The use of integrated fluid inclusion studies in constraining the petroleum charge history at Parson's Pond, western Newfoundland

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1. Summary and Conclusions

This report presents the results of a fluid inclusion study of 58 core and cuttings samples from three wells in the Parson's Pond area (Contact Exploration Inc. Parson's Pond #1;, Nalcor et al. Finnegan, and Nalcor et al. Seamus). Petroleum, gas, wet gas and aqueous bearing fluid inclusions were identified in all three wells, suggesting a complex hydrocarbon charge history at Parson's Pond, with multiple petroleum charge events with multiple compositions.

The main findings of this study are as follows

- Petroleum and gas-bearing fluid inclusions in the allochthonous cover rocks are restricted to calcite and quartz vein material. This indicates that petroleum and gas migration at Parson's Pond was fracture controlled, and that no hydrocarbons were present during the cementation of the essentially tight sandstones of the Lower Head Formation and Cow Head Group.
- Hydrocarbons were most likely generated at multiple times during progressive burial and heating, and the distribution of petroleum and petroleum and gas-bearing inclusions with depth suggests that deeper levels are gas-prone, with petroleum confined to relatively shallow depths.
- The scarcity of hydrocarbon inclusions in autochtonous carbonates indicates that hydrocarbons were not present during hydrothermal dolomitization, and any potential hydrocarbon charge events must have postdated dolomitization (and hence any associated porosity enhancement)

2. Introduction

Hydrocarbon exploration in Western Newfoundland has been ongoing for nearly 200 years (Department of Energy, 1989), with small quantities of oil produced in the 19^{th} and 20^{th} century from the Port au Port Peninsula and the Parson's Pond area (Fig. 1). Recent exploration has indicated the presence of active petroleum systems in Cambro-Ordovician strata, wherein source rocks are located in the allochthon (e.g. organic rich shales in the Green Point Formation) and carbonate reservoirs within the Lower Ordovician St. George Group in the autochthon (Cooper et al., 2001). However, relatively little is known about the relative timing of petroleum migration and potential migration pathways. In addition it is unclear whether the oil and gas shows represent either a single phase petroleum migration event or multiple migration events from multiple sources. Further understanding of syn- and post-diagenetic petroleum and aqueous fluid flow has important implications for new exploration strategies, particularly at Parson's Pond where oil and gas shows have been recorded in allochthonous sandstones and underlying carbonate reservoirs in the autochthon.

Fluid inclusions represent micro-scale samples of fluids that are trapped during the fluid evolution of sedimentary basins; analysis of these inclusions provides information on the fluid composition associated with diagenetic and post-diagenetic fluid processes. In particular fluid inclusion studies can be used to investigate fossil petroleum systems. This project integrates fluid inclusion petrography and microthermometry of petroleum, gas-bearing and aqueous inclusions with the fluorescence microspectroscopy of inclusion oils, in order to determine the nature and relative timing of oil and gas migration events at Parson's Pond.

3. Geological Setting

Lower Paleozoic rocks in western Newfoundland form part of the outer domain of the Humber Zone, the westernmost of five tectonostratigraphic zones in the Canadian Appalachians (Williams, 1979). The evolution of these rocks during the lower Paleozoic has been discussed by several authors and has been summarized by Cooper et al. (2001). The sedimentary rocks may be divided into autochthonous strata which were, for the most part, deposited in relatively shallow, nearshore settings, and allochthonous units which were deposited in relatively deep, oceanic conditions that were originally some distance to the east (Fig. 2). During the Taconic Orogeny, the allochtonous sediments were thrust up to 100km westwards over the autochthonous strata (Stockmal et al., 1995).

Lower Cambrian to Middle Ordovician autochthonous sequence

Significant rifting, associated with the opening of the Iapetus Ocean, began during the late Proterozoic and early Cambrian (Waldron and van Staal, 2001) and is first represented in western Newfoundland by late Proterozoic, fault-bounded, terrestrial clastics and volcanic rocksof the lower Labrador Group. These strata are unconformably overlain by clastic rocks of the early Cambrian, upper Labrador Group (James et al., 1989). These mixed clastic-carbonate sediments were overlain by a thick (1.5 km) carbonate platform succession, which was deposited as a passive margin to the south of Laurentia. The middle to late Cambrian Port au Port Group is a narrow, high-energy carbonate platform which evolved into a wide, low-energy carbonate platform represented by the early to middle Ordovician St. George Group (James et al., 1989).

