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Palynological analysis of 3 samples from Pan Am Franklin-1 and Skelly Winkler-1 Wells, Cayo Energy

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Introduction

This report documents the results of palynological analysis completed on three cutting samples from two wells Pan Am Franklin-1 (19434 – 19487ft and 19531 – 19636ft), and Skelly Winkler-1 (15488 – 15529ft), provided by Cayo Energy to determine age and paleoenvironments.

The samples were collected from the Smackover Formation, an Upper Jurassic reservoir distributed throughout the U.S. Gulf Coast region that consists of limestones, grainstones, boundstones and dolostones.

The palynological slides were prepared in the UK by Palynological Laboratory Services (PLS) Ltd, and the microscopy analysis was carried out by Carlos Santos.

The three samples yielded abundant to moderate organic matter but poor recovery in terms of palynomorphs. The two samples from the Pan Am Franklin-1well (19434 – 19487ft and 19531 – 19636ft) are characterized by the occurrence of abundant amorphous organic matter, usually over mature, and the poor occurrence of palynomorphs, which when observed, exhibit extremely poor preservation. The sample from Skelly Winkler-1 well (15488 – 15529ft) showed a moderate recovery of amorphous organic matter but a better record of palynomorphs including the recovery of a few dinoflagellate cysts, pollen, and spores.

Summary of Results

Palynological analysis were carried out on three cutting samples from two wells, Pan Am Franklin-1 (19434 – 19487ft and 19531 – 19636ft) and Skelly Winkler-1 (15488 – 15529ft).
The two samples from the Pan Am Franklin-1 (19434 – 19487ft and 19531 – 19636ft) are dominated by the occurrence of Amorphous Organic Matter (AOM) with minor occurrences of opaque equidimensional organic matter, opaque laths, and translucent biostructured material. Both samples recorded the occurrence of *Leiosphaerids*, with sample 19434 – 19487ft showing a higher frequency and occurrence of a couple of poorly preserved palynomorphs. Age diagnostic biostratigraphy markers were not identified on this well.
The only sample from Skelly Winkler-1 (15488 – 15529ft) yielded moderate organic matter content with dominance of opaque equidimensional organic matter, frequent occurrence of opaque laths, and translucent banded biostructured material. Amorphous organic matter is also common. Palynomorph recovery in this sample was better but still poor with few occurrences of *Leiosphaeridia* spp. and poorly preserved unidentified dinoflagellate cysts, in addition to *Micrhystridium* spp. and *Podocarpidites* spp. Unique occurrences of cf. *Ellipsoidyctium cinctum* and fragments of Cf. *Parvisaccites radiatus* and *Systematophora* cf. *areolata* were also observed, and if in situ, indicate a Late Jurassic age, probably Oxfordian to Tithonian.

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Laboratory Processing

The three samples were subject to standard palynological preparation, which involves treating them with warm hydrochloric acid (HCl) to remove carbonates and warm hydrofluoric acid (HF) to dissolve silicates. Residues were diluted with water and split in two. One fraction remained un-sieved and unoxidized and was mounted on a glass slide for kerogen analysis. The second one was sieved through a 10 μm aperture nylon mesh. An aliquot of the sample residue was oxidized using warm nitric acid (HNO3), and the other one was sieved but not oxidized. Two separate coverslips were used for oxidized and un-oxidized preparations, each of which was mounted on a glass slide using Norland Optical Adhesive 61 (NOA 61).

Microscopy Analysis

Microscopy palynological analysis were intended to provide representative counts of dinoflagellate cysts (dinocysts), acritarchs, pollen, spores, algae, fungi, and reworked palynomorphs. Counts of all palynomorphs were planned with the aim of obtaining at least 200 – 300 grains, when possible. However, due to the low recovery in terms of palynomorphs, all the fossils present on each slide, including the oxidized and non-oxidized covers were counted.
The organic matter analysis was performed using the criteria proposed for palynofacies analysis by Batten and Stead (2005), Calvalho et al. (2013) and Niemeyer (2011). Palynofacies analysis was done in a semiquantitative manner counting up to 150 grains, recording any type of palynomorphs including organic matter, dinocysts, acritarchs, and sporomorphs.
The taxonomic identifications of the few dinocysts, acritarchs, pollen, spores and algae recovered were made from numerous sources including Norris (1970), Olmstead et al. (1996), Riding. (2005), Riding and Thomas (1988), Rogers (1987), Stovert et al. (1996), and Williams et al. (1993).

