EUB/AGS Geo-Note 2005-01

Early to Late Campanian Palynological Ages of Mudstone and Siltstone in the Sawn Lake Area, Southern Buffalo Head Hills, Alberta

Alberta Energy and Utilities Board
Alberta Geological Survey

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Abstract

Palynological results are reported for six mudstone samples cored during an Alberta Geological Survey (AGS) auger-drilling program near the K4 kimberlite complex in the Sawn Lake area of the southern Buffalo Head Hills. Ages for these core samples, collected over an east-west distance of four kilometres, range from Early to Late Campanian (83.5 to 71.3 millions of years ago). The Late Campanian assemblages are indicative of nonmarine fluvial-lacustrine, paralic and nearshore, restricted marine environments, whereas the Early Campanian assemblages reflect open marine conditions.

The Early Campanian ages are consistent with existing geological maps of the region that show the youngest rocks in the Buffalo Head Hills to be marine shales of the Smoky Group. However, the existence and distribution of sedimentary rocks with Late Campanian ages indicate a significant part of the uppermost southern Buffalo Head Hills is underlain by rocks correlative to the Wapiti Formation. This is consistent with the presence of numerous sandstone units within the Upper Campanian auger core sections and the palynological change to a nonmarine (fluvial-lacustrine) depositional environment.

The upper part of the K4 kimberlite complex occurs at a higher elevation than the Lower Campanian to Upper Campanian boundary. The occurrence of kimberlite within Upper Campanian sedimentary rocks suggests the possibility of kimberlitic volcanism during the Late Campanian (or later). However, published isotopic dates for four other kimberlites within the Buffalo Head Hills kimberlite field and the inferred age of the bedded volcaniclastic kimberlite north of the K4 complex are all pre-Campanian. An alternate interpretation is that the upper part of the K4 kimberlite complex represents the preserved portion of a volcanic summit formed by a pre-Campanian eruption that was subsequently buried, at least in part, by Early Campanian and Late Campanian sedimentation.

1 Introduction

The Alberta Geological Survey (AGS) drilled eleven auger-coreholes during 2002 to collect information about Quaternary stratigraphy in the southern Buffalo Head Hills within the Sawn Lake map area (NTS 84B/13; Figure 1). These auger holes were drilled within the Buffalo Head Hills kimberlite field, which contains a minimum of 38 kimberlites (Figure 2; Eccles et al., 2003; Skelton et al., 2003). Holes were cored to depths of 10 to 44 m and, in addition to Quaternary core, bedrock was recovered from seven of the auger holes drilled near the K4 kimberlite complex, which consists of kimberlites K4A, K4B and K4C (Figure 3). The purpose of this report is to release palynological ages obtained from the bedrock core and to discuss the geological significance of these data.

2 Methodology

A truck-mounted auger rig equipped with a hollow stem auger and a CME coring tube was used. The rig could drill to a maximum depth of 50 m. The core was logged in the field by AGS personnel (J. Pawlowicz and M. Fenton assisted by J. Weiss). Core samples for palynological study were collected at the AGS Mineral Core Research Facility in Edmonton. Palynological analysis was completed by G. Dolby of Calgary (Dolby, 2003). Locations of hole collars were determined using a single, hand-held GPS unit. Collar elevations were estimated by determining the elevations at each collar location from the 1:50 000 topographic map of the area (Energy, Mines and Resources Canada, 1989; Sawn Lake, 84B/13, Edition 2). A summary of the 2002 auger-core drilling is presented in Table 1.

Table 1. Summary of the 2002 auger-coring program

Auger Hole	East[1]	North[1]	NTS Map Area	Collar Elevation (masl)[2]	Depth (m)[3]	Bedrock Intersection
BHH02-01	577678	6301069	84B/13	768	25.3	yes
BHH02-02	577706	6300759	84B/13	758	11.6	yes
BHH02-03	577660	6301281	84B/13	779	11.6	yes
BHH02-04	576440	6301278	84B/13	758	11.9	no
BHH02-05	578377	6300975	84B/13	761	13.1	yes
BHH02-06	574761	6301658	84B/13	751	11.6	yes
BHH02-07	575047	6301929	84B/13	774	13.1	yes
BHH02-08	575284	6302188	84B/13	786	36	no
BHH02-09	575433	6301009	84B/13	738	16.2	yes
BHH02-10	566305	6309085	84B/13	781	23.8	no
BHH02-11	571286	6304213	84B/13	796	43.6	no

[1]NAD 83, UTM Zone 11
[2]metres above sea level
[3]metres below ground surface

3 Results

3.1 Palynological Analysis of Samples From the 2002 Auger-Coring Program

Results of the palynological analysis of samples from the 2002 auger-coring program are summarized in Table 2, and individual descriptions of the six samples are presented in Appendix 1