The St. George Group comprises of a sequence of subtidal and peritidal limestones and dolostones which have been subdivided, in ascending order, into the Watts Bight, Boat Harbour, Catoche and Aguathauna formations. The group has been mapped throughout western Newfoundland (Knight and James, 1987) and is extensively dolomitized in many areas (Knight et al., 2008). A regional unconformity, the St. George Unconformity, marks the top of the St. George Group, representing a shift from a passive margin to a foreland basin (Knight et al. 1991). The St. George Group is overlain by shelf carbonates of the middle Ordovician Table Head Group (Stenzel et al., 1990), which represent shallow to deep subtidal limestones deposited in the foreland basin. These are overlain by muddy sandstones of the Goose Tickle Group.

Lower Cambrian to Middle Ordovician allochthonous sequence

In western Newfoundland, the Lower Cambrian to Middle Ordovician allochthonous sediments represent a sequence of basinal sedimentary rocks (e.g., Humber Arm Allochton) and ophiolites (e.g., Bay of Islands Complex) which were tectonically transported and thrust upon the autochtonous sequence. The allochton consists of a basal mélange, which is overlain by deepwater sedimentary rocks which together represent the Humber Arm Supergroup (James and Stevens, 1986). The Humber Arm Supergroup is sub-divided into the Cow Head and Curling groups, a sequence of Middle Cambrian to Lower Ordovician sediments which are considered to be the distal equivalents of the autochtonous rocks (James and Stevens, 1986). They consist of deep-water limestones, limestone conglomerates and shales (with minor sandstones and conglomerates) which represent turbidites and debris flows at the continental edge and slope. The Humber Arm Supergroup is conformably overlain by of the Lower Head Formation, a sand-rich synorogenic flysch which is the basinal equivalent of the Table Head and Goose Tickle groups (Quinn, 1995).