Palynological Analysis Results

Pan Am Franklin-1

Both samples analyzed from this well yielded good recovery in terms of abundant amorphous organic matter (AOM), with frequent amorphous organic matter aquatic (AOMA) and low occurrences of opaque equidimensional particles, opaque laths, and translucent biostructured material. Both samples recorded the occurrence of Leiosphaerids, with sample 19434 – 19487ft showing a higher frequency of *Leiosphaeridia* spp. associated with a few occurrences of poorly preserved palynomorphs. Non-age diagnostic palynomorphs were recognized on this well.

Sample 19434 – 19487ft

This sample is characterized by the occurrence of abundant amorphous organic matter (AOM) associated with frequent amorphous organic matter aquatic (AOMA) and low occurrences of opaque equidimensional particles, opaque laths, and translucent biostructured material (Fig. 1, Appendix 1). Palynomorph recovery was poor, and the assemblage is composed by the occurrence of frequent *Leiosphaeridia* spp., and only a few poorly preserved dinocysts and sporomorphs were observed.

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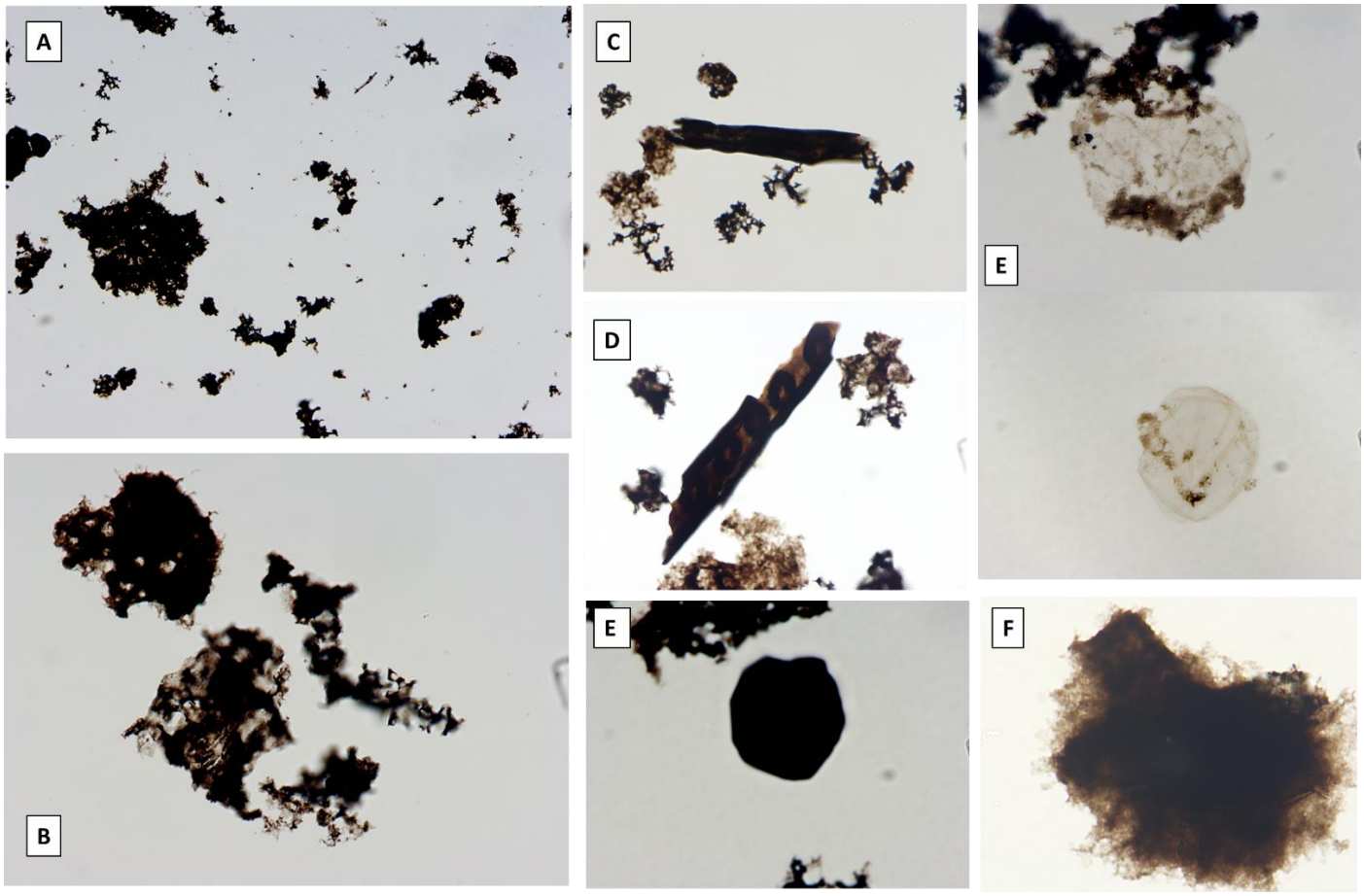