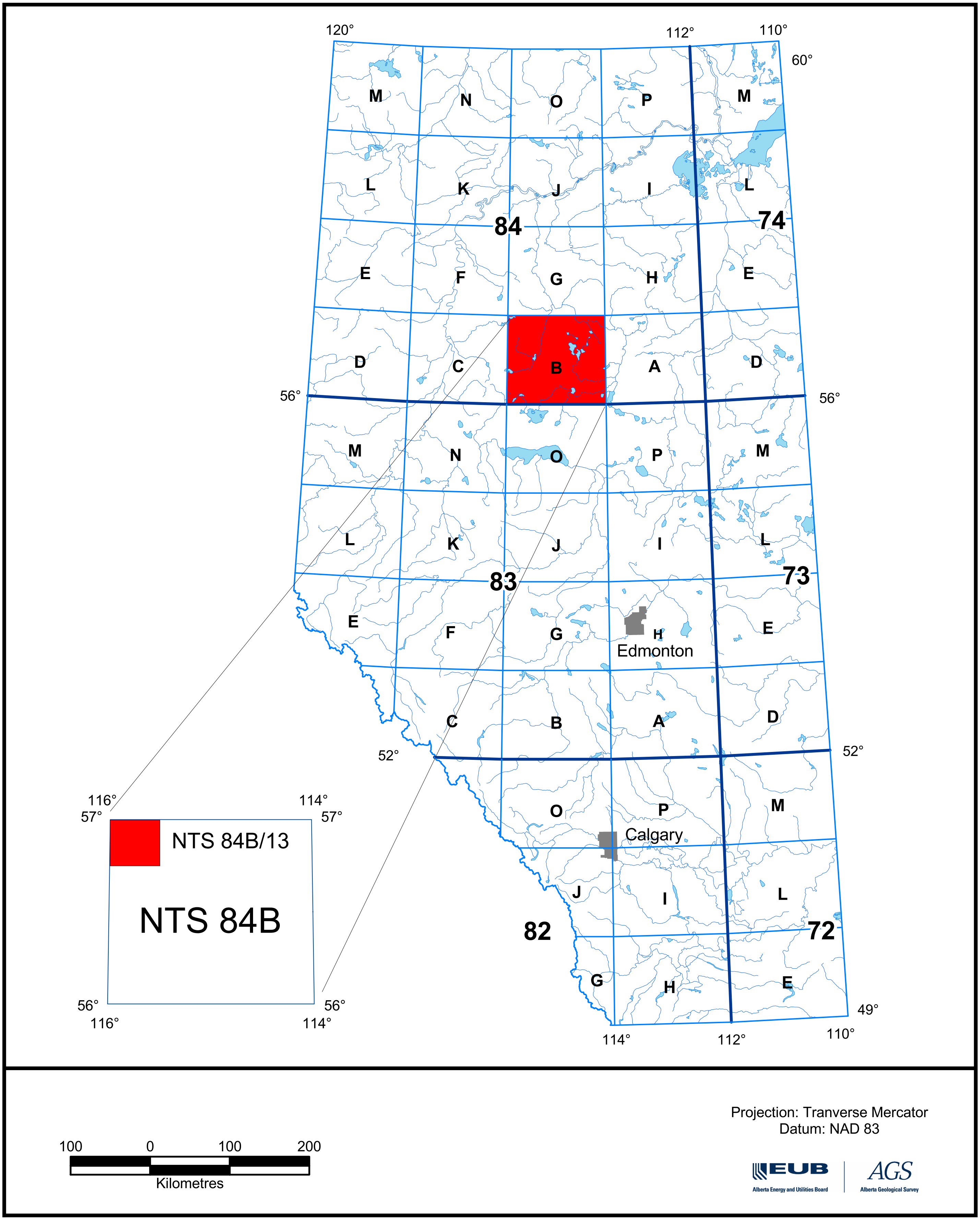


Figure 1. Location of the Sawn Lake (NTS 84B/13) map area, Alberta.

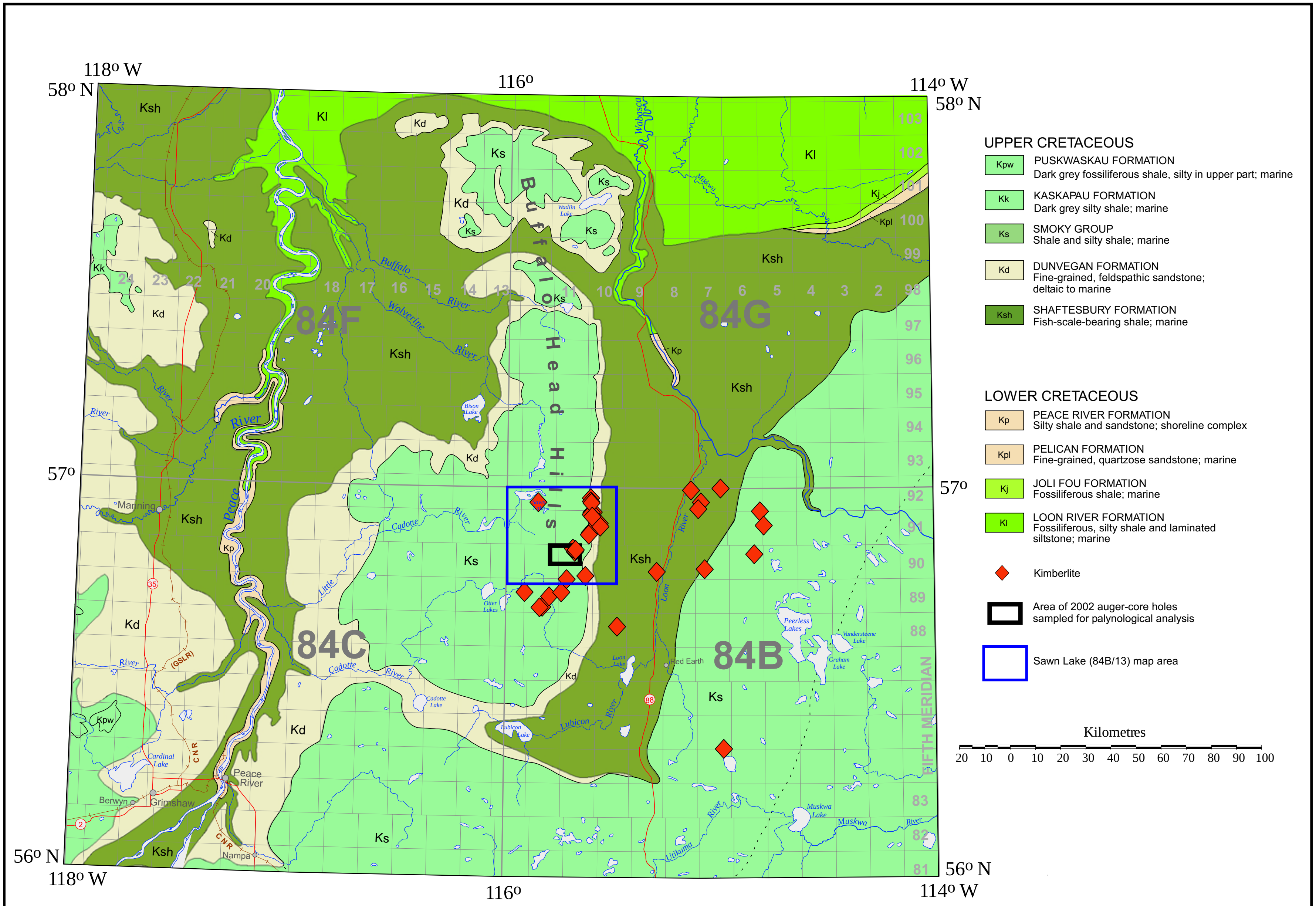


Figure 2. Bedrock geology of the Buffalo Head Hills area (NTS 84B, C, F and G).

