Palynological Evidence for Jurassic and Triassic(?) Ages of the Upper Watrous and Lower Gravelbourg Formations, Southern Saskatchewan[1]

J.M. White [2], T.P. Poulton [2], and J. Jansonius [2]

White, J.M., Poulton, T.P., and Jansonius, J. (2002): Palynological evidence for Jurassic and Triassic(?) ages of the upper Watrous and lower Gravelbourg formations, southern Saskatchewan; *in* Summary of Investigations 2002, Volume 1, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2002-4.1, p83-99.

Abstract

The rich variety of terrestrial and marine palynomorphs in the lower member of the Gravelbourg Formation, southern Saskatchewan, confirms its Middle Jurassic age and suggests freshwater to brackish depositional environments. The Middle Jurassic age sets a younger age limit for the underlying upper member of the Watrous Formation. Mudstones in the upper Watrous anhydrite unit contain a sparse palynoflora, which nonetheless allows the determination of a Middle Triassic older age limit and stressed depositional environments. These mudstones, of Middle Triassic to Middle Jurassic age determined by palynology, interfinger with anhydrites previously interpreted as Late Pennsylvanian, based on strontium isotope ratios. Determining the age of the upper Watrous involves a new technique for plotting and analyzing the large volume of global palynological literature contained in the Palynodata database.

Keywords: *Classopollis*, Gravelbourg, Jurassic, palynology, strontium, Triassic, Watrous, Williston Basin.

1. Introduction

This report presents palynological fossil determinations and interpretations from samples collected in order to clarify the problematic age of the upper member of the Watrous Formation and of the now more confidently dated lower member of the Gravelbourg Formation. It also presents a commentary on some of the interpretations in Pocock's (1970) comprehensive palynological treatment of the Jurassic formations in southern Saskatchewan.

The Watrous and Gravelbourg formations lie within the northern Williston Basin, in a long-undated sequence between well dated Middle Jurassic and younger strata above, and an equally well dated Mississippian and older Paleozoic succession below. They have most commonly been assigned to the lower, early transgressive portion of the Mesozoic sequence in Canada of Jurassic and, possibly, Triassic ages (Milner and Thomas, 1954; Stott, 1955; Poulton, 1984; Kreis, 1991; Poulton *et al.*, 1994).

a) Age of the Watrous Formation

Dominated by red beds and anhydrite, the Watrous Formation more closely resembles, in general lithological characteristics, certain parts of the Pennsylvanian and Permian succession in adjacent northern U.S. states than the superjacent Jurassic strata in Saskatchewan (Denison *et al.*, 2001). Denison *et al.* (2001) presented a highly consistent set of strontium and sulphur isotope data from many wells scattered across the northern Williston Basin. These data indicated probable Late Paleozoic (Late Pennsylvanian) age for the upper Watrous anhydrites, and precluded their being Jurassic in age. The proposal by Denison *et al.* (2001) requires the re-interpreting of certain northern North Dakota and northern Montana lithostratigraphic correlations. Enkin *et al.* (2001), on the basis of paleomagnetic polar-wandering data from a single well, indicated a probable Pennsylvanian age for the lower part of the lower member (red beds) of the Watrous Formation, but Permian or Triassic ages for the upper part of the red beds. They apparently precluded a Pennsylvanian age for the upper member (anhydrites). The palynological data reported here and the stratigraphic relationships impose Middle Triassic to Middle Jurassic ages for the upper member of the Watrous Formation. This age is derived from samples of mudstone intimately interbedded with the anhydrites that suggested Late Paleozoic ages to Denison *et al.* (2001). Fifteen mudstone samples were processed

[1] Geological Survey of Canada Contribution No. 2001227.

[2] Geological Survey of Canada, 3303 - 33rd Street NW, Calgary, AB T2L 2A7; E-mails: jwhite@nrcan.gc.ca; tpoulton@nrcan.gc.ca; or jjansoni@nrcan.gc.ca.

for micropaleontology and studied by J.H. Wall, but no foraminifera or ostracodes were found. A few questionable spores were recovered from two upper Watrous samples but their origin is dubious. Neither the red beds of the lower member nor the anhydrite beds of the upper member have yielded palynomorphs.

b) Age of the Gravelbourg Formation

Microfossils from the upper member of the Gravelbourg Formation have previously permitted determination of its Middle Jurassic age based on their similarity to those from the overlying Bajocian-Bathonian Shaunavon Formation (Wall, 1960; Brooke and Braun, 1972). However, the lower member had not been firmly dated until now because of its sparse fossil content, the long-ranging character of the fossils it had yielded, and uncertainties regarding the significance of palynological reports by Pocock (1970, 1972). In view of the uncertain age of the underlying upper Watrous, the age of the lower Gravelbourg cannot be assumed on the basis of lithological similarity with overlying formations, especially because a significant disconformity is present within the lower Gravelbourg (Kreis, 1991).

The lower Gravelbourg is a heterogeneous unit of limestones, mudstones, and sandstones, described most recently and most comprehensively by Kreis (1991), who subdivided it into two units, the upper of which (B) oversteps the limits of the lower (A) in southeastern Saskatchewan. In many places, unit A has at its top a zone of chalcedonic chert indicating an interval of subaerial exposure and, therefore, a disconformity prior to deposition of unit B.

Kreis (1991) noted the presence in unit B of a locally abundant "stressed" biota suggesting less than normal marine salinities. The fossils he reported include fish remains, small and thin-shelled bivalves, and both freshwater and brackish water ostracodes (*Limnocythere, Darwinula,* and *Norcanolella*), all of which have been confirmed and expanded by Wall *et al.* (this volume), who also identified other species, and poorly preserved palynomorphs including *Leiosphaeridia*. Kreis reported only a few *Leiosphaeridia* and terrestrial palynomorphs from unit A, which, he suggested, had a more "restricted" depositional environment than unit B. Pocock's (1972) identification of 21 terrestrial and seven marine palynomorphs from the lower Gravelbourg are reviewed in this report.

This report and the accompanying report on micropaleontology and bivalves by Wall *et al.* (2002) firmly date unit B of the lower Gravelbourg as Middle Jurassic. Lying below a disconformity with evidence of subaerial weathering and erosion, unit A contains microfloral assemblage that is less diagnostic than, but not taxonomically distinct from, that of unit B. Unit A cannot, therefore, be distinguished in age from unit B.

2. The Upper Watrous Samples and Palynoflora

The lower member of the Watrous Formation is dominated by red siltstone and mudstone, but contains minor thin green siltstone laminae. The upper member is dominantly nodular to massive anhydrite with interbedded dololutite, limestone and mudstone (Kreis, 1991; Denison *et al.*, 2001). The correlation of the units, which are almost entirely devoid of fossils, is therefore based on their main lithologies and log markers. The palynomorphs reported here were found in core samples of upper Watrous grey silty mudstone collected by T. Poulton and K. Kreis in 2000 and 2001 (Figure 1; Table 1). The samples were assigned to stratigraphic units by Kreis, who also provided depths to unit tops (Table 2). Many were collected from mudstone beds, which are interlayered with anhydrites and some of which yielded the palynomorphs that contradict Late Paleozoic ages proposed by Denison *et al.* (2001) for the anhydrites (Table 3).

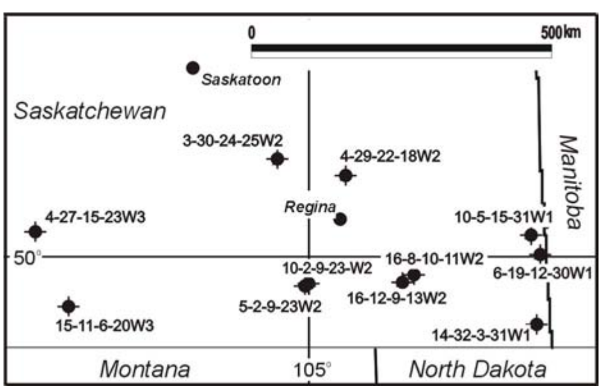

Figure 1 - Index map showing locations of the sampled wells.

a) Control for Drilling Mud Contamination

Preliminary palynological work on the upper Watrous samples indicated the presence of *Classopollis classoides* pollen. However, further work was required to demonstrate that *Classopollis* pollen could not have been introduced by contamination of the sample by drilling mud.

To test for possible contamination of the residues by drilling mud, core chip samples were cleaned in an ultrasonic bath. The material removed was allowed to settle, prepared with standard HCl and HF treatment, and mounted as kerogen slides. Although the core chip samples were at first very clean, these "drilling mud" preparations represent any potential contamination by drilling mud. "Drilling Mud" samples were individually mounted and the remaining residue from six samples (C-404576 to C-404581) was pooled and

Table 1 - Palynological samples archived by the Geological Survey of Canada indicating depth locations and stratigraphic assignation.

