youngest kimberlites at Star occur within the predominantly marine Lower Colorado Group (Joli Fou and Viking Formations; Fig. 2). Kimberlite beds, which occur at several horizons within these units, consist of subaerial and marine fall deposits, the latter commonly exhibiting evidence of wave reworking. Black shale-encased resedimented kimberlite beds, likely deposited as subaqueous debris flows and turbidites, are particularly common in the Lower Colorado Group (Fig. 3).

The volumetrically most significant eruptive phase of the Star kimberlite is the early Joli Fou equivalent age kimberlite, which is observed to overlie Pense kimberlite in a subset of drill holes. The early Joli Fou kimberlite is stratigraphically defined on the basis of vent distal drill holes in which this kimberlite conformably overlies lower Joli Fou Formation shale (Spinney Hill Member). Very thick (75 – 150 m) early Joli Fou pyroclastic airfall deposits are preserved due to the development of accommodation space in the sedimentary succession. This accommodation space developed as a result of: 1.) ring faults and half-grabens forming around the early Joli Fou feeder vent (Fig. 3), and; 2.) high energy, directed, base surge deposits eroding wide channels or tongues into the sedimentary substrate away from the feeder vent. The early Joli Fou eruptive phase culminated in the development of a positive relief tephra cone with a volcanic crater, into which limited volumes of early Joli Fou kimberlite was resedimented.

The final two eruptive phases of the Star kimberlite occur within the upper half of the Joli Fou Formation and are denoted as the mid Joli Fou equivalent and late Joli Fou equivalent kimberlites, respectively. The mid Joli Fou feeder vent is situated to the west of the early Joli Fou feeder vent (i.e. west of the Star kimberlite exploration shaft). Medium grained mid Joli Fou kimberlite is not aerially widespread, but primary volcanic and resedimented (mass flow) deposits are locally thick



(up to 75 m), where they in-fill the early Joli Fou crater. The primarily fine-grained, late Joli Fou kimberlite forms a thin (10 – 20 m thick) veneer, which covers most of the central and northern part of the Star kimberlite (Fig. 3). The location of the late Joli Fou feeder vent is unknown, but is inferred to be northwest of the Star kimberlite, based on bed thickness and geometry arguments.

Sediments of the Viking Formation cap the late Joli Fou kimberlite. Lags of kimberlite indicator minerals are common within glauconitic shoreface successions of the Viking Formation. As well, a laterally restricted, pyroclastic airfall kimberlite of Viking equivalent age, but of unknown source occurs on the northeastern part of the Star body.

The Star kimberlite experienced a complex history consisting of short intervals of violent volcanism punctuated by longer, volcanically quiescent intervals. Regional tectono-stratigraphic setting influenced both the eruptive processes that governed the nature of individual kimberlite volcanic events and post-eruptive kimberlite preservation. Sedimentologic, volcanologic and stratigraphic evidence indicate that the Star kimberlite evolved from a simple feeder vent with an associated shallow, asymmetric tuff ring into a positive-relief tephra cone. The shape of the volcanic edifice was strongly modified, initially by subaerial processes and subsequently by wave reworking during marine transgressions.

Preservation of extra-crater pyroclastic kimberlite at FALC is a function of available accommodation space, which is related to both volcanic style and local tectono-stratigraphic setting. Increased accommodation space in the study area resulted from both a regional marine transgression (i.e. expansion of the lower Cretaceous Moosebar-Clearwater Seaway) and concomitant encasement of kimberlite deposits in marine shale as well as volcanically induced faulting (including ring-faults and half grabens). Primary and reworked pyroclastic kimberlite in these deposits can be differentiated by a number of means including facies relationships, assessment of sedimentologic characteristics (grading, sorting, bedforms, etc...), petrographic characterization and geophysical techniques.