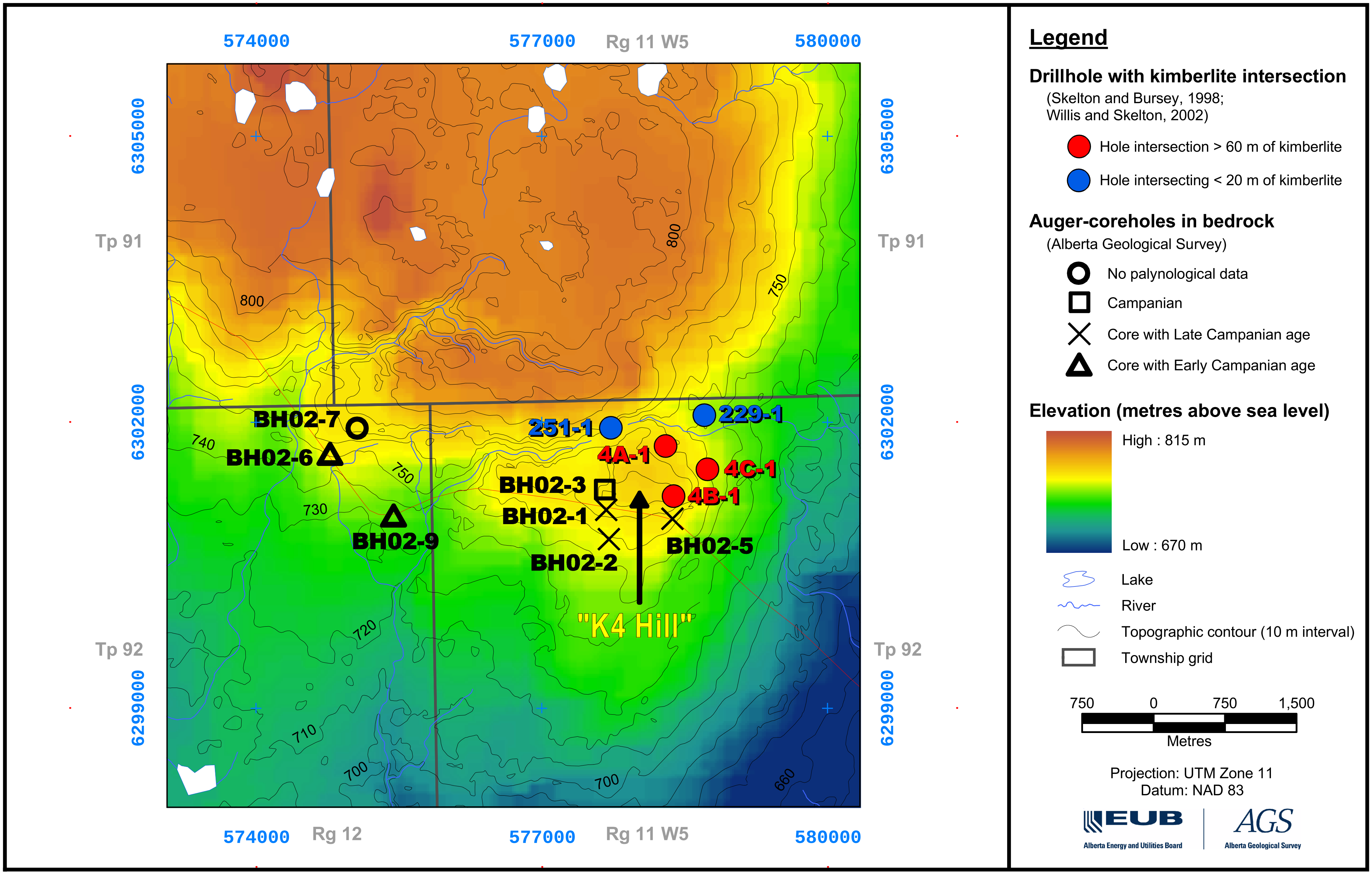


Figure 3. Drillholes that intersect bedrock near the K4 kimberlite.

Table 2. Summary of palynological results for samples from the 2002 auger-coring program

Auger Hole	Sample Depth (m)[1]	Sample Number	Lithology	Age[2]	Environment[2]
BHH02-01	14.5	2135	Mudstone	Early Late Campanian	Nearshore Restricted Marine
BHH02-02	11.5	2136	Siltstone	Late Campanian	Probably Fluvio-Lacustrine
BHH02-03	4.8	2137	Siltstone	Campanian	Probably Fluvio-Lacustrine
BHH02-05	6.8	2138	Mudstone	Late Campanian	Marginal Marine (Paralic?)
BHH02-06	3.2	2139	Mudstone	Early Campanian	Marine
BHH02-09	11.5	2140	Mudstone	Early Campanian	Marine

[1]metres below ground surface

[2]from Dolby, 2003

Ages for the six mudstone and siltstone core samples, collected over an east-west distance of four kilometres, range from Early to Late Campanian (Dolby, 2003). The Campanian spans the interval from 83.5 to 71.3 million years ago (Okulitch, 2002). The Late Campanian assemblages are indicative of nonmarine fluvial-lacustrine, paralic and nearshore, restricted marine environments, whereas the Early Campanian assemblages reflect open marine conditions (Dolby, 2003). Photographs showing examples of Upper Campanian sandstone core and Lower Campanian mudstone core are presented in Figure 4 and Figure 5.

3.2 Previously Obtained Ages From Sedimentary Rocks of the Buffalo Head Hills

3.2.1 Southern Buffalo Head Hills

Two surface samples for palynological analysis were collected by AGS within the western part of the Sawn Lake map area prior to the 2002 auger-core drilling program. Information on these samples, which contain returned Late Campanian ages, is summarized in Table 3. A photograph of the mudstone from which sample JP-01-1365 was collected, along with overlying sandstone and till, is presented in Figure 6.

Table 3. Summary of palynological results for surface samples from the Sawn Lake area collected prior to 2002

Sample	East[1]	North[1]	NTS Map Area	Lithology	Age	Citation
RE98-84B-166	562577	6309030	84B/13	Silty shale with layers of brown, rusty sandstone	Late Campanian	McIntyre, D.J. (pers. comm., 2005)[2]; Eccles et al. (2001)
JP01-70-1365	564620	6299324	84B/13	Mudstone (overlain by sandstone)	Late Campanian	Dolby (2001); Pawlowicz and Fenton (2002)

[1]NAD 83, UTM Zone 11

[2]D. McIntyre, in McIntyre (1998), originally suggested an Early Maastrichtian age

3.2.2 Northern Buffalo Head Hills

Wall and Singh (1975) obtained marine microfossils of probable Late Campanian age from a shale sample collected in the northern Buffalo Head Hills. Based on the similarities of the foraminiferal assemblages, Wall and Singh (1975) suggest the northern Buffalo Head Hills shale is coeval with the Upper Campanian Bearpaw Formation of southern Alberta.

Figure 4. Upper Campanian sandstone core from auger hole BH02-3.

Figure 5. Lower Campanian mudstone core from auger hole BH02-9.