Sample No.	Well and Depth	Formation
C-404589	10-2-9-23W2 1322m	lower Gravelbourg B
C-404590	10-2-9-23W2 1322.3m	lower Gravelbourg B
C-404591	10-2-9-23W2 1322.5m	lower Gravelbourg B
C-418556	10-2-9-23W2 1322.6-1322.8m	lower Gravelbourg B
C-418558	10-2-9-23W2 1322.9-1323.3m	lower Gravelbourg B
C-404592	10-2-9-23W2 1323m	lower Gravelbourg B
C-404593	10-2-9-23W2 1323.5m	lower Gravelbourg B
C-418557	10-2-9-23W2 1323-1323.5m	lower Gravelbourg B
C-418559	10-2-9-23W2 1324-1324.5m	lower Gravelbourg B
C-404594	10-2-9-23W2 1324.6m	lower Gravelbourg B
C-418560	10-2-9-23W2 1325.5-1325m	lower Gravelbourg B
C-418561	10-2-9-23W2 1335-1336m	lower Gravelbourg A
C-418562	10-2-9-23W2 1337-1338m	lower Gravelbourg A
C-404595	10-2-9-23W2 1338m	lower Gravelbourg A
C-404582	5-2-9-23W2 1308.6-1309.3m	upper Gravelbourg, near basal contact
C-418552	5-2-9-23W2 1311.1-1311.4m	lower Gravelbourg B, near upper contact
C-404583	5-2-9-23W2 1311-1312m	lower Gravelbourg B
C-418553	5-2-9-23W2 1312.2-1313.5m	lower Gravelbourg B
C-404584	5-2-9-23W2 1313-1313.26m	lower Gravelbourg B
C-404585	5-2-9-23W2 1314-1314.8m	lower Gravelbourg B
C-418554	5-2-9-23W2 1315.5-1317m	lower Gravelbourg B
C-404586	5-2-9-23W2 1316.1-1318m	lower Gravelbourg B
C-404588	5-2-9-23W2 1318.5m	lower Gravelbourg B
C-418555	5-2-9-23W2 1319.7-1320m	lower Gravelbourg B
C-404587	5-2-9-23W2 1321m	lower Gravelbourg A
C-404596	4-27-15-23W3 3438 ft	lower Gravelbourg A
C-404597	4-27-15-23W3 3449 ft	lower Gravelbourg A
C-404598	4-27-15-23W3 3453.5 ft	lower Gravelbourg A
C-404571	10-5-15-31W1 2183.5 ft	lower Gravelbourg B, base
C-404572	10-5-15-31W1 2194.5 ft	upper Watrous
C-404573	14-32-3-31W1 3481 ft	upper Watrous
C-404574	14-32-3-31W1 3486 ft	upper Watrous
C-404575	14-32-3-31W1 3487.3 ft	upper Watrous
C-404576	14-32-3-31W1 3488.6 ft	upper Watrous
C-404599	15-11-6-20W3 4907 ft	Gravelbourg, basal
C-404600	15-11-6-20W3 4908.5 ft, 4909 ft	upper Watrous, uppermost
C-404568	16-12-9-13W2 3979-3985 ft	upper Watrous
C-404569	16-12-9-13W2 3988-3992 ft	upper Watrous
C-404570	16-12-9-13W2 3994-3999 ft	upper Watrous
C-404580	16-8-10-11W2 3816 ft	upper Watrous
C-404581	16-8-10-11W2 3822 ft	upper Watrous
C-404723	3-30-24-25W2 2461 ft	upper Watrous, near base
C-404577	6-19-12-30W1 782.7m	upper Watrous
C-404578	6-19-12-30W1 784.3m	upper Watrous
C-404579	6-19-12-30W1 785.8m	upper Watrous
C-404724	4-29-22-18W2 2387 ft	upper Watrous

concentrated by ultrasonic screening using a 7 µm nominal mesh.

After the ultrasonic cleaning, the core chips were prepared by normal palynological preparation, but the kerogen residue was screened using an ultrasonic probe and a 7 µm nominal mesh to concentrate the palynomorphs sufficiently to make useful microscope slides.

The interpretation of this test for drilling mud contamination is not straightforward. The drilling of the formation will contaminate the mud sample with palynomorphs from the formation, so some contemporaneous palynomorphs can be expected in any mud adhering to the sample. Also, ultrasonification of the sample might release some of the actual sample exterior into the "drilling mud" residue. The potential for drilling mud contamination of the sample has to be assessed as to whether the assemblage in the "mud" plus exterior part of the core chip sample is different from that of the washed core chip sample.

The upper Watrous samples yielded very sparse palynological assemblages and would probably not have yielded useful slides were they not concentrated by screening. *C. classoides* was the most commonly occurring palynomorph, but bisaccate pollen, *Chasmosporites canadensis*, ?*Callialasporites*, and *Botryococcus* occur rarely. *C. classoides* is the most useful

Table 2 - Tops of stratigraphic units picked from geophysical logs of the sampled wells.

Well	Unit of Depth	Lower Shaunavon Unit 1	upper Gravelbourg	lower Gravelbourg Unit B	lower Gravelbourg Unit A	upper Watrous	lower Watrous	Mississippian
6-19-12-30W1	metres			740	not present	748	791	794.3
14-32-3-31W1	feet			3250	3281	3373	3509	3634
10-5-15-31W1	feet			2138	not present	2184	not present	2230
16-8-10-11W2	feet	3542	3576	3618	3675	3715	3830	3951
16-12-9-13W2	feet	3726	3756	3790	3835	3919	4027	4173
4-29-22-18W2	feet	2198	2238	2275	not present	2322	2431	2452
5-2-9-23W2	metres	1283	1294.7	1310.5	1320	1364.7	not reached	
10-2-9-23W2	metres	1287	1300	1315.4	1326.1	1363.6	1383.3	1399.8
3-30-24-25W2	feet	2281	2320	2360	not present	2372	2505	2695
15-11-6-20W3	feet	not present	4820	not present	4870	4909	not present	4922
4-27-15-23W3	feet	not present	3333	3373	3392	3458	not present	3500

Table 3 - Upper Watrous samples from four wells, showing the alternation of samples yielding either palynological and isotopic ages. Sample numbers to the left of the depth column show only the mudstone samples producing palynomorphs. Samples to the right of the depth column are anhydrites yielding $Sr^{87/86}$ ratios implying Late Paleozoic ages (Denison *et al.*, ***2001). Δ_{sw} indicates the difference between the $Sr^{87/86}$ ratios determined from anhydrite samples and those from modern seawater. Δ_{sw} values close to -89.7 characterize many of the upper Watrous anhydrites. Comparison with the global curve for strontium isotope variation in seawater through geological time provides the Pennsylvanian age for the upper Watrous, whereas Mesozoic Δ_{sw} values generally exceed -100 (see Denison*** *et al.*, ***2001, Figures 12 and 13). The palynological samples contain*** *Classopollis classoides* ***(* shown in Lab. No. column), except C-404570, which contains instead*** *Callialasporites* ***and*** *Distalanulisporites* ***(+).***

Well	Palynology Samples		Depth	Sr samples	Stratigraphic relation of the palynological and $Sr^{87/86}$ samples
	GSC No.	Lab. No.		Δ_{SW}	
14-32-3-31W1			3479.5 ft	-88.9	These mudstones with *Classopollis* are intimately interbedded with anhydrites with characteristic Pennsylvanian Sr values
	C-404573	P4570-6 *	3481.0 ft		
			3483.0 ft	-90.5	
			3484.5 ft	-88.9	
			3485.0 ft	-88.8	
	C-404575	P4570-8 *	3487.3 ft		
	C-404576	P4570-9 *	3488.6 ft		
			3489.5 ft	-88.7	
6-19-12-30W1			782.0 m	-90.2	The palynological and Sr samples are interlayered; Δ_{SW} -90 is the characteristic Pennsylvanian Sr value for the Watrous
	C-404577	P4570-10 *	782.7 m		
			783.0 m	-96.1	
	C-404578	P4570-11 *	784.3 m		
			789.0 m	-93.2	
16-8-10-11W2	C-404580	P4570-13 *	3816.0 ft		An anhydrite with Pennsylvanian isotope value below a mudstone with *Classopollis*
			3818.0 ft	-88.6	
16-12-9-13W2	C-404568	P4570-1 *	3979-3985 ft		three anhydrite samples with Pennsylvanian Sr values occur between palynology samples
			3986-3988 ft	-87, -90.2, -90.4	
	C-404570	P4570-3 +	3994-3999 ft		

taxon to resolve the age of the Watrous because of its common occurrence and Mesozoic age implication.

Table 4 shows the occurrence of *Classopollis classoides* in the upper Watrous samples in the cleaned core chips and in the possible "drilling mud". Where *C. classoides* was present in the core chips in samples, C404576 to C404578, it was also in the "mud". Where the core sample was barren (C-404579 and C-404581), the "mud" was also barren. In one sample (C-404580), the core yielded *C. classoides* but the "mud" was barren. These results show that *C. classoides* was present in the cleaned core chip samples, and that the supposed "drilling mud" was probably the cortex of the core chip removed by ultrasonification. The presence of *C. classoides* in the upper member of the Watrous Formation is thus demonstrated.

b) Age of *Classopollis* and *Callialasporites trilobatus*

The Watrous Formation has low palynomorph content. However, the maximum age of the formation is indicated as being no older than Mesozoic, and probably no older than Middle Triassic, by the presence of: a) a small palynological assemblage dominated by *C. classoides* and b) *Callialasporites trilobatus* in a single sample.

Pollen of the genus *Classopollis* occurs abundantly in the Upper Mesozoic. Its biostratigraphic value has been assessed by retrieving relevant records from Palynodata v6.0 (March 2000), a database of over 20,000 items of global palynological literature. The Palynodata retrieval for *Classopollis* spp. yielded 2,224 literature references, and 4,331 plottable records (each literature reference may record more than one locality).

Table 4 - Comparison of the occurrence of *Classopollis classoides* ***in core samples and in "drilling mud" washed from the exterior of the core chips.***

Sample and Depth	Cleaned core chips	"Drilling mud"
14-32-3-31W1		
C-404576, P4570-9, 3488.6 ft	*C. classoides*	*C. classoides*
6-19-12-30W1		
C-404577, P4570-10, 782.7 m	*C. classoides*	*C. classoides*
C-404578, P4570-11, 784.3 m	*C. classoides*	*C. classoides*
C-404579, P4570-12, 785.5-785.8 m	barren	barren
16-8-10-11W2		
C-404580, P4570-13, 3816 ft	*C. classoides*	barren
C-404581, P4570-14, 3822 ft	barren	barren
Pooled "Drilling Mud"		
P-4570-9 to 14W, pooled "drilling mud" kerogen	n/a	*C. classoides*

White and Jessop (in press) have described the theory and technique of approximating the time/space distribution of any fossil taxon by plotting the distribution of literature records stored in Palynodata. Using this technique, literature records of *Classopollis* spp. are plotted by ages (Figure 2) on the van Eysinga (1978) geological time scale, incorporated into Palynodata.