Figure 1. Sample 19434 – 19487ft Pan Am Franklin-1 **A.** Photograph showing a general view of the organic matter present which is characterized by abundant Amorphous Organic Matter (AOM) [transmitted light at 20x]. B. Detailed picture of the AOM [transmitted light at 60x]. C. Opaque Lath [transmitted light at 60x]. D. Translucent Biostructured [transmitted light at 60x]. E. Opaque equidimensional [transmitted light at 60x]. E. *Leiosphaeridia* spp. which are frequent in the sample [transmitted light at 60x]. F. Amorphous organic matter aquatic (AOMA) [transmitted light at 60x].

Sample 19531 – 19636ft

In this sample, the amorphous organic matter (AOM) is dominant and still associated with frequent amorphous organic matter aquatic (AOMA). The occurrence of opaque equidimensional particles is lower compared to the overlying sample, as well as the occurrence of opaque laths and translucent biostructured material (Fig. 2, Appendix 1). Palynomorph recovery was poor and characterized by lower frequency of *Leiosphaeridia* spp., associated with a poorly preserved algae, some broken palynomorphs, and a single specimen of *Micrhystridium* spp.

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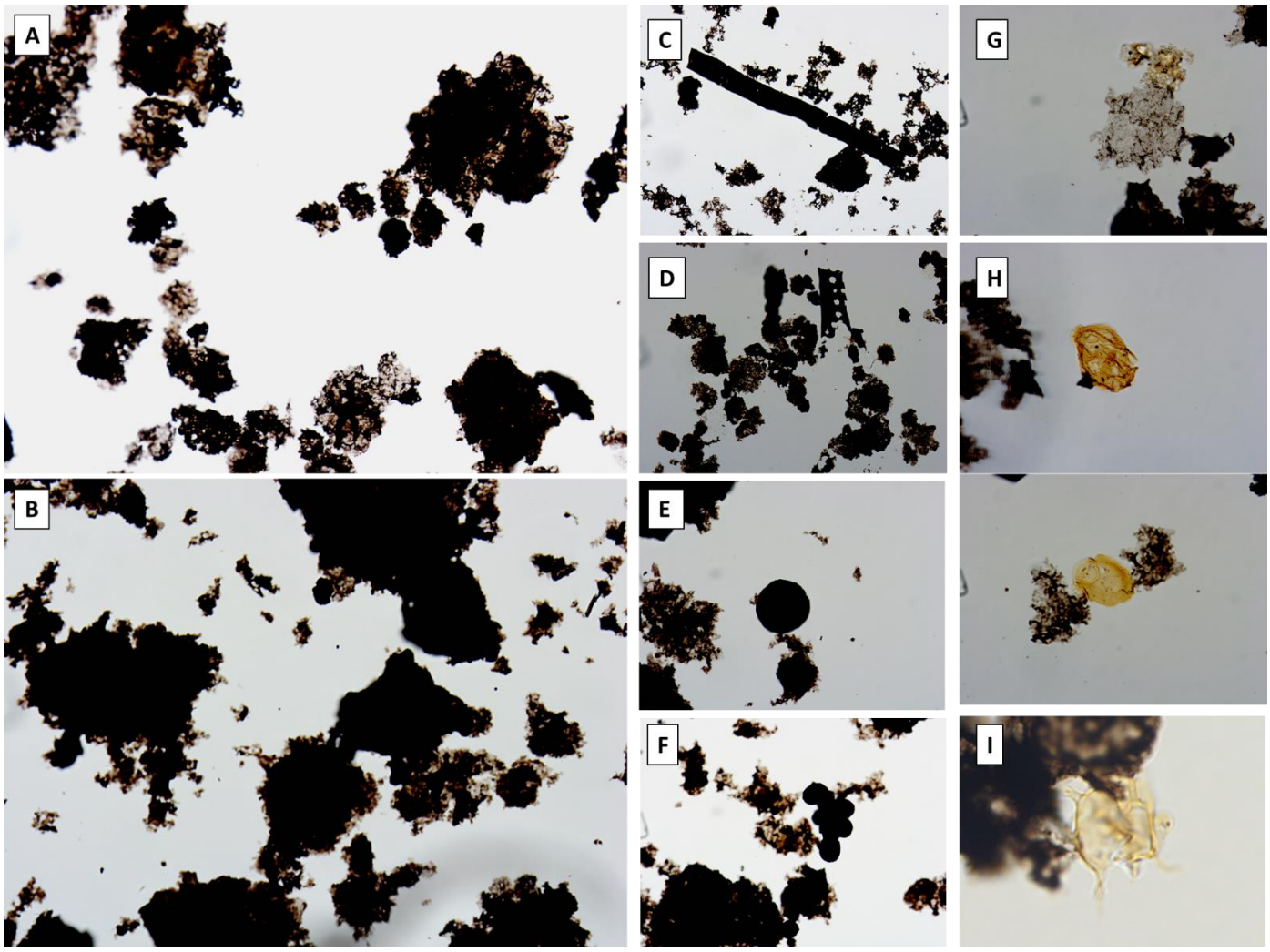

Figure 2. Sample 19531 – 19636ft Pan Am Franklin-1 **A.