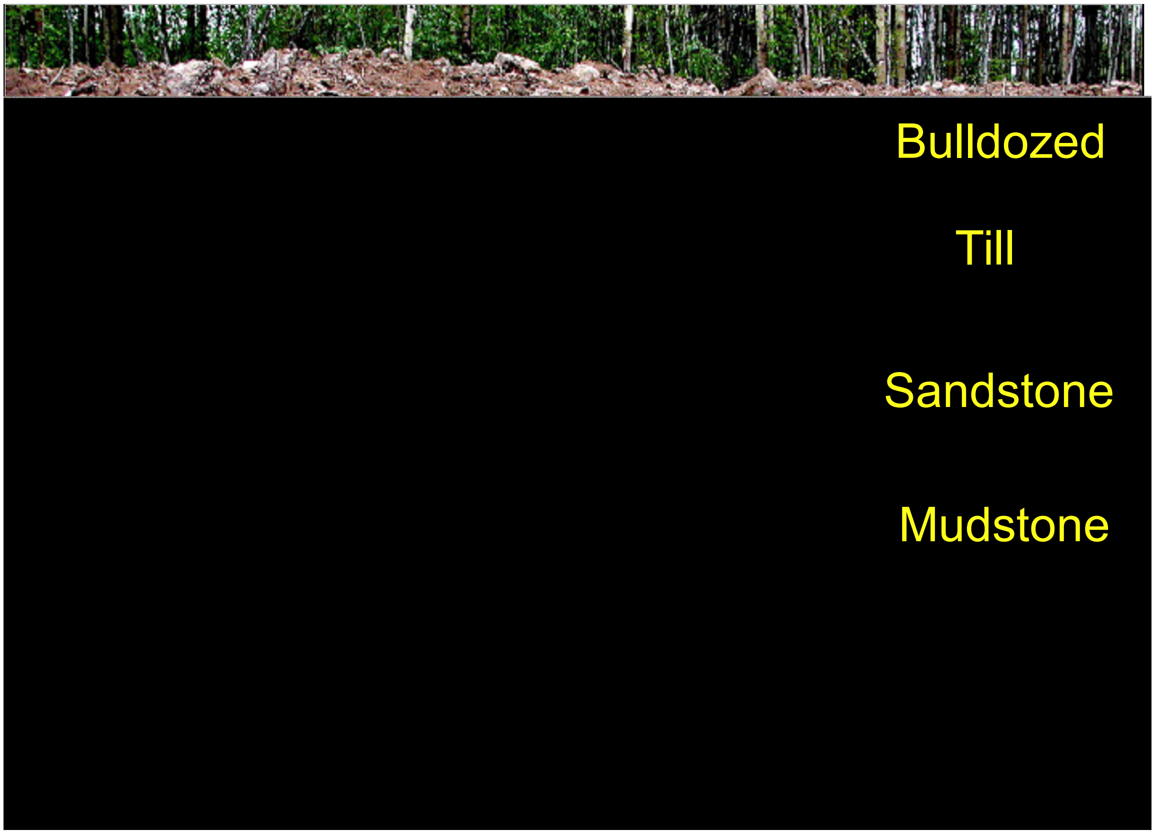


Figure 6. Thin till cover over Upper Campanian (Wapiti Formation correlative) sandstone and mudstone, western part of map area 84B/13. A Late Campanian palynological age was obtained from mudstone collected at this location.

4 Discussion

4.1 Regional Stratigraphy

The vertical positions of samples submitted for palynological analyses are shown in Figure 7, a section showing the lithologies logged in the bedrock core. The Lower Campanian to Upper Campanian boundary in the K4 kimberlite area occurs at an elevation between 745 masl and 750 masl.

The Early Campanian ages are consistent with existing geological maps of the region that show the youngest rocks in the Buffalo Head Hills to be marine shales of the Smoky Group (Green et al., 1970; Hamilton et al., 1999; Figure 2). However, the existence and distribution of sedimentary rocks with Late Campanian ages indicate part of the uppermost southern Buffalo Head Hills may be underlain by rocks correlative to the Wapiti Formation (Figure 8; Figure 9). This is consistent with the presence of sandstone units within the Upper Campanian auger core sections and at the sites of the palynology samples from surface exposures in the western part of the Sawn Lake map area (Figure 4; Figure 6; Figure 7; Table 3; Dawson et al., 1994). The age data are also consistent with the change from an open marine environment to a nonmarine (fluvial-lacustrine) depositional environment determined by palynology (Table 1 and Appendix 1). The existence of rocks correlative to the Wapiti Formation in the southern Buffalo Head Hills was previously reported by Eccles et al. (2001) and Pawlowicz and Fenton (2002).

Based on stratigraphic markers in the lower part of the Upper Cretaceous succession, it is estimated the dip of the Lower to Upper Campanian boundary in the Sawn Lake map area is approximately horizontal (D. Chen, pers. comm., 2005). Therefore, Upper Campanian rocks are likely to occur in the Sawn Lake map area where elevations on the bedrock surface (surface elevation less drift thickness) exceed approximately 750 masl as shown in Figure 7. Regional drift thickness mapping indicates much of the upland in the Sawn Lake map area is covered by 0 to 40 m of overburden with up to 80 m of overburden locally (Pawlowicz and Fenton, 2002; Pawlowicz and Fenton, 2005a). Bedrock topography mapping for NTS map area 84B (Peerless Lake), presented by Pawlowicz and Fenton (2002), and Pawlowicz and Fenton (2005b), indicates the bedrock surface occurs at elevations in excess of 750 masl over a considerable area south of Sawn Lake. The area on Figure 8 identified as probably underlain by Upper Campanian (lower Wapiti correlative) rocks is based upon an estimation of where the bedrock surface lies above 750 masl (modified after Pawlowicz and Fenton (2005b) with incorporation of the 2002 auger coring data).

4.2 Thickness of Smoky Group in Southeastern Buffalo Head Hills

Geological mapping by Green et al. (1970) places the contact between the Dunvegan Formation and the overlying Smoky Group in the southeastern Buffalo Head Hills at an elevation of approximately 600 masl (Figure 8). However, petroleum well geophysical log signatures indicative of sandstone suggest the top of the Dunvegan Formation (base of the Smoky Group) may occur at elevations as shallow as 650 masl to 670 masl in the Sawn Lake map area (e.g., wells 12-29-91-12W5 and 16-21-91-11W5). The top of the Smoky Group in the northern Alberta plains occurs in the lower part of the Campanian (Stott et al., 1993, p. 404). Palynological evidence presented above indicates the Lower Campanian to Upper Campanian boundary occurs at an elevation of about 750 masl in the study area. Thus, the thickness of the Smoky Group in the southeastern Buffalo Head Hills appears to be in the 80 to 150 m range.

