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Abstract

Five unoxidized palynological (kerogen) slides from the lowermost section of the Gannet O-54 well (part of the Geological Survey of Canada – Atlantic's archived slide collection) were re-analyzed with the hope of providing refined ages for this mainly indeterminate interval: slides P3580-07 (9590'/2923.0 m), P3581-07 (9690'/2953.5 m), P3582-07 (9790'/2984.0 m), P3583-07 (9890'/3014.5 m), and P3584-07 (10 000'/3048.0 m). Thermal alteration indices (TAIs) were also measured where possible. Three of the slides are barren (P3581-07, P3583-07, and P3584-07). One slide (P3582-07) contains two spores: Middle to Late Devonian *Ancyrospora* sp. with a TAI value of 6+ and an indeterminate spore with a TAI value of 5+. Both spores are interpreted as caved and thus not useful in determining age. Only one slide, P3580-07 (9590'/2923.0 m), yields in situ, identifiable spores, indicating a Middle to Late Devonian age, which is consistent with previously published palynological data for Gannet O-54.

1. Introduction

Paleozoic rocks in the southern Grand Banks region (offshore Newfoundland, Canada) are understudied due to their uncommon occurrence (encountered in only eight offshore wells; Avery and Bell, 1985; Bell and Howie, 1990), their characteristic high degree of alteration (both diagenetic and thermal), and their lack of hydrocarbon potential. Furthermore, the Grand Banks area has had limited recent exploration activity, with only one exploration well drilled in the last twenty years (Lewis Hill G-85 in 2005), making new data scarce. As such, little research has been conducted on the Paleozoic of the southern Grand Banks in the past few decades despite advances in geology, including palynology. This study focusses on the palynology of the Amoco-Imperial Gannet O-54 well (UWI 300O544510052300), from which the most recent published palynological data from 1990 reported Upper Devonian strata overlying basement rocks that are listed as either Precambrian metasediments (Bell and Howie, 1990) or Paleozoic metasediments (Williams et al., 1990). Archived palynology (kerogen) slides from the Geological Survey of Canada – Atlantic were evaluated in this study for the lowermost interval of Gannet O-54 (9590–10 000' / 2923.0–3048.0 m) in light of a better current understanding of the palynology and Paleozoic geology of offshore Newfoundland. As a result, refinement of the age of this interval is presented here. Additionally, where possible, thermal alteration indices were measured to provide new maturation information.

1.1. Well history

The Amoco-Imperial Gannet O-54 well is located offshore on the Grand Banks, approximately 240 kilometres south of St. John's, Newfoundland (45° 03′ 54.57″ N and 52° 38′ 06.07″ W; Fig. 1) (Amoco Canada Petroleum Company Limited, 1972; Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007). The well was originally spudded on 24 September 1971 where it was drilled to a depth of 961' (292.9 m) before being suspended on 27 March 1971. The well was re-entered on 6 March 1972 and drilled to a final total depth of 10 000' (3048 m) by 24 April 1972 (Amoco Canada Petroleum Company Limited, 1972). No hydrocarbon shows were reported from the well and thus it was plugged and abandoned (Amoco Canada Petroleum Company Limited, 1972; Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007). The Gannet O-54 well penetrates Cenozoic, Mesozoic, and Paleozoic rocks before terminating in basement (total depth (TD) at 10 000'/3048.0 m) (Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007).