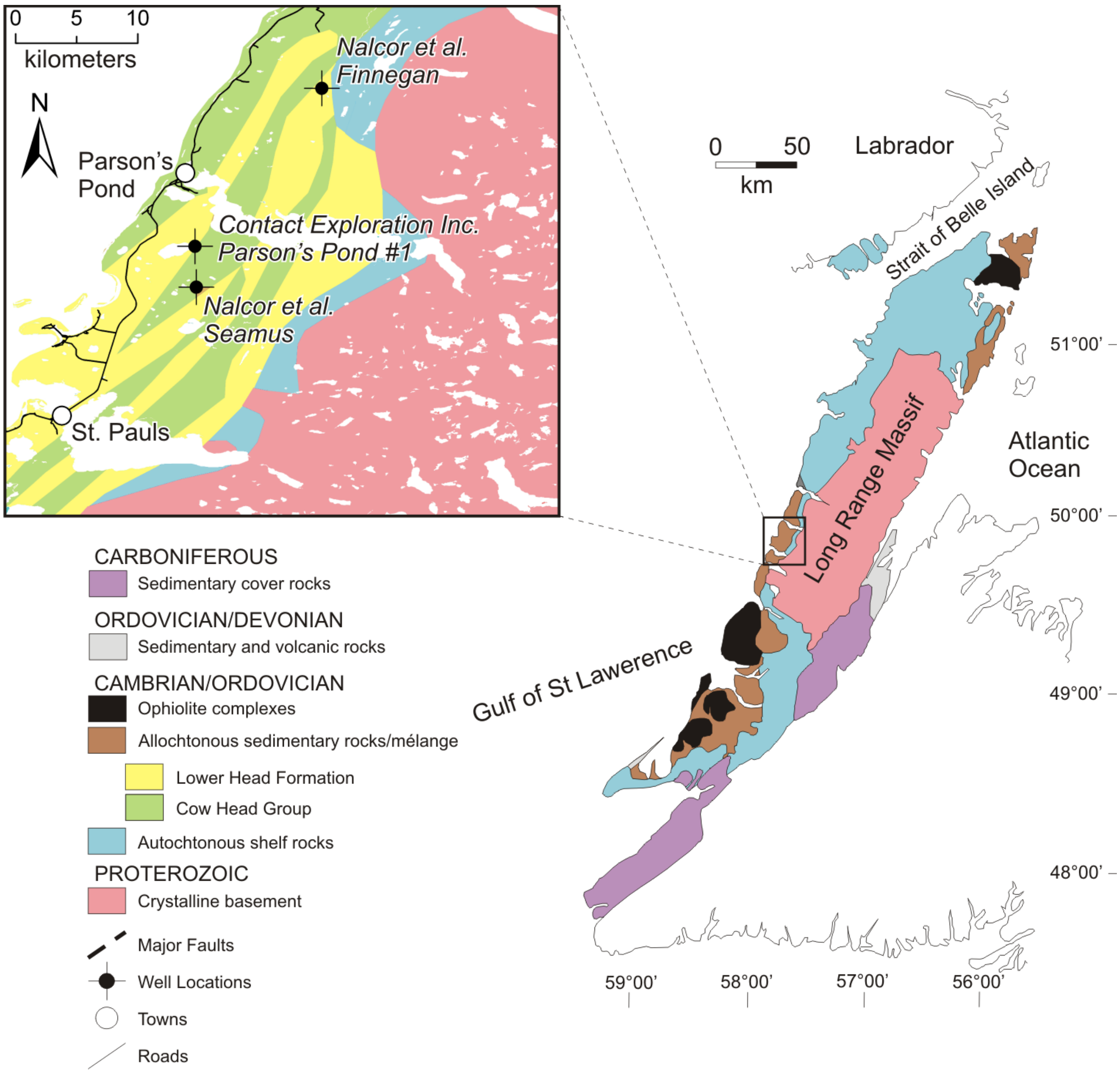

Figure 1: Simplified map of the geology of western Newfoundland, showing the location of Parson's Pond (adapted from Zhang and Barnes, 2004). Inset map showing detailed geology of Parson's Pond area, with locations of exploration wells.