4.3 Implications Regarding the K4 Kimberlite Eruption

Three closely spaced positive magnetic anomalies, numbered 4A, 4B and 4C, occur in the central part of map area 84B/13 (Skelton and Bursey, 1999). These magnetic anomalies were tested by drilling near the centres of the anomalies by Ashton Mining of Canada Inc. (Ashton) in 1997 (Table 4; Figure 3; Skelton and Bursey, 1998). The drilling confirmed that each of the magnetic anomalies represented kimberlite and these were designated kimberlites K4A, K4B and K4C. Collectively, these three kimberlites form the K4 kimberlite complex. Only seven holes have been drilled into the K4 kimberlite complex with a maximum hole depth of 200 m, so the geometry of the complex at depth is unknown. At surface, the K4 kimberlite complex, and in particular kimberlite K4B, forms a hill with about 30 m of relief.

Table 4. Summary of 1997 drilling on the K4A, K4B and K4C kimberlites (*after* Skelton and Bursey, 1998).

Hole number	Magnetic anomaly	Kimberlite	Length (m)	Inclination at collar (degrees)	Interval (m)	Summary
DDH4A-1	4A	K4A	128.0	-90	0.0 - 24.7 24.7 - 128.0	overburden kimberlite
DDH4A-2	4A	K4A	51.5	-60	0.0 - 25.8 25.8 - 51.5	overburden kimberlite
DDH4A-3	4A	K4A	152.4	-60	0.0 - 26.4 26.4 - 29.6 29.6 - 39.7 39.7 - 152.4	overburden carbonate-rich rock mudstone kimberlite
DDH4B-1	4B	K4B	200.3	-90	0.0 - 8.5 8.5 - 200.3	overburden kimberlite
DDH4B-2	4B	K4B	32.0	-60	0.0 - 8.2 8.2 - 32.0	overburden kimberlite
DDH4C-1	4C	K4C	105.7	-90	0.0 - 44.0 44.0 - 105.7	overburden kimberlite
DDH4C-2	4C	K4C	121.0	-59	0.0 - 50.9 50.9 - 121.0	overburden kimberlite

Geochemical results for rock samples from kimberlites K4A, K4B and K4C are similar to one another and distinct from other kimberlites in the area (Eccles, 2004). Their geochemical similarity suggests kimberlites K4A, K4B and K4C may share a common magmatic source. No ages are available for kimberlite from the K4 complex.

Two holes drilled by Ashton to the north and northwest of the K4 kimberlite complex, holes 229-1 and 251-1, intersected bedded volcaniclastic kimberlite and mudstone with kimberlite over vertical intervals of 6.9 m and 13.6 m, with both intersections underlain by mudstone (Figure 3; Willis and Skelton, 2002). Based on proximity, it is likely the bedded volcaniclastic kimberlite intersected in holes 229-1 and 251-1 is related to the eruption and/or subsequent wasting of the K4 kimberlite complex.

The bedded volcaniclastic kimberlite intersected in hole 229-1 lies at an elevation of approximately 60 m below the Lower Campanian–Upper Campanian boundary within the central part of the marine Smoky Group. The stratigraphic position of the bedded volcaniclastic kimberlite suggests it was deposited during the Turonian, Coniacian or Santonian (93.0 to 83.5 millions of years ago; Figure 9). This time interval includes the perovskite (U-Pb) dates obtained for other Buffalo Head Hills kimberlites, which indicate emplacement ages of 88±5, 91.9±2, 86±3 and 87±3 millions of years ago for kimberlites K5, K6, K7A and K14, respectively (Skelton et al., 2003; Eccles, 2004).

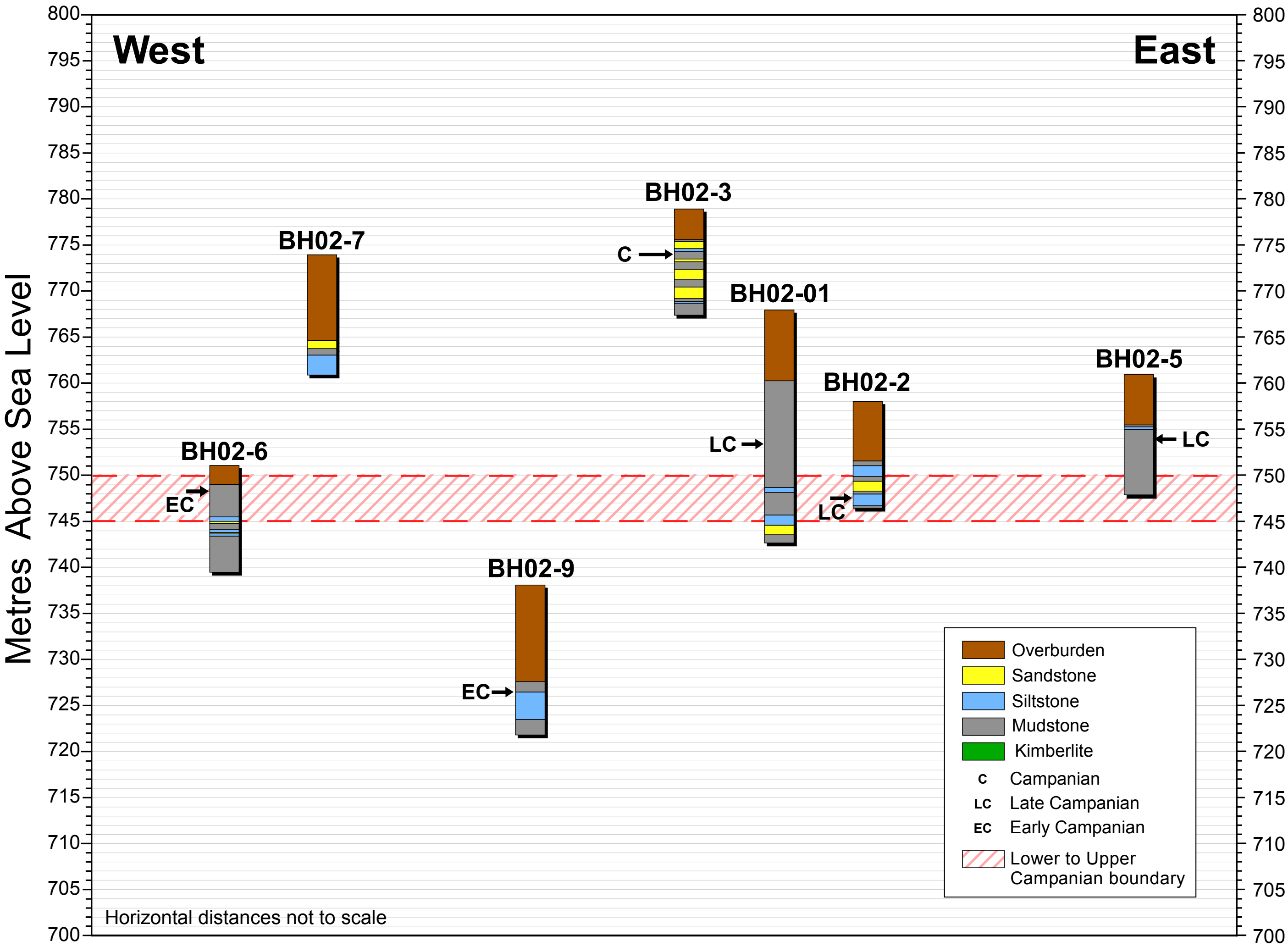


Figure 7: Section showing auger core-holes that intersect bedrock and palynological ages determined from core.