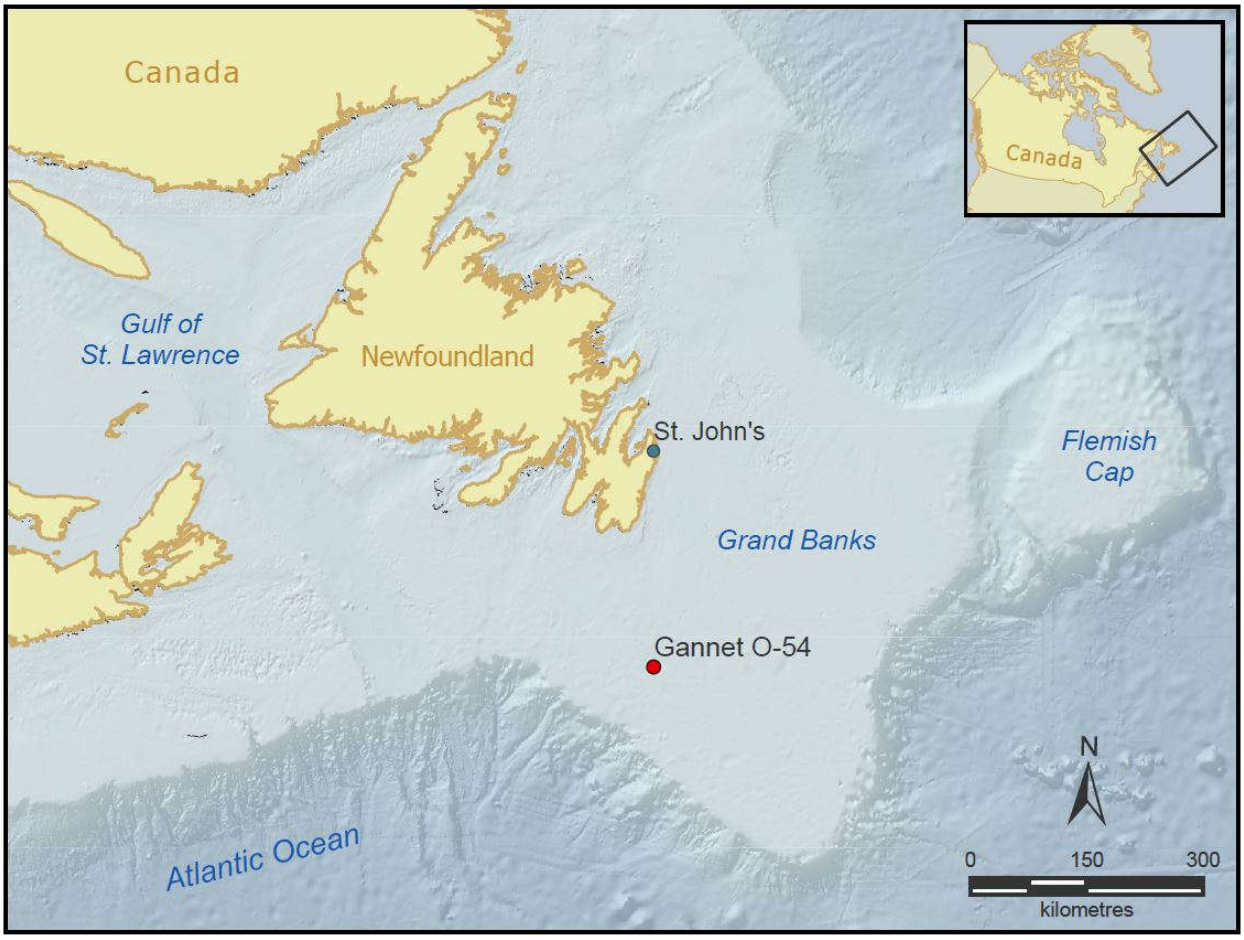

Figure 1. Location map of the Gannet O-54 well on the Grand Banks, south of St. John's Newfoundland. Main map projection: NAD 83 UTM 22N. Inset map projection: Canada Albers Equal Area Conic.

2. Paleozoic Geology Summary of the Gannet O-54 well

The Gannet O-54 well penetrates just over 1000 m of Paleozoic rocks (Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007) before terminating in basement. The basement rocks were initially identified by Amoco Canada Petroleum Company Limited (1972) as quartzite. Devonian spores were later found within the basement interval, leading to its designation as Paleozoic basement (Barss, 1974; Barss and Williams, 1979; Williams et al., 1990), though it could not be determined whether the spores were in situ or caved. The basement interval was also labelled as Precambrian metasediments by Bell and Howie (1990). Upper Devonian shales, siltstones, and sandstones belonging to the Horton Group overlie the basement rocks (Amoco Canada Petroleum Company Limited, 1972; Bell and Howie, 1990; Williams et al., 1990; Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007), and are in turn, overlain by Lower Carboniferous Windsor Group rocks consisting of evaporites (anhydrite, halite), dolostones, and shales (Amoco Canada Petroleum Company Limited, 1972; Bell and Howie, 1990; Williams et al., 1990; Canada-

Newfoundland and Labrador Offshore Petroleum Board, 2007). Lower Cretaceous rocks unconformably overlie the Paleozoic interval in the Gannet O-54 well (Amoco Canada Petroleum Company Limited, 1972; Amoco Production Company Research Centre, 1972; Canada-Newfoundland and Labrador Offshore Petroleum Board, 2007).