The first Palynodata retrieval (not illustrated here) yielded a few references giving an extended left 'tail' of the distribution into the Paleozoic (i.e. *Classopollis* spp. ages older than the Permo-Triassic boundary at 230 Ma on van Eysinga's (1978) time scale). Compared to the bulk of the literature, these Paleozoic

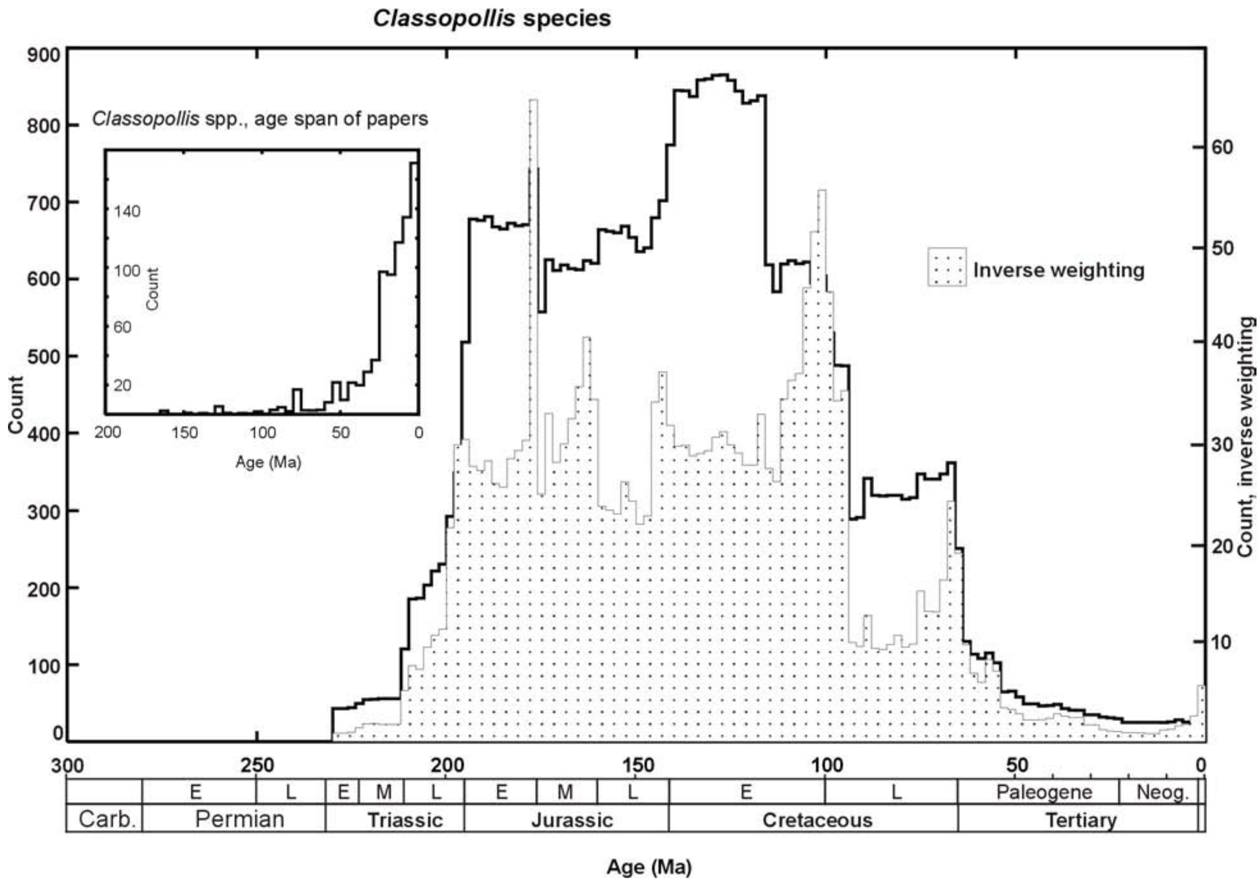

Figure 2 - Distribution of literature records of the genus* Classopollis *from Palynodata v6.0, using the geological time scale of van Eysinga (1978) and the technique of White and Jessop (in press). The bold line (left scale) indicates the number of literature records. The thin line (right scale) is the distribution of literature records inversely weighted (whereby each record is inversely weighted according to the age span which it gives for* Classopollis*, thus attaching less importance to more generalized age ranges in generating the histograms). Inset is a distribution of the age spans given in the literature comprising* Classopollis *results (most age spans are given as less than 30 million years).

records for the genus *Classopollis* were rare and were, therefore, assessed by reviewing the original papers. All the Paleozoic records were rejected for reasons given in annotations to the papers (see Appendix 1). Reasons for including *Classopollis* spp. as part of Permian assemblages are: 1) generalizing too broadly the ages and assemblages when the information was entered into the Palynodata system, 2) mistranslation of the literature, or 3) omitting to note that the original author had dismissed its presence as due to contamination.

Figure 2 shows the distribution of *Classopollis* after deletion of the literature which yielded spurious Paleozoic ages (Appendix 1). The left tail of the distribution is truncated at 230 Ma. Also plotted in Figure 2 (thin line and right-hand scale) is the same Palynodata retrieval with the age range data “inversely weighted”, such that the contribution of each literature citation to the age bins is inversely proportional to the chronological span of the age interpretation (White and Jessop, in press). This minimizes the effect of long, generalized age interpretations on the shape of the distribution. Inverse weighting has an effect on the shape of the distribution, but the basic central tendency and stratigraphic range of *Classopollis* remain intact. Inset into Figure 2 is the age span, in millions of years, given for *Classopollis* by papers comprising the input data for Figure 2. This is information complementary to inverse weighting, allowing the assessment of the quality of the literature and the effect of very generalized and long-ranging age spans on the distribution. The inset shows that most of the literature is of reasonable high resolution, generally citing age spans of less than 30 million years.

The shape of the *Classopollis* distribution (Figure 2) does not differ markedly from that expected in depicting the origin and increasing abundance of a fossil genus, although the distribution, as plotted after literature review, is truncated at the left tail. This part of the curve should theoretically be expected to have a more gradual gradient. It would, however, take a considerably more onerous literature review to refine this gradient.

Figure 3 is a contoured representation of the distribution of *Classopollis* by time and modern latitude of the study site. The 0.1 contour is an approximation of the temporal/latitudinal “footprint” of the genus. It shows that, in the

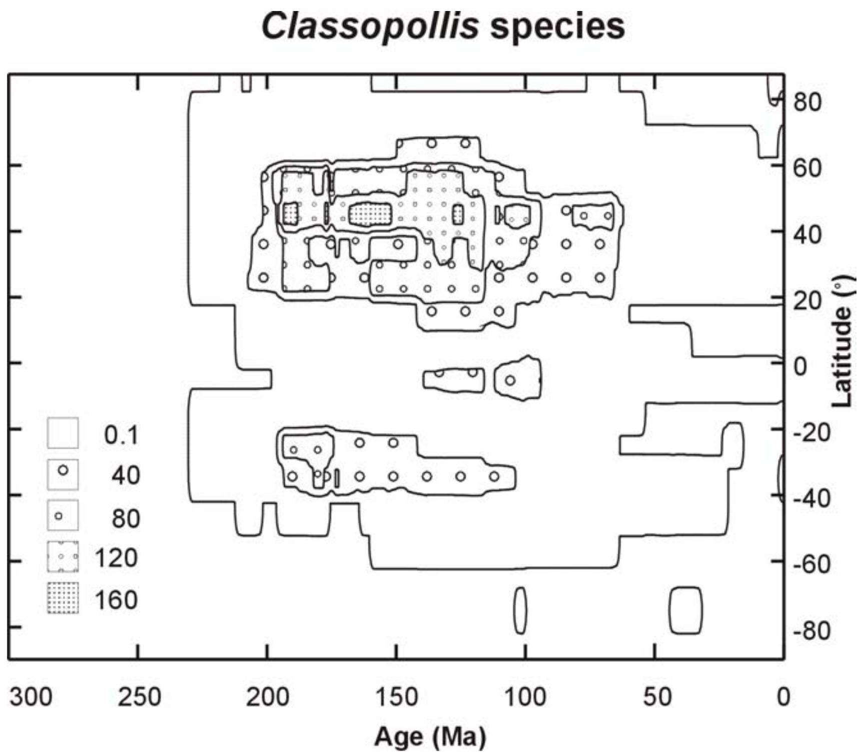

Figure 3 - The unweighted Classopollis results plotted by time and modern latitude using the technique of White and Jessop (in press). The upper Watrous Formation in the Saskatchewan study area, near 50ºN, and falling between the Middle Triassic and Middle Jurassic, is within the latitude and time interval where *Classopollis* ***is recorded abundantly. The values are the binned counts of literature references.***

geological record, *Classopollis* has been commonly observed near the latitude of southern Saskatchewan (about 50ºN) after 214 Ma, or Late Triassic and younger on the van Eysinga (1978) timescale. Its occurrence in upper Watrous time is therefore to be expected.

The results and age interpretation reported here for 2,224 literature references and 4,331 records of *Classopollis* constitute more than 86% of the literature and records for this pollen morphotype. *Classopollenites*, listed in Palynodata as an orthographic variation of *Classopollis*, yielded only 20 literature references and 38 records, which were not included in data used to construct Figures 2 and 3. Also, the genus *Corollina*, considered synonymous with *Classopollis* (Jarzen and Nichols, 1996), was not included in the Palynodata search and plots. Palynodata yielded 331 literature references and 584 records for *Corollina*. Unpublished plots show a similar distribution for *Corollina* as for *Classopollis*, with a few records in the Paleozoic Era. Paleozoic records are virtually removed by inverse weighting of the literature. Thus, generalized ages given in the literature for *Corollina* are largely responsible for the apparent Paleozoic record. Inclusion of either of these taxa in the search results would not alter exclusion of the Paleozoic ages in the record of the *Classopollis* morphotype.