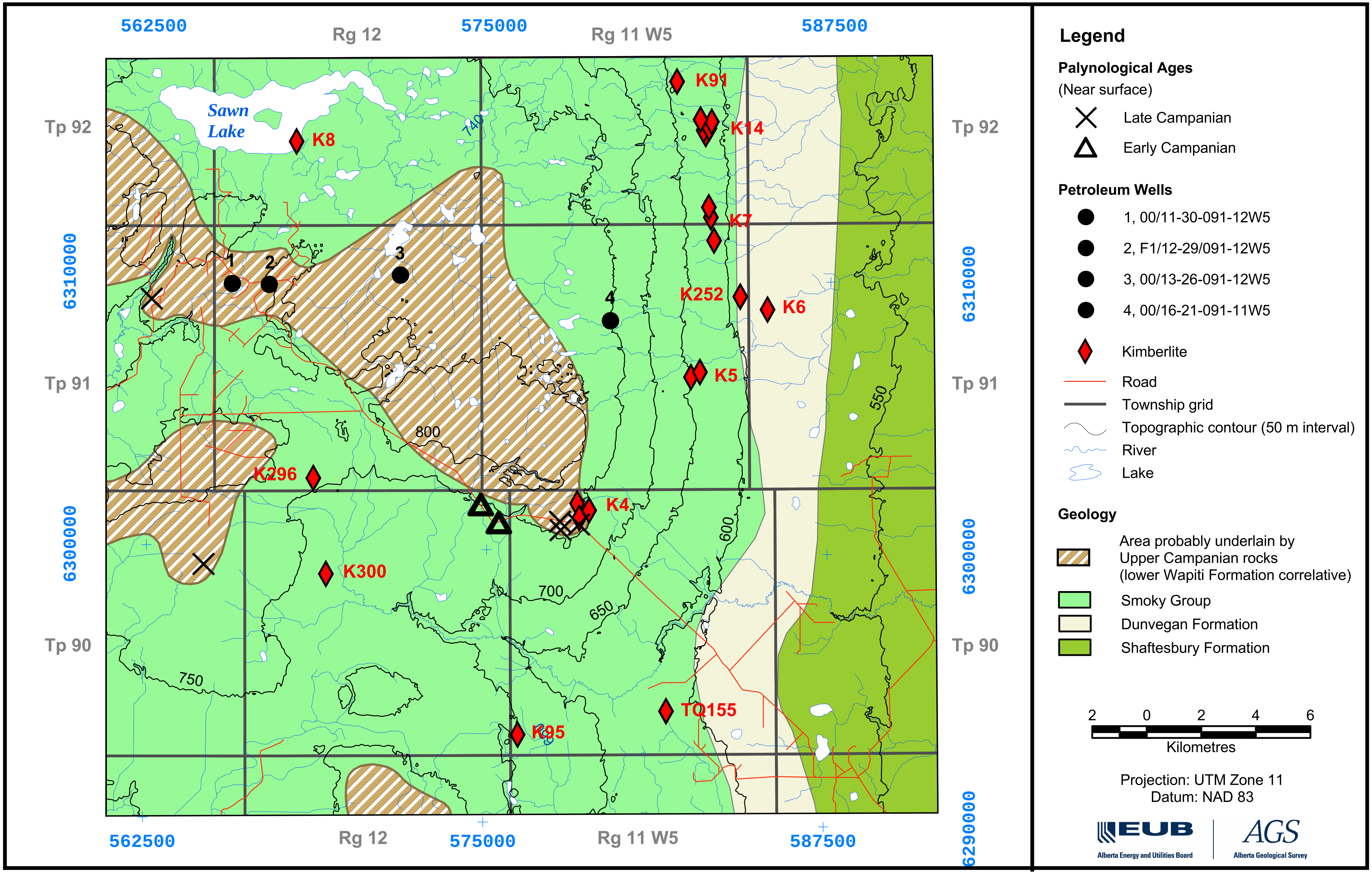
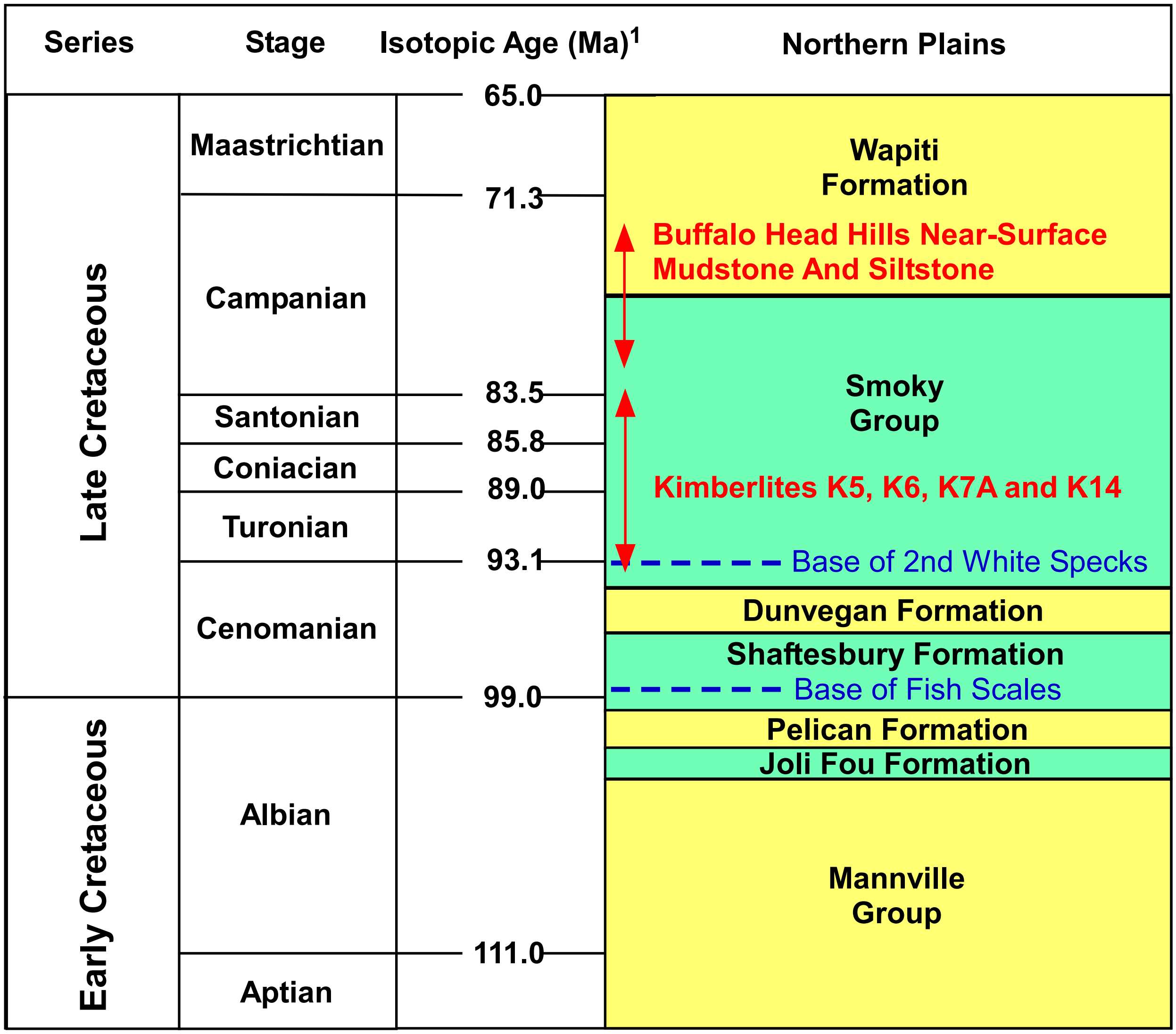