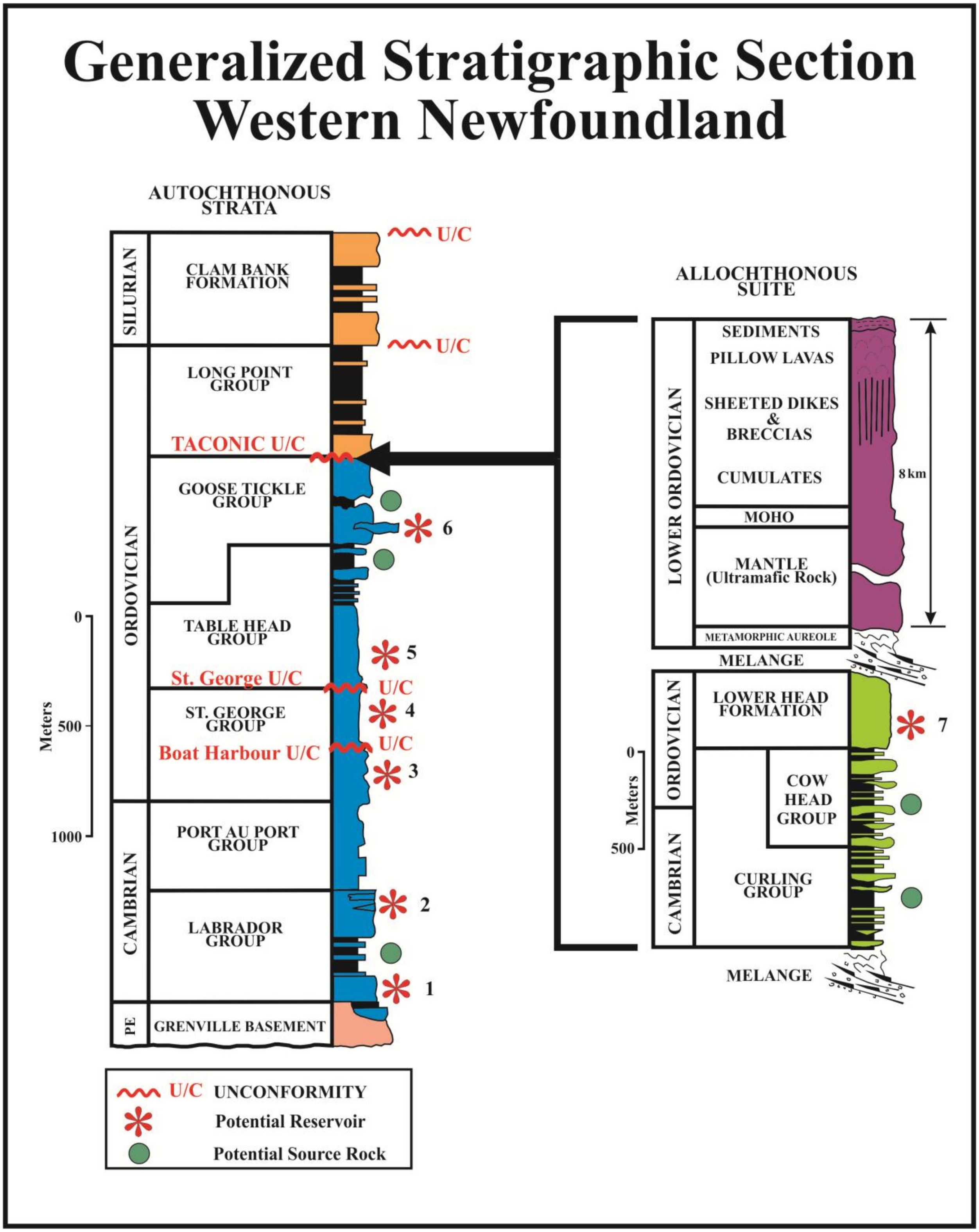

Figure 2: Generalized stratigraphic section of autochthonous and allochthonous strata in Western Newfoundland, showing potential reservoir and source rocks

Parson's Pond Geology and Hydrocarbon Potential

The surface geology in the Parson's Pond area is dominated by allochthonous sediments of the Lower Head Formation and Cow Head Group (Green Point Formation), which form a series of imbricate thrust sheets (Fig. 1). Macauley (1987) found that the shales of the Green Point Formation are the most likely source for the petroleum in the Parson's Pond area, and thermal maturity and burial history studies indicate that these outcrops are likely marginally mature to mature (Williams et at. 1998). A number of potential reservoir rocks have been proposed in the Parson's's Pond area (Department of Energy, 1989), including the porous sandstones of the Lower Head Formation. However, Kunkle (1986) showed that these sandstones commonly have poor porosity and permeability and fracture-enhanced porosity would be required to account for historical production from these sandstones. Other potential reservoir rocks include dolomitized carbonate sands in the Cow Head Formation and porous dolomite and clastic formations in the underlying autochthonous rocks (similar to potential reservoir rocks on the Port au Port Peninsula; Cooper et al., 2001).

4. Exploration history

The presence of oil seeps in the Parson's Pond area has been recorded since 1812, and the first shallow exploration well at Parson's Pond was drilled in 1867, and encountered small volumes of oil. From the 1890's to the 1960's approximately 27 shallow exploration wells were drilled into the allochthonous Cow Head Group. Oil and gas shows were commonly recorded from these wells, with at least 6000 barrels of oil produced (Department of Energy, 1989). In 1965, the Newfoundland and Labrador Company (Nalco) drilled one well in the area (Nalco 65-1). It encountered shows of oil and gas and was abandoned at 1302m in the Lower Head Formation .

Seismic studies in the 1990's led to increased interest in the hydrocarbon potential of western Newfoundland (Stockmal et al., 1998; Cooper et al., 2001). In 2004, Contact Exploration Inc. drilled the Parson's Pond #1 well about 5km southeast of the town of Parson's Pond (Fig. 1). Core was recovered from 111m to 1062m and encountered gas (up to 4%) in several fractured zones.