The literature review demonstrates that there are no valid Paleozoic records of pollen identified as *Classopollis*. This conclusion is strengthened by the fact that it is an abundantly recorded genus with a very large base in the literature. The origins of the Circumpolles, pollen of the Cheirolepidiaceae, are found in the Middle Triassic (Jarzen and Nichols, 1996; Warrington, 1996) and *Classopollis* pollen, a genus of the Circumpolles, is accepted as part of the Upper Triassic record by Warrington (1996). Thus the maximum age of *Classopollis* is no older than Triassic, and probably no older than Middle Triassic.

The lowest palynological sample in well 16-12-9-13W2, C-404570 (Table 3), contains *Callialasporites trilobatus*, although it did not yield *C. classoides*. Palynodata v6.0 listed 332 literature references and 403 records for *C. trilobatus*, but no records are older than the Triassic, and very few records are older than the Late Triassic. Thus, this sample argues strongly against a Paleozoic age for the overlying anhydrite sample.

c) Re-evaluation of Pocock's "Watrous" Samples

The publications by Pocock (1970, 1972) on the terrestrial and marine palynomorphs of the Jurassic of Saskatchewan stand as major documents that deservedly have received much attention in the dating of some of the problematic units. Jansonius attempted to check the fossil content of as many slides as were mentioned or listed in Pocock's papers, relevant to the Watrous Formation. The review by J. Jansonius (Appendix 2) concludes that those samples attributed to the Watrous Formation by Pocock provide little information useful for dating the unit.

3. Age and Palynoflora of the Lower Gravelbourg Formation

The lower Gravelbourg samples are generally productive of palynomorphs. Most of the samples collected are from the upper unit of the lower Gravelbourg (unit B of Kreis, 1991). They produce a larger variety of palynomorphs than samples from unit A. Similarly, unit B yields a greater variety of microfossils and produces a more reliable age than unit A, which was deposited in more restricted sedimentary environments (Wall *et al.*, this volume).

The samples were prepared by standard techniques and concentrated, before a kerogen slide was mounted, using a 10 µm nominal screening and an ultrasonic probe. In this report, the taxonomic usage of Pocock (1962, 1 970, 1972) has generally been followed in order to facilitate comparison with Pocock's established palynological zonation for the Jurassic of Saskatchewan.

a) Lower Gravelbourg Unit A

The palynological record of unit A is limited. In 10-2-9-23W2, the record includes two samples from depths 1335 to 1336 m and 1337 to 1338 m. The upper sample yielded no palynomorphs, and the lower yielded only sparse *C. classoides*. In 4-27-15-23W3, three samples were taken from 3453.5 to 3438 ft. No biostratigraphic subdivision was apparent over this interval. The palynomorph assemblages included the following taxa, although not all palynomorphs appeared in all samples.

acritarchs
- *Tasmanites* sp.

dinoflagellates
- *Gonyaulacysta* sp.
- cf. *Jansonia jurassica* Pocock 1972

pollen
- bisaccate pollen
- ?*Cerebropollenites macroverrucosus* Thiergart 1949
- *Classopollis classoides* Pflug emend Pocock and Jansonius 1961
- *Cycadopitys* sp.

spores
- *Baculatisporites comaumensis* Cookson 1953
- *Concavissimisporites montuosus* (Döring) Fensome 1983
- ?*Contignisporites* sp.
- *Distalanulisporites schulzii* Pocock 1970
- *Gleicheniidites circinidites* (Cookson) Dettmann 1963
- *Harrisispora subsimplex* (Bolkovhitina) Pocock 1970
- *Klukisporites* ? n. sp.
- *Matheisporites tumulosus* Döring 1964
- ?*Polycingulatisporites reduncus* (Bolkhovitina) Playford and Dettman 1965

The assemblage is dominated by continental fossils. The marine fossils are extensively pyrite scarred. *Matheisporites tumulosus* is more abundant in these samples than in lower Gravelbourg unit B samples. The age of the assemblage is discussed below with that of the lower Gravelbourg unit B assemblages.

b) Lower Gravelbourg Unit B

Unit B samples are palynologically more abundant and more productive than unit A samples. They are also floristically richer, perhaps a consequence of the greater abundance. However, assemblages from units A and B are not taxonomically distinct, so they cannot be distinguished in age.

The taxa from unit B assemblages are listed below (all taxa do not necessarily occur in every sample). The ages assigned to several of these taxa by Pocock and by other authors is indicated with the taxon.

foraminifera
- microforaminiferal linings

fungal spores
- *Microsporonites* sp.

acritarchs
- *Dictyotidium eastendense* Pocock 1972; $J1^2$ to $J2^2$, Lower Jurassic (upper part) to Upper Bajocian (Pocock, 1972)
- *Pterospermopsis* sp.
- *Tasmanites* sp.

alga
- *Botryococcus* sp.
- *Exesipollenites* sp.

dinoflagellates

Jansonia jurassica Pocock 1972; J2[2], upper Bajocian (Pocock, 1972; Jansonius, 1986), although a Palynodata v6.0 search yielded rare occurrences ranging from Sinemurian to Valanginian
Batiacasphaera group dinoflagellate

pollen

bisaccate pollen
Callialasporites dampieri (Balme) Sukh Dev 1961
Callialasporites trilobatus (Balme) Sukh Dev 1961; J1[3] to J3[3], upper Lower Jurassic to post-Kimmeridgian (Pocock, 1970)
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Classopollis classoides (Pflug) Pocock and Jansonius 1961
Eucommiidites troedssonii Erdtman 1948

spores

Baculatisporites comaumensis (Cookson) Potonié 1956
Chasmosporites stelckii Pocock 1970; J2[1], Lower Bajocian (Pocock, 1970)
Ceratosporites sp. of Pocock 1970
Ceratosporites rotundiformis (Kara-Murza) Pocock 1970; J1[3] to J3[1], upper Lower Jurassic to Callovian (Pocock, 1970)
Concavissimisporites delcourtii Pocock 1970; J2[1], Lower Bajocian (Pocock, 1970)
Concavissimisporites southeyensis Pocock 1970; J2[1], Lower Bajocian (Pocock, 1970)
Concentrisporites pseudosulcatus (Briche, Danzé-Corsin and Laveine) Pocock 1970; J2[1], Lower Bajocian (Pocock, 1970)
Contignisporites sp.
Distalanulisporites schulzii Pocock 1970
Gleicheniidites senonicus Ross 1949
Harrisispora subsimplex (Bolkovhitina) Pocock 1970; J3[1], Callovian (Pocock, 1970)
Gleicheniidites senonicus Ross 1949
Klukisporites pseudoreticulatus Couper 1958, robust form. *K. pseudoreticulatus* Couper 1958 occurs in the Late Jurassic to Cenomanian according to Singh (1971, p96) and is equivalent to *Ischyosporites pseudoreticulatus* (Couper) Fensome 1983, occurring in the Kimmeridgian to earliest Valanginian according to Fensome (1987, p18) and is also equivalent to *Dictyotriletes (Klukisporites) pseudoreticulatus* (Couper) Pocock 1964, which occurs in the upper Jurassic according to Pocock (1964, p41)
Klukisporites foveolatus Pocock 1964, robust form
Lycopodiacidites sp.
Lycopodiacidites spinatus Pocock 1970; J3[1], Callovian (Pocock, 1970)
Matheisporites tumulosus Döring 1964
Neoraistrickia truncata (Cookson) Potonié 1956
Obtusisporis sp.
Reticulatisporites jurassicus Pocock 1970
Triangulopsis discoidalis Döring 1961; J2[1] to J3[1], Lower Bajocian to Callovian (Pocock, 1970)
Uvaesporites argenteaeformis (Bolkhovitina) Schulz 1967; Lower and Middle Jurassic to Lower Cretaceous (Tralau, 1968)
Verrucosisporites variabilis Pocock 1970; J3[1], Callovian (Pocock, 1970)

The absence of a more complete dinoflagellate assemblage and presence of the freshwater to brackish water *Botryococcus* argues that the lower Gravelbourg unit B assemblage represents a range of freshwater to brackish water, probably representing estuarine or marginal marine environments. This is consistent with the dominance of the assemblages by a continental microflora.

The age of the lower member of the Gravelbourg Formation can be estimated from the palynological assemblages. *Jansonia jurassica* is a poorly known (probably gonyaulacacian) dinoflagellate (Fensome *et al.*, 1993) to which Pocock (1972) assigns a J2[2], Late Bajocian, age. A Palynodata v6.0 search shows that records of this fossil occur most commonly between the Bajocian and Callovian, although records range as young as Valanginian. The continental palynomorphs fit with a Middle Jurassic assemblage. *Chasmosporites stelckii*, *Concavissimisporites southeyensis* and *Concentrisporites pseudosulcatus* are Early Bajocian; and *Triangulopsis discoidalis* is Early Bajocian to Callovian, and *Harrisispora subsimplex* is considered to be Callovian (Pocock, 1970). Moreover, no schizaeaceous spores occur in these samples, and thus is consistent with an age no younger than Middle Jurassic.

4. Conclusions: Ages and Environments

The presence of *Classopollis* pollen in the upper Watrous member indicates that the unit cannot be Paleozoic in age. The maximum age of *Classopollis* is probably Middle Triassic. A useful minimum age limit for the Watrous

Formation cannot be determined from the palynomorphs recovered. The overlying lower Gravelbourg member, of Middle Jurassic age, indicates, however, that the Watrous must be Middle Jurassic or older. The upper Watrous member is, therefore, likely to be Middle Triassic to Middle Jurassic in age.

The upper Watrous palynological assemblages are too limited to reliably interpret the environment of deposition, although the assumption seems reasonable that the environment was too stressful to support a diversity of continental or marine organisms. The lower Gravelbourg was apparently deposited in a variety of freshwater to brackish water environments, although samples from unit A in the 10-2-9-23W2 well have suggestions of a greater marine influence.