Figure 8. Geology and near surface palynological ages, Sawn Lake map area (NTS 84B/13), southern Buffalo Head Hills.



[1]Millions of years before present; Okulitch (2002)

Figure 9. Geological time chart for the northern plains of Alberta showing the palynological age range obtained from near-surface mudstone and siltstone samples of the southern Buffalo Head Hills. Also shown is the range of perovskite (U-Pb) dates obtained for kimberlites K5, K6, K7A and K14 (Skelton et al., 2003; Eccles, 2004).

A section showing results for three of the Ashton diamond-drill holes is shown in Figure 10. Also shown is the change from Lower to Upper Campanian sedimentary rocks at approximately 750 masl based on the above presented palynological results. In Ashton diamond-drill hole 4B-1, drilled near the top of the 'K4 Hill' (Figure 3), olivine-rich kimberlite was intersected for 192 m within the K4 kimberlite complex (kimberlite K4B) from the top of bedrock to the bottom of the hole (Skelton and Bursey, 1998). The uppermost kimberlite intersected in this hole (at the base of overburden) occurs at an elevation of approximately 776 masl. Ashton hole 229-1, drilled 900 m northeast of hole 4B-1, intersected 7 m of bedded volcaniclastic kimberlite with the lower contact at 689 masl and an upper contact at 696 masl. A unit logged as mudstone with kimberlite was intersected at a similar elevation (lower contact at 688 masl) in Ashton hole 251-1, which was drilled 1 km west of hole 229-1 (Willis and Skelton, 2002).

The occurrence of kimberlite within Upper Campanian sedimentary rocks, as is the case in the upper part of the K4 kimberlite complex, suggests the possibility of kimberlitic volcanism during the Late Campanian (or later). However, the isotopic dates obtained for kimberlites K5, K6, K7A and K14 and the inferred age of the bedded volcaniclastic kimberlite north of the K4 complex (intersected in hole 229-1) are all pre-Campanian. An alternate interpretation is that the upper part of the K4 kimberlite complex represents the preserved portion of a volcanic summit formed by one or more pre-Campanian eruptions.

Based on spatial relationships, it seems probable that bedded volcaniclastic kimberlite intersected in hole 229-1 was derived from the K4 kimberlite complex as either pyroclastic or resedimented volcaniclastic material. If this inference is correct, and if the K4 kimberlite complex was formed by pre-Campanian volcanism, it is likely the summit of the K4 kimberlite volcanic complex stood at least 87 m above the surrounding sediments when the bedded volcaniclastic kimberlite was deposited (Figure 10). It may also be inferred that the K4 kimberlite volcanic complex was subsequently buried, at least in part, by Early Campanian and Late Campanian sedimentation.