In 2010 Nalcor Energy drilled two exploration wells in the Parson's Pond area (Nalcor et al. Seamus and Nalcor et al. Finnegan; Fig. 1). These wells reached 3160m and 3130m respectively, and were the first wells at Parson's Pond to penetrate the allochthonous cover rocks and reach potential reservoir rocks in the autochthonous sequence. Both wells encountered gas shows during drilling.

5. Methodology

All analytical work was carried out at Memorial University and administered by the pan-university Core Research Equipment and Instrument Training Network (CREAIT). CREAIT is designed to maximize the impact of Memorial's institutional investments in research in the oil and gas sector through enhanced access to and utilization of major research equipment. CREAIT consists of eight interconnected satellites across the St. John's campus, The satellites are coordinated through a small administrative office, and managed by an overall Director reporting directly to the Vice-President (Research). Organized by theme each satellite supports clusters of instrumentation and equipment, and has its own staff. The staff are responsible for maintaining the instruments, training users, and processing samples and data and interact directly with researchers and graduate students.

Doubly polished wafers for fluid inclusion analysis were prepared from well core and cuttings samples. Petrographic studies established a fluid inclusion classification scheme, with aqueous, petroleum bearing and gas bearing fluid inclusions (>2 µm in size) identified. Textural relationship between inclusions and host mineral were used to constrain the relative timing of fluid migration and/or reservoir filling. The fluid inclusion petrographic study adopted the concept of fluid inclusion assemblages (FIA) described by Goldstein (2003) – an approach that places fluid inclusions into assemblages interpreted to have been trapped at approximately the same time.

The presence of petroleum bearing fluid inclusions was determined using an Olympus BX51 microscope with both visible and ultraviolet (UV) light sources. The UV excitation was approximately 365 nm and was provided by a high pressure mercury lamp. A 420 nm epi-fluorescence barrier filter allows only the longer-wavelength fluorescence to reach the observer.

Fluid inclusion microthermometry was conducted using a Linkam THMSG600 heating freezing stage. Calibration was carried out using synthetic H_2O and CO_2 standards; precision of ± 0.2 ºC at –56.6 ºC and ± 0.5 ºC at 300 ºC. Homogenization temperatures (T_h) were recorded in aqueous, petroleum bearing and gas bearing fluid inclusions. Eutectic temperatures (temperature of first ice melting) were recorded in rare Type 2 inclusions, which were used to estimate the composition of aqueous inclusions. In addition, fluid salinities in aqueous inclusions were calculated using temperatures of last ice melting ($T_m$ice), according to the equation of Bodnar (1993).

Samples with petroleum bearing fluid inclusions were selected for Ultraviolet Fluorescence Microspectroscopy. The Ultraviolet Fluorescence Microspectrophotometry Laboratory in the Earth Science Building consists of a CRAIC QDI 202^{Tm} Microspectrophotometer, which is designed to measure the spectra of microscopic samples. It integrates three components: a microscope, an ultraviolet visible near infrared (350-1000nm) spectrometer and a high resolution color imaging system. The Microspectrophotometer with its integrated spectral analyses and instrument control software package was used to measure how crude oils or petroleum bearing fluid inclusions are affected by ultraviolet light. System software, supplied with the unit, was used to collect the fluorescence relative energy verses wavelength data. In order to discriminate between different oil types, the maximum intensity of peaks (λ_{max}) and the relative intensity at 650 and 500nm ($Q_{650/500}$; Stasiuk and Snowdon, 1997) and at 510 and 430nm ($Q_{510/430}$; Bourdet et al., 2010) were calculated for petroleum bearing fluid inclusions.

6. Sample descriptions

Contact Exploration: Parson's Pond #1

In total 15 drill core samples were taken from Contact Exploration Limited's Parson's Pond #1 well. Samples were selected from the Eagle Island Sandstone, Cow Head Limestone and associated calcite vein material, with particular focus on highly fractured zones identified in the well report and areas with high (< 1%) gas shows. A brief lithological description of the core samples is presented in Table 1.