5. Acknowledgments

K. Kreis helped with sampling the mudstones and anhydrites and providing stratigraphic interpretations. We acknowledge A. Duk-Rodkin and D. Nuñez for their courteous assistance in the translation of papers in Russian, German and Portuguese, and R. Fensome and the GSC Calgary Library for assistance in obtaining the documents annotated in Appendix 1. A.R. Sweet and J. Utting provided valuable palynological advice. L. Dancey carefully prepared the samples for palynological study. J.E. Christopher, over many years, has provided much help and advice regarding the Jurassic of Saskatchewan.

6. References

Brooke, M.M. and Braun, W.K. (1972): Biostratigraphy and Microfaunas of the Jurassic System of Saskatchewan; Sask. Dep. Miner. Resour., Rep. 161, 83p.

Denison, R.E., Krouse, H.R., and Poulton, T.P. (2001): Isotopic data (Sr, S, and O) from anhydrites in the northern Williston Basin, and Pennsylvanian ages for the Watrous and Amaranth formations of Saskatchewan and Manitoba; *in* Summary of Investigations 2001, Volume 1, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2001-4.1, p77-93.

Enkin, R.J., Baker, J., and Osadetz, K.G. (2001): Paleomagnetic indications for a Late Paleozoic age for part of the Watrous Formation, Williston Basin, southern Saskatchewan; *in* Summary of Investigations 2001, Volume 1, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2001-4.1, p72-76.

Fensome, R.A. (1987): Taxonomy and Biostratigraphy of Schizaealean Spores from the Jurassic-Cretaceous Boundary Beds of the Aklavik Range, District of Mackenzie; Palaeontographica Canadiana, No. 4. Can. Soc. Petrol. Geol., Geol. Assoc. Can., 49p.

Fensome, R.A., Taylor, F.J.R., Norris, G., Sarjeant, W.A.S., Wharton, D.I., and Williams, G.L. (1993): A classification of living and fossil dinoflagellates; Micropalaeont., Spec. Publ. No. 7; Amer. Mus. Nat. Hist., 351p.

Fensome, R.A., Riding, J.B., and Taylor, F.J.R. (1996): Chapter 6. Dinoflagellates; *in*: Jansonius, J. and McGregor, D.C. (ed.), Palynology: Principles and Applications, Amer. Assoc. Strat. Palynol. Found., Vol. 1, p107-169.

Jansonius, J. (1962): Palynology of Permian and Triassic sediments, Peace River area, western Canada; Palaeontographica, Abst. B., Band 110, p35-98.

__________ (1986): Re-examination of Mesozoic Canadian dinoflagellate cysts; S.A.J. Pocock (1962, 1972), Palynol., v10, p201-223.

Jarzen, D.M. and Nichols, D.J. (1996): Chapter 9, Pollen; *in*: Jansonius, J. and McGregor, D.C. (eds.), Palynology: Principles and Applications, Amer. Assoc. Strat. Palynol. Found., Vol. 1, p261-291.

Kreis, L.K. (1991): Stratigraphy of the Jurassic System in the Wapella-Moosomin Area, Southeastern Saskatchewan; Sask. Energy Mines, Rep. 217, 90p.

Milner, R.L. and Thomas, G.E. (1954): Jurassic system in Saskatchewan; in Clark, L.M. (ed.), Western Canada Sedimentary Basin, Amer. Assoc. Petrol. Geol., Ralph Leslie Rutherford Memorial Volume, p250-267.

Pocock, S.A.J. (1962): Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the western Canada plains; Palaeontographica, Abt. B, Bd. 111, Lfg. 1-3, p1-95.

__________ (1964): Pollen and spores of the Chlamydospermidae and the Schizaceae from upper Mannville strata of the Saskatoon area; Grana Palynologica, v5, no2, p129-209.

__________ (1970). Palynology of the Jurassic sediments of western Canada, Part 1, Terrestrial species; Palaeontographica, Abt. B, Bd. 130, p12-136.

__________ (1972): Palynology of Jurassic sediments of Western Canada, Part 2, Marine species; Palaeontographica, Abt. B, Bd. 137, p85-153.

Pocock, S.A.J. and Jansonius, J. (1961): The pollen genus *Classopollis* Pflug, 1963; Micropaleont., v7, no4, p439-449.

Poulton, T.P. (1984): The Jurassic of the Canadian Western Interior, from 49ºN Latitude to Beaufort Sea; *in* Stott, D.F. and Glass, D.J. (eds.), The Mesozoic of Middle North America, Can. Soc. Petrol. Geol., Mem. 9, p15-41.

Poulton, T.P., Christopher, J.E., Hayes, B.J.R., Losert, J., Tittemore, J., Gilchrist, R.D., Bezys, R., and McCabe, H.R. (1994): Chapter 18. Jurassic and Lowermost Cretaceous of the Western Canada Sedimentary Basin; *in* Mossop, G.D. and Shetsen, I. (comp.), Geological Atlas of the Western Canada Sedimentary Basin, Can. Soc. Petrol. Geol./Alta. Geol. Surv., p297-316.

Singh, C. (1971): Lower Cretaceous Microfloras of the Peace River Area, Northwestern Alberta; Resear. Counc. Alta., Bull. 28, Vols. 1 and 2 and Appendix, 542p.

Stott, D.F. (1955): Jurassic Stratigraphy of Manitoba; Manit. Dep. Mines Miner. Resour., Publ. 54-2, 78p.

Tralau, H. (1968): Botanical investigations into the fossil flora of Eriksdal in Fyledalen, Scania. II: The Middle Jurassic microflora; Sveriges Geologiska Undersökning, Serie C, p1-185.

van Eysinga, F.W.B. (1978): Geological Time Table; 3rd ed., Elsevier Scientific Publishing Company, Amsterdam.

Wall, J.H. (1960): Jurassic microfaunas from Saskatchewan; Sask. Dep. Miner. Resour., Rep. 53, 229p.

Warrington, G. (1996): Chapter 20A, Triassic spores and pollen; *in*: Jansonius, J. and McGregor, D.C. (ed.) Palynology: Principles and Applications; Amer. Assoc. Strat. Palynol. Found., v2, p755-766.

White, J.M. and Jessop, C.M. (in press): Population-based analysis and graphic interpretation of fossil palynomorph records from Palynodata: Taxonomic and biostratigraphic implications; Palaeogeog., Palaeoclim., Palaeoecol.

Appendix 1

This is an annotated list of apparent but spurious Paleozoic records of *Classopollis* that were retrieved and listed from Palynodata v6.0. This review by J. White corrects the supposed Paleozoic records that appear in the database. Palynodata output format has been retained, with some spelling corrections and reformatting.

PALYNODATA DOCUMENT NO: 00091
YEAR: 1965
AUTHORS: DE JERSEY, N.J.
ENG. TITLE: PLANT MICROFOSSILS IN SOME QUEENSLAND CRUDE OIL SAMPLES
REFERENCE: GEOLOGICAL SURVEY OF QUEENSLAND, Volume 0, (329), Page:1-9

In this study, microfossils from oil samples were studied, showing that oil from Permian rocks yielded microfossil assemblages consistent with a migration of oil from a Jurassic source into the Permian. *C. classoides* is used as an indicator of a Jurassic source for the oil. This interpretation is backed up by the carbon ratios of Permian sediment, indicating that it is not a potential source rock due to thermal maturity.

PALYNODATA DOCUMENT NO: 00402
YEAR: 1962
AUTHORS: CHALONER, W.G. and CLARKE, R.F.A.
ENG. TITLE: A NEW BRITISH PERMIAN SPORE.
REFERENCE: PALAEONTOLOGY, Volume 4 (0), Page: 648-652

Chaloner and Clarke dispute that *Classopollis belloyensis* Pocock and Jansonius 1961 is in fact a *Classopollis* grain. They suggest that it is a pollen organized like *Vittatina*, and that the holotype (1961, Pl. 1, fig. 10-12) corresponds to a polar view of a *Vittatina*-like grain, rather than an equatorial view of *Classopollis*. They note that *Vittatina* has been recorded with certainty from the Permian. Thus, they would restrict *Classopollis* from the Rhaetic to the Mesozoic. Chaloner and Clarke (1962) think that Tertiary records may have been derived from the Mesozoic, but Jarzen and Nichols (1996) accredit the Paleocene records of *Classopollis*.

PALYNODATA DOCUMENT NO: 00466
YEAR: 1966
AUTHORS: KEDVES, M. and BOHONY, E.
ENG. TITLE: SHORT REVIEW OF THE PALYNOLOGIC YIELD FROM THE PRE-QUATERNARY OF HUNGARY WITH PARTICULAR REGARD TO THE STRATIGRAPHIC POSITON OF THE URKUT MANGANITE.
FOR. TITLE: KURZER UEBERBLICK UEBER DIE PALYNOLOGISCHEN ERGEBNISSE AUS DEM PRAEQUARTAER UNGARNS MIT BESONDERER BERUECKSICHTIGUNG DER STRATGRAPHISCHEN STELLUNG DES URKUTER MANGANERZES.
REFERENCE: ACTA MINERALOGICA-PETROGRAPHICA, (SZEGED), Volume 17 (2), Page:115-122

This paper reports on the pre-Quaternary palynological sequence of Hungary. *Classopollis* is not reported in Permian deposits. The accompanying range chart shows *Classopollis classoides* as present in the Late Triassic and the Liassic (early Early Jurassic). (Original in German, translated by J. Jansonius, 2 Nov 2001).

PALYNODATA DOCUMENT NO: 00569
YEAR: 1961
AUTHORS: POCOCK, S.A.J. and JANSONIUS, J.
ENG. TITLE: THE GENUS CLASSOPOLLIS PFLUG,1953
REFERENCE: MICROPALEONTOLOGY, Volume 7 (4), Page:439-449

Pocock and Jansonius (1961) published the species *Classopollis belloyensis* from the Permian Belloy Formation of northern Alberta. Jansonius (1962) did not record any specimen of *Classopollis* in his later monograph on the palynology of Permian and Triassic sediments of the Peace River area.