** Photograph showing the abundant Amorphous Organic Matter (AOM) present in the sample [transmitted light at 20x]. B. Detail of the AOM [transmitted light at 20x]. C. Opaque Lath [transmitted light at 20x]. D. Opaque Biostructured organic matter [transmitted light at 20x]. E. Opaque equidimensional [transmitted light at 20x]. F. Fungal Fruiting body [transmitted light at 20x]. G. Poorly preserved unidentified freshwater algae, it might correspond to *Pediastrum* spp. [transmitted light at 60x]. H. Poorly preserved palynomorphs [transmitted light at 60x]. I. *Micrhystridium* spp., a wide age-range acritarch [transmitted light at 60x].

Chronostratigraphy

No age diagnostic markers were recognized. Both *Leiosphaeridia* spp. and *Micrhystridium* spp. are acritarchs with a wide stratigraphic range and do not constraint the age of the samples.

Environmental Inferences

Palynofacies in these two samples are composed primarily of amorphous organic matter of large size and poorly sorting. Large amounts of AOM indicate environments with high preservation rates and low energies and the preservation of AOM is usually related to dysoxic conditions. The low occurrence of small opaque equidimensional particles and laths might indicate some minor degree of terrestrial influx. In addition to this, acritarchs *Leiosphaeridia* spp. and *Micrhystridium* spp. are considered marine phytoplankton, and their occurrence is indicative of marine conditions. Hence, sediments associated with the samples described above were probably deposited in a marine environment, most likely in dysoxic to anoxic conditions with minor terrestrial influx.