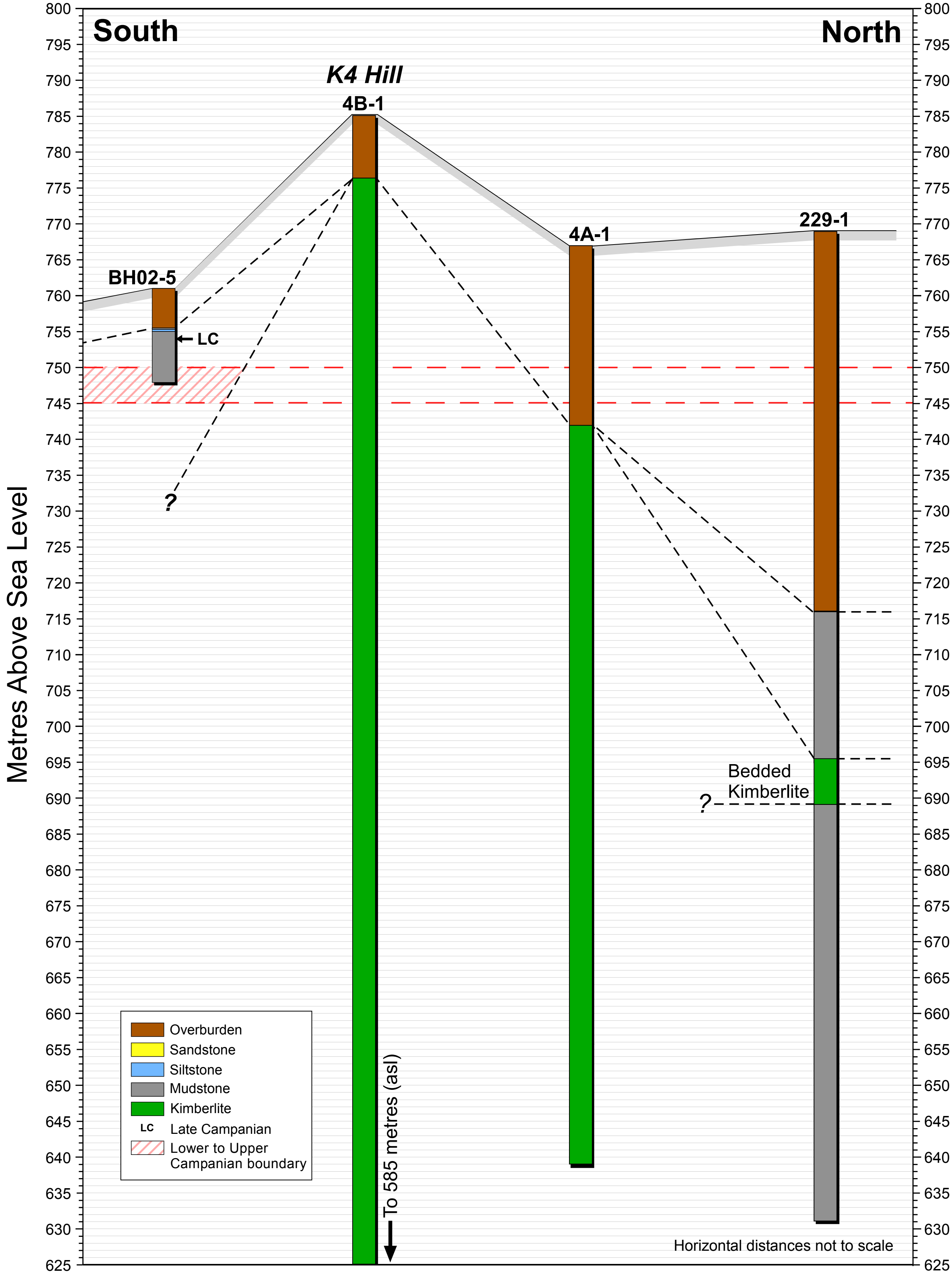


Figure10: Section showing AGS hole BH02-5 and Ashton holes 4A-1, 4B-1 and 229-1.

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Appendix 1 – Palynological Analysis of Core Samples From the Sawn Lake Area

(from Dolby, 2003, and Dolby pers. comm., 2005)

SAMPLE: 2135
Age: Early Late Campanian
Zone: *Aquilapollenites trialatus* zone (Sweet et al., 1989).
Environment: Nearshore, restricted marine

Remarks

Small, indeterminate, peridinioid dinocysts are abundant but larger forms are extremely rare and fragmented. In addition, typically open marine, chorate cysts are absent. Bisaccate pollen and small spores are abundant and the overall impression is of a nearshore, shallow, restricted marine environment.

The members of the *Aquilapollenites* group and other angiosperms indicate an early late Campanian age equivalent to the *A. trialatus* Zone, which is confirmed by the occurrence of *Chatangiella ditissima*, an essentially Early Campanian and older species.

Significant Species

Aquilapollenites trialatus	*A. clarireticulatus*
A. turbidus	*Azonia* cf. *hirsuta*
Pleurospermaepollenites sp.	
Chatangiella granulifera (R)	*C. ditissima* (R)
Microdinium ornatum	*Laciniadinium* spp. (R)
Isabelidinium acuminatum	*Dorocysta litotes*

SAMPLE: 2136
Age: Late Campanian
Zone: *?Triprojectus unicus* (Sweet et al., 1989).
Environment: Probably fluvio-lacustrine

Remarks

This is a poor assemblage with relatively few palynomorphs compared to most of the samples in this study. Bisaccate pollen and small spores overwhelmingly dominate the assemblage, and one dinocyst fragment may not be *in situ*.

There are too few angiosperms with which to assign an accurate age, but the presence of single specimens of *Aquilapollenites trialatus* and *Mancicorpus* cf. *calvus* favour a Late Campanian age, possibly equivalent to the *T. unicus* Zone.

Significant Species

Aquilapollenites trialatus	*Mancicorpus* cf. *calvus*
Pleurospermaepollenites sp.	

SAMPLE: **2137**
Age: Campanian
Environment: Probably fluvio-lacustrine

Remarks

This sample is significantly richer than 2136, but contains very few angiosperm pollen and one poorly preserved dinocyst. A Campanian age is indicated by the species of *Aquilapollenites,* but there are too few to assign a precise age.

Significant species

Aquilapollenites trialatus	*A. rigidus* complex

SAMPLE: **2138**
Age: Late Campanian
Zone: *?Aquilapollenites trialatus* Zone (Sweet et al., 1989).
Environment: Marginal marine, ?paralic

Remarks

This assemblage is similar to 2137, but is slightly more diverse and there are a few dinocysts. However, the dominance of the terrestrial fraction suggests a marginal marine or possibly paralic environment rather than fully marine conditions.

As in 2137, there are too few angiosperms to assign a precise age, but the few species present tend to favour an Early Late Campanian date.

Significant species

Aquilapollenites trialatus	*A. rigidus* complex
A. rigidus-stelkii	*A.* cf*. quadrilobus*
Pleurospermaepollenites sp.	*Erdtmanipollis* sp.
Laciniadinium sp.	*Isabelidinium acuminatum*
Chatangiella sp.	

SAMPLE: 2139
Age: Early Campanian
Environment: Marine

Remarks

Dinocysts are abundant in this sample, indicating an open marine environment. Mississippian spores comprise 14 per cent of the assemblage, and this level of reworking points to the close proximity of a flooding surface.

The age is based on the occurrence of abundant *Chatangiella ditissima* along with specimens of *Aquilapollenites trialatus* and *Mancicorpus* sp.

Significant species

Chatangiella ditissima (A)
Laciniadinium spp. (A)
Dinogymnium euclaense
Alterbidinium minor
Isabelidinium thomasii (A)
I. acuminatum
Trigonopyxida ginella
Chlamydorphorella grossa complex

Aquilapollenites trialatus (R)
Pleurospermaepollenites sp. (R)
Mancicorpus sp. (R)

SAMPLE: 2140
Age: Early Campanian
Environment: Marine

Remarks

This assemblage is similar to 2139 except the angiosperm fraction is slightly richer and more diverse.

Significant species

Chatangiella ditissima (A)
C. decorosa
Laciniadinium spp. (VA)
Microdinium spp.
Chlamydophorella grossa complex
Isabelidinium thomasii (C)
I. acuminatum
Spinidinium spp. (C)
Wallodinium lunum
Alterbidinium minor

Aquilapollenites trialatus
A. rigidus-stelkii
A. aptus
Mancicorpus sp.