Slides from the sample containing the holotype of *H. belloyensis* were retrieved by Jansonius from the Imperial Oil palynological slide collection which now is housed at GSC-Calgary. The slide containing the holotype, H-385-2, was not in the collection, but 15 slides from the same sample were found. Slide H-385-3 is virtually barren, but a scan yielded a specimen of *C. classoides* (93.0/11.5), as well as a dinoflagellate of the *Batiacasphaera* group (Williams et al., 1993). This indicates Mesozoic contamination in the sample, because the dinoflagellates range chiefly from Late Triassic to Recent (Fensome et al., 1996). Slide H-385-4 yielded woody organic detritus and amorphous kerogen, but virtually no palynomorphs. Slide H-385-24 has woody organic detritus and plant tissue but very few palynomorphs, although two specimens of *Classopollis classoides* were found (100.6/11.9, 87.6/14.0; 32-26 µm). J. Utting confirmed that the slide does not contain a Permian palynomorph assemblage (pers. comm., 1 Nov 2001). Although the holotype of *C. belloyensis* was not found, the presence of a dinoflagellate indicates that Mesozoic contamination is present, and the type of *Classopollis* pollen found in this preparation is consistent with Mesozoic contamination in an otherwise barren sample. Because the sample was prepared from core material, the contamination presumably was introduced, or not removed, in the laboratory. It must be recognized that the sample was prepared and reported on over 40 years ago, during a pioneering period of palynology when stratigraphic ranges of taxa were not as well known and dinoflagellates were scarcely understood.

PALYNODATA DOCUMENT NO: 00606
YEAR: 1962
AUTHORS: JANSONIUS, J. and STAPLIN, F.L.
ENG. TITLE: LATE PALEOZOIC SACCATE POLLEN
REFERENCE: POLLEN ET SPORES, Volume 4 (2), Page:353-354

This is an abstract with dendrogram proposing evolutionary relationships amongst saccate pollen. A questionable origin in the Stephanian (Carboniferous) is indicated for *Classopollis*, and a certain presence in the Permian is indicated. There are no original data reported, and the age of *Classopollis* is surely derived from Pocock and Jansonius (1962, reference 00569, discussed above).

PALYNODATA DOCUMENT NO: 00915
YEAR: 1964
AUTHORS: COMBAZ, A.
ENG. TITLE: PALYNOFACIES.
FOR. TITLE: LES PALYNOFACIES.
REFERENCE: REVUE DE MICROPALEONTOLOGIE, Volume 7 (3), Page:205-218

A Permian record of *Classopollis* is recorded in Palynodata from Combaz (1964), but the entry is apparently due to a mistranslation of the manuscript, in which "Permian" and *"Classopollis"* are juxtaposed in the same paragraph. Combaz (1964) interprets palynofacies. He notes (1964, p. 208) that *Disaccites* dominance is well known in the Permian, as *Classopollis* is typically over-represented in the Infralias. The Liassic is Lower Jurassic. (Original in French.)

PALYNODATA DOCUMENT NO: 02053
YEAR: 1968
AUTHORS: GEIGER, M.E. and HOPPING, C.A.
ENG. TITLE: TRIASSIC STRATIGRAPHY OF THE SOUTHERN NORTH SEA BASIN
REFERENCE: PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, BIOLOGICAL SCIENCES, Volume 254 (790), Page:1-36

For practical purposes, Geiger and Hopping (1968) consider *Classopollis classoides* and *Classopollis torosus* to be the same species. They accept a Rhaetian and younger age for *C. torosus*. *C. torosus* is not as common in the Rhaetian and Early Jurassic as *Circulina meyeriana*, with which they say *C. torosus* has been confused by earlier workers.

PALYNODATA DOCUMENT NO: 02339
YEAR: 1987
AUTHORS: SLABOSPITSKAYA, E.A.
ENG. TITLE: SPORES AND POLLEN CONTENT LOCAL DISTRIBUTION FUNCTION
FOR. TITLE: FUNKTSIYA LOKAL'NOGO PASPREDELENNYA SODERZHANII TAKSONOV SPOR I PYL'TSY
REFERENCE: SOVETSKAYA GEOLOGIYA, Volume 0 (10), Page:17-20

This paper reports an experiment for a 'clarification of function of local distribution of the content of spore and pollen taxa'. It investigates the numerical distribution of 5 taxa in 41 preparations of the same 70 g rock sample from one interval of a well. No age is given for the sample, but the presence of *Trilobosporites* in the sample with *Classopollis* indicates a Late Jurassic to Cretaceous age. (Original in Russian, read by A. Duk-Rodkin, 6 Nov. 2001).

PALYNODATA DOCUMENT NO: 02892
YEAR: 1960
AUTHORS: DE JEKHOWSKY, B., SAH, S.C.D. and LETULLIER, A.
ENG. TITLE: PALYNOLOGICAL RECONNAISANCE OF THE PERMIAN, TRIASSIC AND JURASSIC OF BOREINGS DONE BY THE PETROLEUM SOCIETY OF MADAGSCAR IN THE MORONDAVA BASIN.
FOR. TITLE: RECONNAISSANCE PALYNOLOGIQUE DU PERMIEN, TRIAS ET JURASSIQUE DES SONDAGES EFFECTUÉS PAR LA SOCIÉTÉ DES PETROLES DE MADGASCAR DANS LE BASSIN DE MORONDAVA.
REFERENCE: SOCIÉTÉ GEOLOGIQUE DE FRANCE. COMPTES RENDU SOMMAIRE DES SEANCES DE L'ACADÉMIE DES SCIENCES, Volume 7, Page:166-168

This paper deals with zonation of the Permian to the Middle Jurassic of Madagascar. *Classopollis* appears and develops in the Jurassic, and *Classopollis* (2 species) is more or less abundant in the Dogger. *Classopollis* is not mentioned as a component of pre-Jurassic assemblages. (Original in French).

PALYNODATA DOCUMENT NO: 06865
YEAR: 1975
AUTHORS: AKYOL, E.
ENG. TITLE: LOWER PERMIAN PALYNOLOGY OF SARIZ (KAYSERI) AND PAMUCAK YAYLASI (ANATALYA-TURKEY) AND OBSERVED JURASSIC CONTAMINATION DUE TO THE "PAMUCAK" AND "GOYNUK" RIVERS.
FOR. TITLE: PALYNOLOGIE DU PERMIEN INFÉRIEUR DE SARIZ (KAYSERI) ET DE PAMUCAK YAYLASI (ANTALYA-TURQUIE) ET CONTAMINATION JURASSIQUE OBSERVÉE, DUE AUX RUISSEAUX "PAMUCAK" ET "GOYNUK".
REFERENCE: POLLEN ET SPORES, Volume17 (1), Page:141-179

This paper describes a Permian palynological assemblage in Turkey, and concludes that fluvial erosion and transport explains rare contamination of the samples by Upper Jurassic palynomorphs, including *Classopollis torosus* (Reis.) Couper 1958. (Original in French).

PALYNODATA DOCUMENT NO: 08032
YEAR: 1976
AUTHORS: KAR, R.K.
ENG. TITLE: MIOFLORISTIC EVIDENCES FOR CLIMATIC VICISSITUDES IN INDIA DURING GONDWANA.
FOR. TITLE:
REFERENCE: GEOPHYTOLOGY, Volume 6 (2), Page:230-244

Kar (1976) describes the Indian microflora and climatic interpretation from the Permian through to the Lower Cretaceous but *Classopollis* pollen is mentioned only with reference to the Lower Jurassic Lathi Formation.

PALYNODATA DOCUMENT NO: 08952
YEAR: 1978
AUTHORS: DE LIMA, M.R. and ROCHA-CAMPOS, A.C.

ENG. TITLE: MICROFLORA OF THE CASSANJE SERIES (KARROO SYSTEM), ANGOLA. (ABSTRACT)
FOR. TITLE: MICROFLORA DA"SERIE"DE CASSANJE (SISTEMA KARROO), ANGOLA. (ABSTRACT)
REFERENCE: CONGRESO ARGENTINO DE PALEONTOLOGIA Y BIOESTRATIGRAFIA, 2ND, ACTAS Y PRIMER CONGRESO LATINOAMERICANO DE PALEONTOLOGIA, BUENOS AIRES, 1978, Volume 0 (0), Page:22-22

and

PALYNODATA DOCUMENT NO: 14437
YEAR: 1980
AUTHORS: DE LIMA, M.R. and ROCHA-CAMPOS, A.C.
ENG. TITLE: MICROFLORA OF THE CASSANJE "SERIES", ("KARROO SYSTEM"), ANGOLA
FOR. TITLE: MICROFLORA DA "SERIE"DE CASSANJE("SISTEMA KARROO"), ANGOLA
REFERENCE: CONGRESO ARGENTINO DE PALEONTOLOGIA Y BIOESTRATIGRAFIA, 2ND, ACTAS Y PRIMER CONGRESO LATINOAMERICANO DE PALEONTOLOGIA, BUENOS AIRES, 1978, Volume 0 (0), Page:81-101

Paper 14437 describes the palynoflora of the middle unit of three informally named stratigraphic units of the Karroo System of Angola. The lowest, shell-bearing bed is of probable neoPaleozoic age ("neopaleozóica"). The highest, shell-bearing bed is of Early Triassic age ("eotriássica"). The intermediate, 55-m thick bed yields a palynoflora containing elements considered typical of the Mesozoic, especially the Triassic, such as *Vitreisporites*, *Gnetaceaepollenites*, *Bennettitaepollenites*, *Classopollis*, *Cycadopites*, *Dyctiophillidites* and *Lundbladispora*. The manuscript cites references indicating that all of these can occur rarely in the Permian, citing Pocock and Jansonius (1961) for *Classopollis* [but see note herein concerning Pocock and Jansonius (1961)]. It notes that the abundance of *Lundbladispora* is similar to the early Triassic flora of western Europe. Also in this assemblage are *Punctatisporites gretensis*, *Protohaploxypinus sewardii*, *Striatopodocarpites cancellatus*, Gondwanan forms which occur preferentially in Permian strata. No detail is given concerning the stratigraphic distribution of assemblages within the intermediate unit but the unit contains *Classopollis* in a flora of relatively imprecise late Paleozoic-early Mesozoic age. (Original in Portuguese, translation with assistance of D. Nuñez.)