Nalcor et al. Finnegan

A total of 21 cuttings samples (with two duplicates) were prepared for fluid inclusions anlaysis from Nalcor et al. Finnegan. These represent both the allochthonous and autochthonous sedimentary rocks. Samples were selected based on their lithological descriptions (calcite and quartz vein material, well cemented sandstones, late stage hydrothermal dolomites and calcites), with emphasis on samples from horizons with elevated gas shows. Suitable grains were hand picked and mounted on glass slides, which were polished for fluid inclusion analysis. Images of the prepared wafers are shown in Figure 3: a brief lithological description of the core samples is presented in Table 2.

Nalcor et al. Seamus

22 cuttings samples (with two duplicates) were prepared for fluid inclusion analysis from Nalcor et al. Seamus. These samples were from similar Horizons as Nalcor et al. Finnegan, and the same sampling strategy was used. Suitable grains were hand picked and mounted on glass slides, which were polished for fluid inclusion analysis. Images of the prepared wafers are shown in Figure 4; a brief lithological description of the core samples is presented in Table 3.

Table 1: Brief lithological description of samples from Contact Exploration Inc. Parson's Pond #1

Sample Name	Sample Type	Well	Sample Depth	Lithology	Brief Geological Description	Gas Show
CE368.4	Core	Contact	368.4	Sst	Fine-grained sandstone, with occasional calcite veinlets (2-5mm), many fractures ~10cm below sample location	0.0144
CE415.2	Core	Contact	415.2	Sst	Medium-grained sandstone with trace intergranular porosity. Sample is crosscut with vuggy calcite veinlets (85° to CA)	0.0394
CE569.7	Core	Contact	569.7	Sst	Coarse-grained pebbly sandstone sample, 3-5% intergranular porosity. Vuggy calcite-pyrite veinlet crosscuts sample	n/a
CE570.3	Core	Contact	570.3	Sst	Coarse-grained pebbly sandstone sample, similar to CE569.7. Same vuggy veinlet is sampled	< 1%
CE588.9	Core	Contact	588.9	Sst	Medium-grained sandstone sample, 3-5% intergranular porosity.	0.0585
CE605.3	Core	Contact	605.3	Sst	Coarse-grained pebbly sandstone with shale fragments parallel to bedding. Sample fractured with calcite veinlets	0.013
CE607.4	Core	Contact	607.4	Sh	Green shale and fine-grained sandstone, fracture with calcite veining and sandstone fragments	0.013
CE917.4	Core	Contact	917.4	Vein	Calcite vein in possible fault (~15° to CA), large calcite crystals (2-4cm), some minor vugs.	1-2%
CE918.2	Core	Contact	918.2	Vein	Sample from base of vein described in sample CE917.4.	1-2%
CE922.7	Core	Contact	922.7	Lst	Limestone conglomerate with 1cm thick vuggy calcite vein	0.025
CE927.2	Core	Contact	927.2	Vein	1cm thick vuggy calcite veinlet	~1%
CE949.2	Core	Contact	949.2	Lst/Sh	Heavily faulted section, shale and limestone fragments with calcite cement	2-3%
CE950.4	Core	Contact	950.4	Lst/Sh	Heavily faulted section, shale and limestone fragments with calcite cement and oily residue on fractures	3-4%
CE955.5	Core	Contact	955.5	Lst/Sh	Heavily fractured with fault gouge material, shale and limestone fragments with calcite cement	1-2%
CE1054.2	Core	Contact	1054.2	Lst	Limestone sample, with numerous small calcite filled fracture	2-3%

Table 2: Brief lithological description of samples from Nalcor et al. Finnegan.