Skelly Winkler-1

Sample 15488 – 15529ft

This sample is dominated by the occurrence of opaque equidimensional organic matter with the occurrence of laths, opaque and translucent biostructured fragments and subordinated amorphous organic matter. The presence of sporomorphs is higher compared to the Franklin-1 samples. They are associated with a single specimen of *Podocarpidites* spp., fragments of unidentified dinocysts, frequent *Leiosphaeridia* spp. and a single occurrence of *Micrhystridium* spp.
Worth to mention the occurrence of poorly preserved cf. *Ellipsoidyctium cinctum, Systematophora* cf. *areolata* and cf. *Parvisaccites radiatus*, taxa with chronostratigraphic value in the Northern Hemisphere and the North Atlantic Coast.

Chronostratigraphy

The presence of cf. *Ellipsoidyctium cinctum* might indicate an age of Oxfordian (Probable M. Oxfordian) to Early Kimmeridgian. In the Northern Hemisphere, *E. Cinctum* has been recognized as spanning the Bathonian (M. Jurassic) - Early Kimmeridgian (Williams et al. 1993), and the Callovian – Oxfordian according to Stancliffe and Sarjeant (1988). Olmstead et al. (1996) assigned a Middle Oxfordian – Early Kimmeridgian age to *E. cinctum* in Arizona. Finally, in the Gulf of Mexico are, *E. cinctum* has been reported as high as the Tithonian – Earliest Cretaceous.

The poorly preserved *Systematophora* cf. *areolata* might indicate a Kimmeridgian – Tithonian age as described by Bebout (1980) in the USA Atlantic Coast, and by Rogers (1988), in Northern Louisiana, where was identified in sediments covering the Late Jurassic – Earliest Cretaceous. In Northern Europe, *S. areolata* is usually recorded in the Oxfordian – Kimmeridgian and the Portlandian in multiple sites in England, Scotland, France, and Germany.

Cf. *Parvisaccites radiatus* is quite common from the Earliest Cretaceous in North America. In Northern Europe, it has its first occurrence in the Kimmeridgian and continues into the Portlandian and the Cretaceous, being quite common in the Late Jurassic and Early Cretaceous in England.

Considering the previous information, an age of Oxfordian – Tithonian, Late Jurassic, is assigned to this sample.

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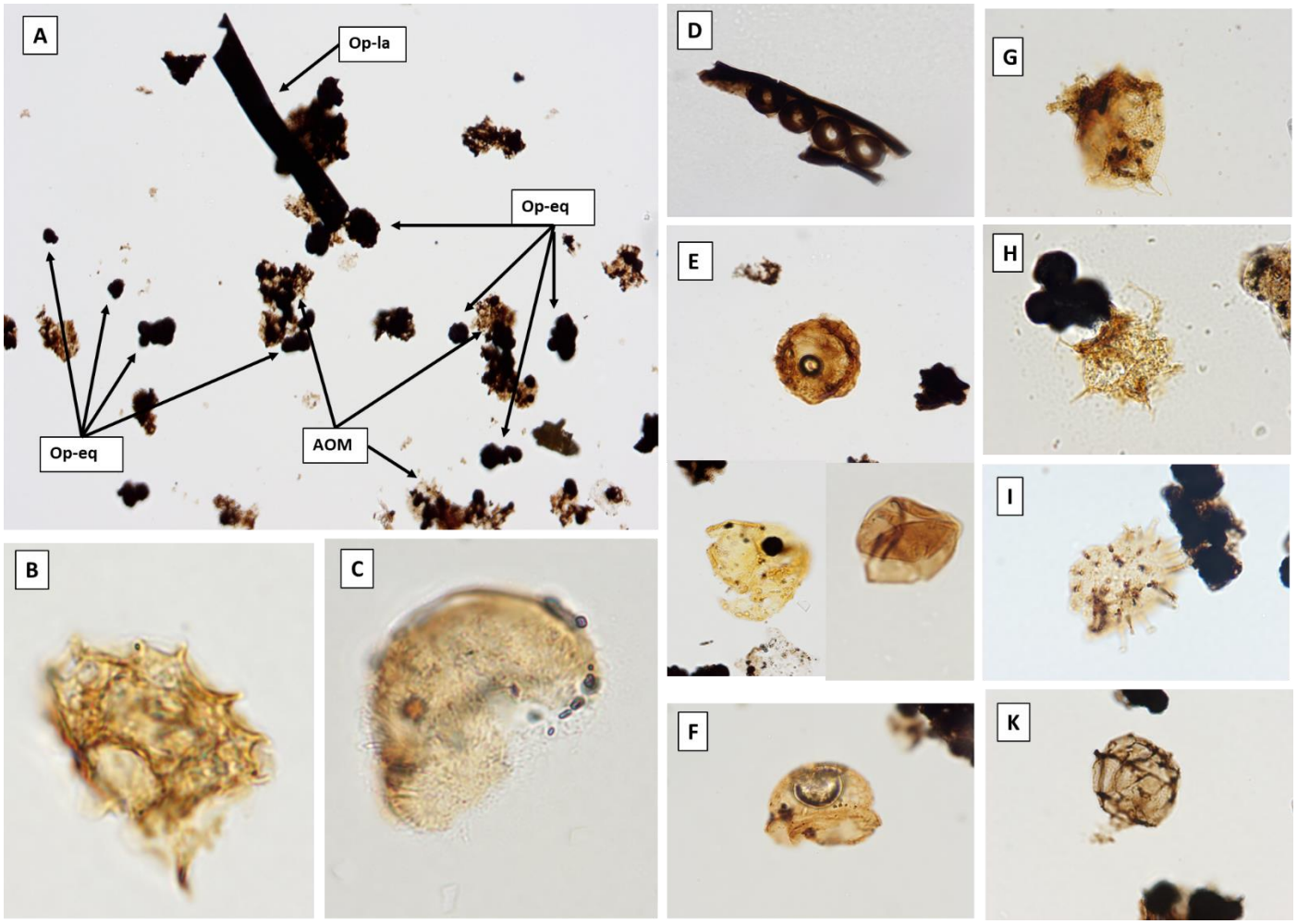