PALYNODATA DOCUMENT NO: 08849
YEAR: 1977
AUTHORS: MCLACHLAN, I.R. and BURGER, D.
ENG. TITLE: AN INVESTIGATION OF THE LOWER PERMIAN MIDDLE ECCA AMMONITE LOCALITY AT ALLETA, NATAL.
REFERENCE: PALAEONTOLOGIA AFRICANA, Volume 20 (0), Page:53-63

This paper investigates the provenance of an ammonite which was reported to have been found in Alleta mine in the Early Permian Ecca Series of Natal, South Africa. *Classopollis* sp., cf. *C. meyeriana*, pollen which was found in the matrix of the ammonite indicates an age no older than Upper Triassic for the ammonite. The palynological evidence, supported by evidence from organic petrography and thermal maturity, indicates that the ammonite was not derived from the mine. The paper concludes from other literature that *Classopollis* pollen has not been reported from the Karroo Basin in Permian or Triassic rocks.

PALYNODATA DOCUMENT NO: 09528
YEAR: 1980
AUTHORS: OUYANG, S. and LI, Z.
ENG. TITLE: MICROFLORA FROM THE KA-YI-TOU FORMATION OF FUYUAN DISTRICT, E. YUNNAN AND ITS BEARING ON STRATIGRAPHY AND PALEOBOTANY.
REFERENCE: NANKING INSTITUTE OF GEOLOGY AND PALAONTOLOGY, ACADEMIA SINICA, PEKING. STRATIGRAPHY & PALAEONTOLOGY OF UPPER PERMIAN COAL -BEARING FORMATION WESTERN GUIZHOU AND EASTERN YUNNAN, CHINA, Volume0 (0), Page:123-194

The illustrated specimen *Classopollis*? sp. (Plate 5, fig. 33) appears to be a spore. (Original in Chinese)

PALYNODATA DOCUMENT NO: 09810
YEAR: 1980
AUTHORS: LUKOSE, N.G. and MISRA, C.M.
ENG. TITLE: PALYNOLOGY OF PRE-LATHI SEDIMENTS (PERMO-TRIASSIC) OF SHUMARWALI TALAI STRUCTURE, JAISALMER, WESTERN RAJASTHAN, INDIA.
REFERENCE: INTERNATIONAL PALYNOLOGICAL CONFERENCE, 4TH, PROCEEDINGS, (LUCKNOW), Volume 2 (0), Page:219-227

The age interpretation in Palynodata is generalized, derived from the abstract and introduction. *Classopollis* spp. pollen are found in Palynozone I, which is assigned a Triassic age. They are not part of Palynozone II, which is assigned a Permian age.

PALYNODATA DOCUMENT NO: 10647
YEAR: 1982
AUTHORS: ALVIN, K.L.
ENG. TITLE: CHEIROLEPIDIACEAE: BIOLOGY, STRUCTURE AND PALEOECOLOGY.
REFERENCE: REVIEW OF PALAEOBOTANY AND PALYNOLOGY, Volume 37 (1), Page:71-98

The age reported here for *Classopollis* is Late Triassic to Turonian, following Srivastava (1976) but Alvin indicates that Paleocene occurrences in the southern Soviet Union may be acceptable.

PALYNODATA DOCUMENT NO: 12758
YEAR: 1978
AUTHORS: MCKELLAR, J.L.
ENG. TITLE: MICROFLORAL ASSEMBLAGES FROM GSQ EDDYSTONE 1
REFERENCE: GEOLOGICAL SURVEY OF QUEENSLAND, Volume 0 (0), Page:1-37

Permian to Rheato-Liassic microfloral assemblages were recovered from the GSQ Eddystone 1 well in the Surat-Bowen Basin, Queensland, Australia. *Classopollis* sp. cf. *C. chateaunovi*, *C. meyeriana*, *C. simplex* and *C*. spp. ind. are listed as occurring only in the 27.35 to 96.42 m interval of the well, which is of Liassic age.

PALYNODATA DOCUMENT NO: 15020
YEAR: 1975
AUTHORS: SAFYAINIKOV, Y.V.
ENG. TITLE: CONCERNING THE FORMATION, SIZE AND AGE OF THE LOWER TRIASSIC TUFFOGENIC STRUCTURE OF SOUTH WESTERN YAKUTS (IN-MATERIAL ON THE BIOSTRATIGRAPHY AND PALEOGEOGRAPHY OF EASTERN SIBERIA)
FOR. TITLE: OSOBENNOSTI FORMIROVANIYA, SOSTAV, I VOZRAST NEZHETRIASCOVYKH TUFOGENNYKH OBRAZOVANII YUGO- ZAPADNOI YAKUTII (IN-MATERIALY PO BIOSTRATIGRAFII I PALEOGEOGRAFII VOSTOCHNOI SIBIRI)
REFERENCE: TRUDY SIBIRSKOYE OTDELENIYE, INSTITUT ZEMNOI KORY, AKADEMIYA NAUK SSR. VOPROSY BIOSTRATIGRAFII I PALEOGEOGRAFII SIBIRSKOY PLATFORMY , Volume 0 (0), Page:49-55
Classopollis pollen was recovered as an element in Early Triassic coniferous assemblages from the Siberian Platform. (Original in Russian, translation by A. Duk-Rodkin, 7 December 2001)

PALYNODATA DOCUMENT NO: 15965
YEAR: 1986
AUTHORS: KEDVES, M.
ENG. TITLE: INTRODUCTION TO THE PALYNOLOGY OF PRE-QUATERNARY DEPOSITS
REFERENCE: STUDIA BIOLOBICA HUNGARICA, Volume 20 (2), Page:1-144

Of these two volumes, vol. 1 is a general introduction to palynology, and vol. 2 is a review of stratigraphic palynology, giving a global summary of previous work. It is not specific to Hungary nor is it a primary source. *Classopollis* in not mentioned in discussions of the Carboniferous (Chapter VI) or Permian (Chapter VII), and is noted with reference to the Triassic (Chapter VIII), with a first appearance noted in the Upper Triassic of the Sahara. The presence of *Classopollis* is noted in the Jurassic (Chapter IX).

PALYNODATA DOCUMENT NO: 17857
YEAR: 1981
AUTHORS: NORVICK, M.S.
ENG. TITLE: PERMIAN AND LATE CARBONIFEROUS PALYNOSTRATIGRAPHY OF THE GALILEE BASIN, QUEENSLAND
REFERENCE: BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUSTRALIA, REPORT 219, Volume 0 (219), Page:1-149

Norvick (1981, p. 100) attributes the presence of *Classopollis classoides* in Permian strata of the Lovelle Downs No.1 well, 1618-1622 m, to contamination by cuttings from younger strata higher in the well. This manuscript is easy to scan for taxa as they are underlined instead of italicized, but from the perspective of data entry to Palynodata, it is impressive that this one record of *Classopollis classoides* was picked out of a 149 page report.

PALYNODATA DOCUMENT NO: 19378
YEAR: 1997
AUTHORS: KRASSILOV, V.A.
ENG. TITLE: SYNGENESIS OF XEROMORPHIC PLANT COMMUNITIES IN THE LATE PALEOZOIC TO EARLY CENOZOIC (ABSTRACTED FROM PALEONTOLOGICAL JOURNAL, VOL. #2, PP.125-134)
REFERENCE: PALEONTOLOGICHESKII ZHURNAL, Volume 1997 (2), Page:3-12

This is a paper on paleoecology, and is not primarily a biostratigraphic work. A. Duk-Rodkin (pers. comm., 23 Oct 2001) reported that in this paper *Classopollis* is noted only from the Jurassic, and has translated a critical paragraph:

> "The question about the ecological importance of *Classopollis* has been addressed in many publications. B.A.Vakhrameev (Vakhrameev, 1981) considered this pollen an indicator of relative warm and dry climate. Others researchers relate them to halofites or somofites (Watson, 1982). Now it is known that in Jurassic transgressions, *Classopollis* pollen complexes extended up to the Yamal region most commonly along marine coastline faces (Rovnina, 1996). Direct evidence of growth along sea-coast is in the preservation of "in growth" brachyofil stems in vertical position within the pre-coastal area sediments (Francis, 1983). Often has been indicated the increase of *Classopollis* pollen along the transition of continental to marine faces. Based on general data reconstruction of Classopolietum relates to pre-marine-littoral society with wide spectrum of halophilous and calcephilous adaptation most likely migrating to the continental interior through bogs from abandoned river basins and coastlines of large lakes". (Krassilov, 1997, p. 7)

(Original in Russian, translation by A. Duk-Rodkin 23 Oct 01).

Appendix 2

This is an evaluation, by J. Jansonius, of some of Pocock's (1970, 1972) floral zone or stage determinations for selected samples listed as derived from the Watrous and a few from the Gravelbourg samples. Pocock expressed the ages in terms of floral zones (e.g. "J2[1]," which is shorthand for "lower Middle Jurassic"), together with their geological formation name as understood in the late 1960s. The Imperial Oil palynological slides described in the Pocock papers are now curated by the Geological Survey of Canada (Calgary).

Jansonius re-examined those samples and concluded that the definition of some of the floral zones and the assignment of the stratigraphic unit from which they were collected were unclear in many instances. Although the Watrous samples do not permit age determination, the organic material in them provides useful information regarding the environment of deposition. The quantitative ratios of the organic matter, and therefore the environmental interpretations introduced below, are approximations because at the time of preparation no slides were made before the oxidation step. Most barren "Watrous" samples are listed in the processing records as "red" or "grey" "silty anhydrites." A few of the "Watrous" samples contain spore/pollen assemblages that are similar to the Middle Jurassic assemblages listed as J2[1,2,3].