3. Review of previous Paleozoic palynology

The ages of the Paleozoic rocks present in the Gannet O-54 well were initially published in the well history report by Amoco in 1972 (Amoco Canada Petroleum Company Limited, 1972; Amoco Production Company Research Centre, 1972). The Paleozoic interval has since been restudied (Barss, 1974; Barss and Williams, 1979), leading to refinements of the ages, with the most recent reference to the age of this section published in Keen and Williams (1990).

3.1. Amoco Well History Report (Amoco Canada Petroleum Company Limited, 1972); Appendix IX -A Paleontological and Palynological Reports (Amoco Production Company Research Centre, 1972)

The initial Paleozoic age data for the Gannet O-54 reported by Amoco in 1972 (Amoco Production Company Research Centre, 1972) included Middle Devonian to Early Mississippian assignments based on palynomorphs from sidewall cores and cuttings.

- 6150–6870’ (1874.5–2094.0 m): Indeterminate
- 6870–8450’ (2094.0–2575.6 m): Early Mississippian
- 8450–9470’ (2575.6–2886.5 m): Devonian (Givetian – Frasnian)
- 9470–10 000’ (2886.5–3048.0 m): Indeterminate
    - 9980–10 000’ (3041.9–3048.0 m): Quartzite (Amoco Production Company Research Centre, 1972), indeterminate (basement; Amoco Canada Petroleum Company Limited, 1972)

3.2. Internal Geological Survey of Canada Palynology Report (Barss, 1974) later published in Geological Survey of Canada Paper 78-24 (Barss and Williams, 1979)

A Geological Survey of Canada internal palynology report (Barss,1974) refined the ages of the Gannet O-54 well, including the Paleozoic interval. These updated ages were based on sidewall cores (swc) and cuttings samples. The internal palynology report was then incorporated as Barss and Williams in Barss et al. (1979), a publication that included age data for 67 wells from offshore eastern Canada.

- 6540’ (1993.4 m; swc): Carboniferous (Visean)
- 6550–6580’ (1996.4–2005.6 m): Possibly Carboniferous (Visean)
- 6580–6600’ (2005.6–2011.7 m): Carboniferous (Visean, early Namurian)
- 6600–7300’ (2011.7–2225.0 m): Carboniferous (Visean)
    - 6640’ (2023.9 m; swc): Likely Carboniferous (Visean)

- 7300–7830’ (2225.0–2386.6 m): Carboniferous (Visean – ?late Tournaisian)
    - 7500’ (2286.0 m; swc): Carboniferous (Visean) fossils with some Devonian (likely Frasnian) specimens (possible reworking)
- 7855’ (2394.2 m): Devonian (Frasnian)
- 7900–9690’ (2407.9–2953.5 m): Devonian (Frasnian-Givetian)
    - 7855’ (2394.2 m; swc): Devonian (Frasnian)
    - 8125’ (2476.5 m; swc): Devonian (Frasnian – possibly Givetian)
- 9690–10 000’ (2953.5–3048 m): Indeterminate

Younger, caved specimens were noted throughout the Paleozoic interval in Barss (1974) and Barss and Williams (1979). The fossils observed in the Visean interval from 6540–7300’ (1993.4–2225.0 m) were predominantly corroded. A minor change in fossil colour was seen in Visean – ?late Tournaisian material from 7300–7330’ (2225.0–2234.2 m). The spores present were highly corroded and remained dark in colour after oxidation. The presence of a specimen of *Pustulatisporites pretiosus* potentially indicated a late Tournaisian age for this thin interval. The authors noted the presence of two fossil assemblages from 7330–7830’ (2234.2–2386.6 m; Visean – ?late Tournaisian) distinguished by preservation and colour. The first assemblage consisted of well-preserved yellow spores, whereas the second assemblage was characterized by highly corroded dark brown spores which may be reworked. The spores interpreted from 7600–7630’ (2316.3–2325.6 m; *Anapiculatisporites* cf. *A. ampullaceous*, *Knoxisporites hederatus, Pustulatisporites* cf. *P. pretisus, Vallatisporites* cf. *V. torulosa, V. vallatus*) further suggested a late Tournaisian age.

A major change in palynomorph colour was noted below 7800’ (2377.4 m; darker fossil specimens below; Barss 1974; Barss and Williams, 1979) which correlated with the interpreted Carboniferous–Devonian transition. The Devonian ages published in Barss (1974) and Barss and Williams (1979) were based on spores observed in cuttings samples and from side wall cores. Devonian spores were reported in the sidewall core at 7500’ (2286.0 m) (Barss, 1974; Barss and Williams, 1979). These spores appeared to be reworked (Barss and Williams, 1979) as the shale fragments were from the anhydrite zone in the Windsor Group and the Amoco lithologic log described the fragments as rounded, suggesting transportation. The authors also reported Devonian spores from 9690–10000’ (2953.5–3048 m) but it is not known whether these spores are caved or in situ.