Figure 3. Sample 15488 – 15529ft Skelly Winkler-1 **A.** Photograph showing the different types of OM present in the sample. Assemblage is dominated by opaque equidimensional organic matters (Op-eq), subordinate Amorphous Organic Matter (AOM), and frequent opaque laths (Op-la) and translucent biostructured fragments [transmitted light at 20x]. B. cf. *Ellipsoidyctium cinctum*, age marker for the M. Oxfordian – E. Kimmeridgian in Arizona [transmitted light at 60x]. C. cf. *Parvisaccites radiatus* [transmitted light at 60x]. D. Translucent biostructured organic matter (tracheids) [transmitted light at 60x]. E. Poor preserved sporomorphs [transmitted light at 60x]. F. Fragmented *Podocarpidites* spp. [transmitted light at 60x]. G. Poorly preserved *Systematophora* cf. *areolata, S areolata* has been recorded in the Kimmeridgian – Tithonian in the USA Atlantic Coast [transmitted light at 60x]. H. *Micrhystridium* spp. [transmitted light at 60x]. I. Fragment of unidentified dinocyst. K. *Leiosphaeridia* spp. [transmitted light at 60x].

Environmental Inferences

Palynofacies in this sample are characterized by the dominance of opaque equidimensional particles associated with laths, opaque and translucent biostructured fragments, and subordinated amorphous organic matter. The presence of sporomorphs, dinoflagellate cysts, and acritarchs is comparatively higher than the other samples analyzed. The particle size is small to medium, the sorting is moderate, and the diversity of components is high. These features, according to Batten

and Stead (2005), are associated with relatively low energy fluvially-influenced settings. The abundant opaque particles might be derived from the oxidation of translucent material transported over a prolonged period (Carvalho et al., 2013). All the previous considerations might indicate an inner neritic – proximal environment with proximity to terrestrial sources or redeposition of terrestrial organic matter from fluvio-deltaic sources.