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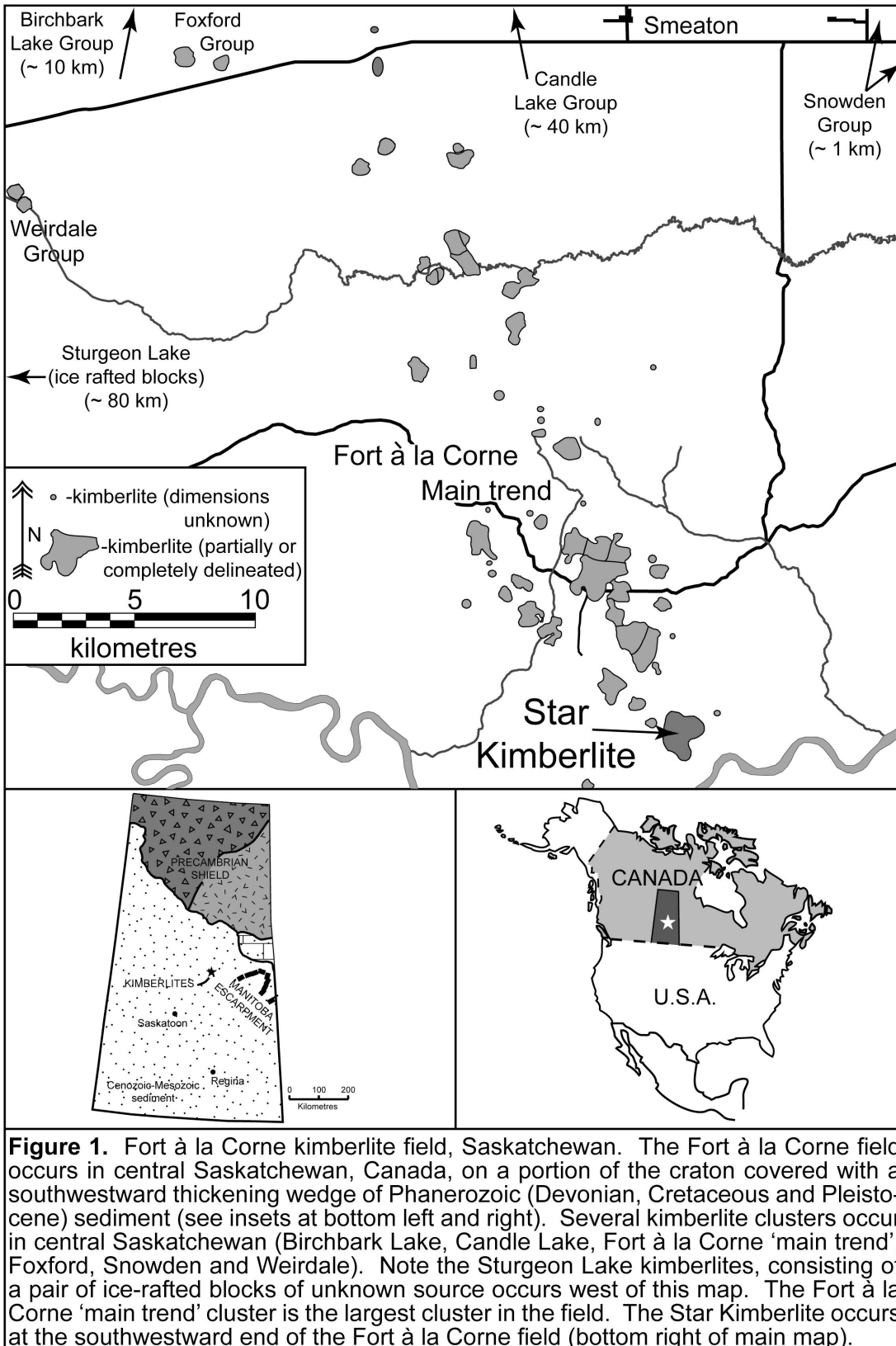


Figure 1. Fort à la Corne kimberlite field, Saskatchewan. The Fort à la Corne field occurs in central Saskatchewan, Canada, on a portion of the craton covered with a southwestward thickening wedge of Phanerozoic (Devonian, Cretaceous and Pleistocene) sediment (see insets at bottom left and right). Several kimberlite clusters occur in central Saskatchewan (Birchbark Lake, Candle Lake, Fort à la Corne 'main trend', Foxford, Snowden and Weirdale). Note the Sturgeon Lake kimberlites, consisting of a pair of ice-rafted blocks of unknown source occurs west of this map. The Fort à la Corne 'main trend' cluster is the largest cluster in the field. The Star Kimberlite occurs at the southwestward end of the Fort à la Corne field (bottom right of main map).