In the list below, the abbreviation, "Proc. bk.", refers to the processing records that still are available. Some of these samples were processed twice, which should give confidence in their fossil content being in place. Pocock's Imperial Oil sample numbers and the stratigraphic label he attached to each sample are shown in quotation marks and parentheses; when not in quotes such indications are my own comments (J.J.). The most recent picks on the top and the base of these formations, derived from Table A2-1, are cited in bold italics.

Imperial Seymour **4-19-3-31W1**

3553 ft (Imp. 2228; "Watrous") ***(upper Watrous, 3457 to 3582 ft)***
Indeterminate age; barren; nothing identifiable. Only some abraded black/opaque (woody?) material.

3668 ft (Imp. 2230; "Watrous") Similar to above sample, except that virtually no organic matter is preserved (pyrobitumen?).

Williamson Nottingham **6-17-4-32W1**

3763 ft (Imp. 2235; "Watrous") ***(lower Watrous, 3637 to 3772 ft)***
As in Seymour at 3668 ft

Socony St. Antoine **5-11-6-32W1**

3560 ft (Imp. 2224; "Watrous") As in Seymour at 3668 ft
(lower Watrous, 3454 to 3577 ft)

3576 ft (Imp. 2226; "Watrous") As in Seymour at 3668 ft.

Precision Queen City #6 **6-31-6-1W2**

3914 ft "Watrous" ***(lower Watrous, 3770 to 3917 ft)***
One slide with much fox-brown, medium/fine, rather thick and lumpy, abraded amorphous material (derived from woody material?). No fossils.

3917 ft Not processed; Watrous (red silty, fide litho log)

Table A2-1 - Formation picks for wells quoted in Appendix 2 (provided by K. Kreis).

Well	Red Jacket	Lower Shaunavon Unit 1 (Rocanville "B")	upper Gravelbourg (Rocanville "A")	lower Gravelbourg Unit B	lower Gravelbourg Unit A	upper Watrous	lower Warous	Mississippian
4-19-3-31W1	3100 ft			3322 ft	3353 ft	3457 ft	3582 ft	3684 ft
6-17-4-32W1	3138 ft			3370 ft	3400 ft	3508 ft	3637 ft	3772 ft
5-11-6-32W1	2968 ft			3188 ft	3220 ft	3295 ft	3454 ft	3577 ft
1-6-31-6-1W2	3276 ft			3534 ft	3565 ft	3648 ft	3770 ft	3917 ft
4-8-7-1W2	3239 ft			3477 ft	3509 ft	3601 ft	3724 ft	3879 ft
9-12-7-1W2	3208 ft			3457 ft	3494 ft	3568 ft	3691 ft	3834 ft
10-23-10-23W2		4108 ft	4140 ft	4211 ft	4253 ft	4367 ft	4441 ft	4743 ft
14-22-15-1W2	2183 ft	2360 ft	not present	2410 ft	not present	2451 ft	not present	2572 ft
13-4-27-28W2		not present	not present	2422	not present	2458 ft	2582 ft	n/a
15-11-6-20W3		not present	4820 ft	not present	4870 ft	4909 ft	not present	4922 ft

3924 ft (Imp. 2222; "Watrous; grey, silty")
Indeterminate age; barren. No organic matter preserved.

Imperial Manor **4-8-7-1W2**

3876 ft (Imp. 2208; "red silty Watrous") ***(lower Watrous, 3724 to 3879 ft)***
Barren; scattered small fragments of pale brown, grey, to opaque unstructured, featureless organic material possibly derived from algal mat.

3881 ft (Imp. 2211; "light grey silty, anhydritic Watrous")
As in Seymour at 3668 ft

Tidewater Manor **9-12-7-1W2**

3825 ft, 3830 ft (Imp. 2232, 2233; "Watrous"; red, silty) ***(lower Watrous, 3691 to 3834 ft)***
Not processed.

3835 ft (Imp. 2234; "Watrous", light grey) As in Seymour at 3668 ft

Imperial Dahinda #1 **10-23-10-23W2**
(lower Gravelbourg unit B, 4211 to 4253 ft)
(lower Gravelbourg unit A, 4253 to 4367 ft)
(upper Watrous, 4367 to 4441 ft)

4226-4230 ft (Imp. 1867; "lower Gravelbourg - J1^{3}")
Middle Jurassic; (Toarcian?-) Bajocian (-Bathonian?)

75%	Small abraded to large angular woody fragments
15%	flakes of degraded algal mat
5%	spores and gymnosperm pollen (very poorly preserved), *Classopollis*, ?bisaccates
5%	acritarchs and ?dinocysts (*Dictyotidium eastendense*, *Acanthodiacrodium jurassicum*)

Probably proximal estuarine environment, with strong fluviatile influx; no rhombic imprints

4242-4247 ft Middle Jurassic (Imp. 1868; as for previous sample)
Bajocian-(?Bathonian), slightly calcareous

88%	flakes of algal mat (enclosed bits of wood)
10%	angular/abraded wood (gymnosperm) fragments
1%	poor (some well) preserved spores/pollen (*Classopollis*)
1%	Poor acritarchs, dinocysts (*Jansonia*)

Probably distal estuarine, with weak fluvial influx; no rhombic imprints

4262-4266 ft (Imp. 1869; "upper Watrous")
Age indeterminable; "barren"; no slides made; "limestone"

4282-4287 ft (Imp. 1870; "upper Watrous")
Age indeterminable; "barren"; no slides made; "limestone"

4307-4312 ft (Imp. 1871; "upper Watrous")
Age indeterminable; "barren"; six slides made; "limestone"
100% thin poor algal mat fragments; no fossils.
Possibly a lateral estuarine, or salt marsh setting; no rhombic imprints.

Tidewater North Wapella **14-22-15-1W2**

2424-2429 ft (Imp. 1968; "Gravelbourg Fm.") ***(Top lower Gravelbourg, 2410 ft)***
Middle Jurassic (J1^{3}?-) J2$_{1}$
Much coarse/fine angular woody material; some amorphous material. No acritarchs (and rare dinocyst fragments?). *Classopollis* spp., bisaccates, *Corrugatisporites amplectiferus*, *Dictyotriletes crateris*, trilete spores.

2444-2449 ft (Imp. 1969; "Watrous; J3$^{?}$[sic]" -- possibly: J1^{3}?) ***(Top upper Watrous, 2451 ft)***

No slides found in trays (three were made).

Tidewater Davidson Crown #1 13-4-27-28W2

2427-2430 ft (Imp. 423; "lower Gravelbourg; J1[3]") ***(lower Gravelbourg, 2422 to 2458 ft)***
Middle Jurassic (J2[1]); Bajocian (-Bathonian?)
Dominant fine/medium dark woody particles.
Classopollis dominant; *Ovalipollis bitorosus*; *Dictyotidium eastendense*, *Chytroeisphaeridia chytroidea*, small acritarchs.

2457-2459 ft (Imp. 425; "Watrous; J1[?]")
{reproc. bk. 11/494} Middle Jurassic (J2[1]), Bajocian (-Bathonian?); slightly calcareous?

49%	amorphous (algal mat?)
44%	angular, coarse to fine woody material
2%	bisaccate, other gymnosperm pollen
2%	*Botryococcus* spp.
3%	spores/pollen; common varied bisaccate, and other gymnosperm pollen; *Corollina* spp., *Classopollis findlaterensis*, *Callialasporites dampieri*, *C. trilobatus*, *Triangulopsis*, *Cerebropollenites mesozoicus*, *Piceites latens*, *Ovalipollis*. *Corrugatisporites anagrammensis*.

{proc. bk. 1/622} ($J1^3$?-) $J2_1$ (-$J3^1$?) abundant *Classopollis*; common *Exesipollenites*, bisaccates; *Cerebropollenites mesozoicus*

Possibly proximal delta plain, with fluviatile input and freshwater ponds as well as algal mat. No dinoflagellates or acritarchs.

2504-2506 ft (Imp. 426; "Watrous") ***(upper Watrous 2458 to 2582 ft)***
Barren; no slides made.

2558 ft (Imp. 428; "Watrous") Middle Jurassic (Bajocian?) or younger?
[Probably contaminated]

80%	f/m woody matter
15%	amorphous matter
3%	varied dinoflagellates; *Evittia*; *Rhynchodiniopsis*, *Gonyaulacysta orthoceras*, *Hystrichokolpoma* (contamination?); *Netrelytron* sp.
2%	spores/pollen; *Appendicisporites* sp., tricolpate pollen.

Much fine (to medium), more or less abraded pieces of dark woody matter; off-shore prodeltaic to marine. Preservation not very good.

2570 ft Barren; no slides made.

Tidewater Eastend Crown #1 15-11-6-20W3

4858-4863 ft (Imp. 1983; "upper Gravelbourg; J2[1]") ***(upper Gravelbourg, 4820 to 4870 ft)***
Middle Jurassic ($J2^1$-$J2^2$?)
OM: all medium/fine, angular woody.
(reproc. bk.69-281) Dominant *Classopollis* spp.; trilete spores, bisaccate and monosulcate pollen, *Exesipollenites, Triangulopsis discoidalis*; small acritarchs (mostly *Filisphaeridium bullosum*), scattered dinoflagellates, *Sentusidinium rioultii*;
Cicatricosisporites sp.

(lower Gravelbourg unit A, 4870 to 4922 ft, unconform. on Miss.***)***

4905 ft (Imp. 1984; "lower Gravelbourg; J1[3]") Indeterminate; barren.
Much fine abraded woody material; comminuted organic material (p.p. *Botryococcus*?, spores/pollen? (Nothing recognizable).

4910 ft Age indeterminate; barren.
(Medium-) fine black woody material 95%; no recognizable fossils (one *Classopollis*?)