Concluding remarks

The two samples from the Pan Am Franklin-1 well are characterized by abundant to moderate mature to over mature amorphous organic matter, frequent acritarchs, low occurrences of sporomorphs and dinocysts, and minor amounts of opaque equidimensional particles and laths. Sediments were probably deposited in low energy marine environment with dysoxic to anoxic conditions and a minor terrestrial influx. The absence of age diagnostic markers did not allow to assign an age to the sediments.
The sample from the Skelly Winkler-1 well is characterized by the dominance of opaque equidimensional particles, laths, opaque and translucent biostructured fragments, and less abundant amorphous organic matter. The presence of sporomorphs, dinoflagellate cysts, and acritarchs is comparatively higher than the Franklin-1 well samples. Sediments were probably deposited in a proximal environment with proximity to terrestrial sources. Based on the occurrence of cf. *Ellipsoidyctium cinctum*, *Systematophora* cf. *areolata* and cf. *Parvisaccites radiatus* an age of Oxfordian – Tithonian, Late Jurassic was assigned to this sample.
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Recommendations

Although the recovery of palynomorphs was poor in most of the samples, the results obtained in the Skelly Winkler-1 are promising regarding the use of Palynology in the Smackover Formation. A future biostratigraphy program should be focused on sampling the most suitable lithologies for palynological analysis to improve the palynological recovery.

References

Batten, D., Stead, D. T., 2005. Palynofacies Analysis and its Stratigraphic Application. Chapter 10. Stratigraphic Application of Palynofacies.

Bebout,J.W., 1980. Biostratigraphy. (In: Geologic and Operational summary, Cost No.G-2 Well, Georges Bank area North Atlantic OCS. R.V.Amato and E.K.Simonis, editors) United States Geological Survey, Open-File Report Vol. 80 # 269 P. 20- 28

Carvalho, M., Cabral-Ramos R., Crud, M. B., Witovisk, L, Kellner, A., de P. Silva, H., Grillo, O., Riff, D., Romano, P., 2013. Palynofacies as indicators of paleoenvironmental changes in a Cretaceous succession from the Larsen Basin, James Ross Island, Antarctica. Sedimentary Geology 295 (2013) 53 -66.

Niemeyer, P. 2011. Sequence Stratigraphy and Source Rock Characterization of Organic-Rich Shales Within the Jurassic Smackover Formation, Conecuh Embayment, Alabama, U.S.A. Theses and Dissertations. 210. University of Mississippi.

Norris, G., 1970. Palynology of the Jurassic-cretaceous boundary in southern England, Geoscience and Man, 1:1, 57-65.

Olmstead, G. A., Cornell, W. C., Waanders, G. 1996. Oxfordian-Kimmeridgian (Jurassic) dinoflagellate cysts from the Chiricahua Mountains, Arizona, Palynology, 20:1, 221-230,

Riding. J. B., 2005. Middle and Upper Jurassic (Callovian to Kimmeridgian) palynology of the onshore moray firth basin, northeast Scotland, Palynology, 29:1, 87-142.

Riding, J.B., Thomas, J.E., 1988 Dinoflagellate cyst stratigraphy of the Kimmeridge Clay (Upper Jurassic) from the Dorset coast, southern England; Palynology, 12: 65-88.

Rogers,R. (1987) A palynological age determination for the Dorcheat and Hosston Formations; the Jurassic-Cretaceous boundary in northern Louisiana Transactions of the Gulf Coast Association of Geological Societies Vol. 37 P. 447- 456.

Stancliffe,R.P.W., Sarjeant,W.A.S., 1988. Oxfordian dinoflagellate cysts and provincialism. International Symposium on Jurassic Stratigraphy P. 763- 798.

Stovert, L. E. , Brinkhuis, H., Damassa, S. P., de Verteuil, L., Helby, R. J., Monteil, E., Partridge, A. D., Powell, A. J., Riding, J.B., Smelror, M., Williams, G. L., 1996. Mesozoic-Tertiary Dinoflagellates, Acritarchs And Prasinophytes. Chapter 19.

Olmstead, G, A., Cornell W. C., Waanders, G. L., 1996. Oxfordian-Kimmeridgian (Jurassic) dinoflagellate cysts from the Chiricahua Mountains, Arizona, Palynology, 20:1, 221-230

Williams, G.L., Stover, L.E., Kidson, E.T. 1993. Morphology and stratigraphic ranges of selected Mesozoic-Cenozoic dinoflagellate taxa in the Northern Hemisphere. Geological Survey of Canada, Paper 92-10: 1-137.