Sample Name	Sample Type	Well	Sample Depth	Lithology	Brief Geological Description	Gas Show
F765	Cuttings	Finnegan	760-765	Lst/sh	Limestone/shale with some calcite stringers	>6
F800	Cuttings	Finnegan	790-800	Lst/sh	Limestone/shale with frequent calcite stringers	>6
F990	Cuttings	Finnegan	985-995	Lst	Limestone with frequent calcite stringers	38.83
F1145	Cuttings	Finnegan	1145-1150	Sst	Quartz dominated sandstone, calcite and siliceous cement, fractures with calcite (clear)	64
F1165	Cuttings	Finnegan	1160-1165	Sst	Quartz dominated sandstone, calcite and siliceous cement, fractures with calcite (clear)	8
F1495	Cuttings	Finnegan	1490-1495	Sst	Sandstone, frequent calcite fractures	1.5-2
F1530	Cuttings	Finnegan	1520-1530	Sst	Quartz dominated sandstone, calcite and siliceous cement	>4
F1800	Cuttings	Finnegan	1795-1800	Sst	Sandstone, mostly quartz with siliceous, calcite and chert cement, abundant fractures	0
F1885	Cuttings	Finnegan	1875-1885	Sh	Shale with calcite stringers, probably poor sample	2.5
F1970	Cuttings	Finnegan	1965-1970	Sst	Quartz dominated sandstone, calcite, dolomite and siliceous cement, fractures with calcite	2
F2045	Cuttings	Finnegan	2040-2045	Sst	Sandstone, abundant calcite fractures	2.5
F2060	Cuttings	Finnegan	2055-2065	Sst	Quartz dominated sandstone, calcite, dolomite and siliceous cement, fractures with calcite	20
F2065	Cuttings	Finnegan	2055-2065	Sst	Quartz dominated sandstone, calcite, dolomite and siliceous cement, fractures with calcite	20
F2135	Cuttings	Finnegan	2130-2135	Sst	Sandstone, mostly quartz with siliceous, calcite and dolomite cement, common fractures	1.8
F2225	Cuttings	Finnegan	2220-2225	Sst	Sandstone, mostly quartz with siliceous, calcite and dolomite cement, common fractures	1
F2480	Cuttings	Finnegan	2475-2480	Lst/dol	Sucrosic dolomite, poor porosity, bitumen staining	1.5
F2575	Cuttings	Finnegan	2565-2575	Lst/dol	Clear dolomite crystals, trace bitumen	0
F2615	Cuttings	Finnegan	2605-2615	Lst/dol	Dolomite with frequent clear calcite and saddle dolomite	0
F2755	Cuttings	Finnegan	2750-2755	Lst/dol	Dolomite, frequent saddle dolomite	0
F2790	Cuttings	Finnegan	2785-2790	Dol	Dolomite, frequent saddle dolomite	0
F2915	Cuttings	Finnegan	2910-2915	Dol	Dolomite, frequent saddle dolomite	0.25