3.3. Geology of the Continental Margin of Eastern Canada (Keen and Williams,1990)

The most recent publications referencing ages of the Paleozoic in Gannet O-54, based on palynology, are Williams et al. (1990) and Bell and Howie (1990); chapters in Keen and Williams (1990). Williams et al. (1990) divided the interval into three palynomorph zones, collectively encompassing the Devonian and Carboniferous:

- 1993.4–2225.0 m: *Rugospora* spp. Zone (early Carboniferous, Mississippian)

- 2225.0–2386.6 m: *Vallatisporites vallatus* Zone (early Carboniferous, Mississippian, Tournasian)
- 2394.2–2953.5 m: *Hystrichosporites multifuractus* Zone (Late Devonian, Frasnian-Famennian)

The lowermost interval of the well (3039.6 – 3047.8 m), previously referred to as quartzite basement (Amoco Canada Petroleum Company Limited, 1972) and indeterminate Paleozoic sediments (Barss and Williams, 1979), was reported as Paleozoic metasediments by Williams et al. (1990) and Precambrian metasediments by Bell and Howie (1990).

4. Re-examination of Paleozoic palynological slides

Five unoxidized kerogen slides were re-analyzed from the lowermost interval of Gannet O-54 (9590–10 000'/2923.0–3048.0 m): P3580-07 (9590'/2923.0 m), P3581-07 (9690'/2953.5 m), P3582-07 (9790'/2984.0 m), P3583-07 (9890'/3014.5 m), and P3584-07 (10 000'/3048.0 m) (Table 1). The preparations are from cuttings and are part of the Geological Survey of Canada – Atlantic's archived collection. Palynomorph recovery is sparse to absent in all slides, and the organic material is thermally blackened. Three of the five slides examined are found to be barren and thus of indeterminate age: P3581-07 (9690'/2953.5 m), P3583-07 (9890'/3014.5 m), and P3584-07 (10 000'/3048.0 m). Rare spores that occur below 9690' (2953.5 m) are interpreted as caved, resulting in an indeterminate age also for slide P3582-07 (9790'/2984.0 m). The only slide with useful palynological material is P3580-07 (9590'/2923.0 m), which contains corroded Middle to Late Devonian spores. No palynomorphs indicative of an older age are found. Thermal alteration index (TAI) values were determined where possible, based on visual estimates of maturation using the Amoco TAI scale.

5. Summary

The re-examination of the slides from 9590–10 000' (2923.0–3048.0 m) of the Gannet O-54 well provide evidence of a Middle to Late Devonian age for the sample at 9590' (2923.0 m). This is consistent with Barss (1974) and Barss and Williams (1979), who interpreted a Devonian (Frasnian-Givetian) age for the interval 7900' – 9690' (2407.9 – 2953.5 m). The depth of this slide (P3580-07; 9590'/2923.0 m) would fall within the Late Devonian (Frasnian-Famennian) *Hytrichosporites multifurcatus* Zone of Williams et al. (1990), but based on palynomorphs observed in the slide, a Middle Devonian age cannot be excluded. The TAI values (5+ and 6+) measured from caved specimens in slide P3582-07 (9590'/2923.0 m) indicate a dry gas to overmature phase for the interval.

Table 1. Results of the palynological re-examination of the 9590–10 000' (2923.0–3048.0 m) interval of the Gannet O-54 well. AOM = Amorphous organic material.

Slide ID	Depth		Interpreted Age	Palynology	Organics
	feet	metres			
P3580-07	9590	2923.0	Middle to Late Devonian	Corroded spores	Black AOM and black structured kerogen
P3581-07	9690	2953.5	Indeterminate	Barren	Minor black AOM and black structured kerogen
P3582-07	9790	2984.0	Indeterminate due to caved palynomorphs	*Ancyrospora* sp. (Middle to Late Devonian). Black colour. TAI 6+ Indeterminate spore. Dark orange-brown colour. TAI 5+	Minor black AOM. Black structured kerogen with irregular margins
P3583-07	9890	3014.5	Indeterminate	Barren	Minor black AOM
P3584-07	10 000	3048.0	Indeterminate	Barren	Minor black AOM

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