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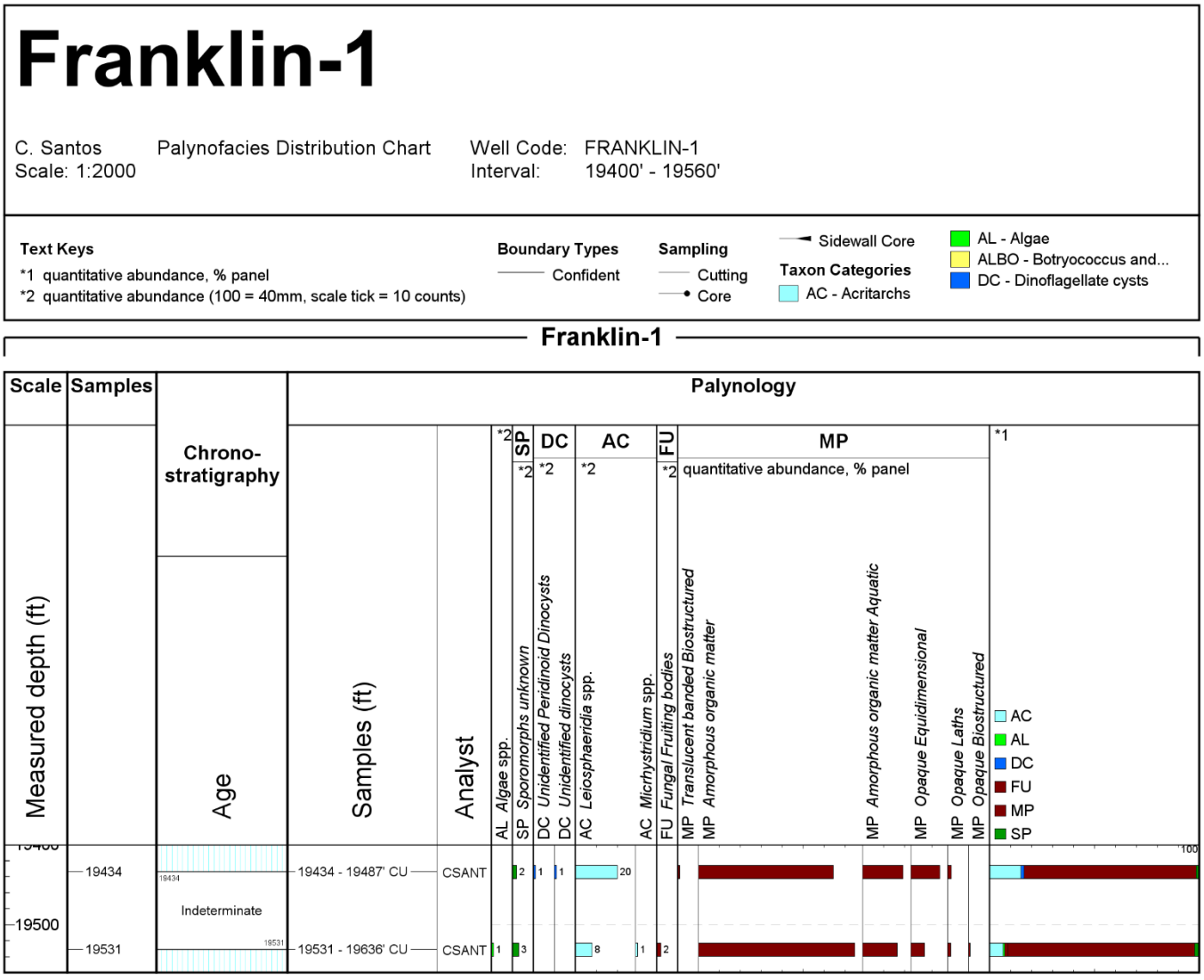
Appendixes

Appendix 1. Palynofacies Distribution Chart Pan Am Franklin-1



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Appendix 2. Palynofacies Distribution Chart Skelly Winkler-1