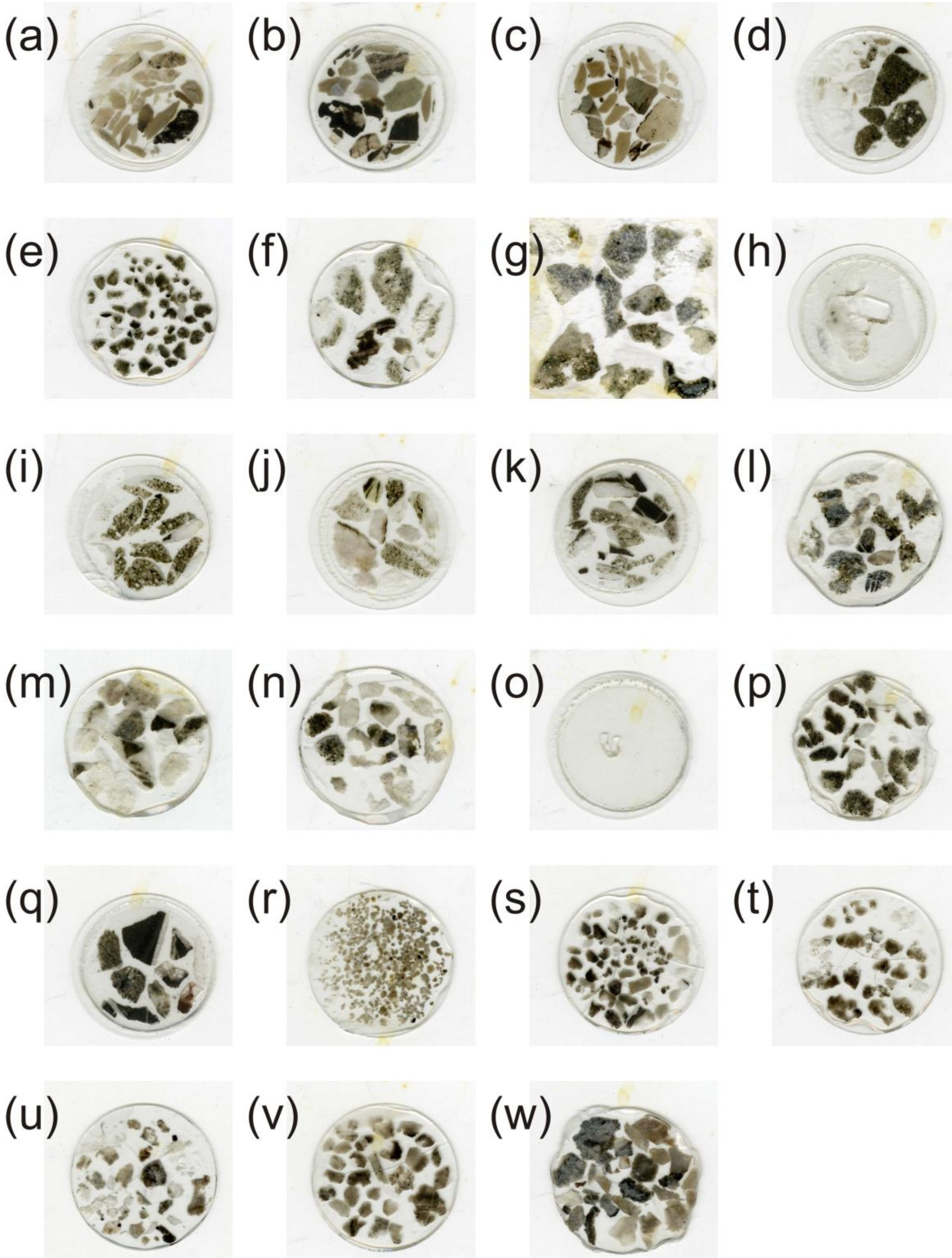

Figure 3: Scanned photographs of wafers from Nalcor et al. Finnegan. (a) F765; (b) F800; (c) F990; (d) F1145; (e) F1165; (f) F1495; (g) F1530a; (h) F1530b; (i) F1800; (j) F1885; (k) F1970; (l) F2045; (m) F2060; (n) F2065a; (o) F2065b; (p) F2135; (q) F2225; (r) F2480; (s) F2575; (t) F2615; (u) F2755; (v) F2790; (w) F2915.

Table 3: Brief lithological description of samples from Nalcor et al. Seamus.

Sample Name	Sample Type	Well	Sample Depth	Lithology	Brief Geological Description	Gas Show
S715	Cuttings	Seamus	710-715	Lst	Limestone, trace bitumen, occasional calcite stringers	0.8
S720	Cuttings	Seamus	715-720	Lst	Limestone, bitumen, frequent fractures	4.18
S810	Cuttings	Seamus	805-810	Lst	Limestone, bitumen, frequent fractures	4.2
S940	Cuttings	Seamus	935-940	Lst	Limestone, bitumen, frequent fractures with clear calcite	6.06
S1050	Cuttings	Seamus	1045-1050	Lst	Limestone, fault zone, bitumen, frequent fractures with clear calcite	20.5
S1105	Cuttings	Seamus	1100-1105	Lst/dol	Trace bitumen, occasional calcite stringers	3.7
S1320	Cuttings	Seamus	1315-1320	Sst	Bitumen stained sandstone, calcite cement	3.8
S1420	Cuttings	Seamus	1415-1420	Lst	Abundant clear calcite, rare bitumen	2.5
S1860	Cuttings	Seamus	1855-1860	Sst	Sandstone with calcite cement, occasional bitumen	1.4
S1885	Cuttings	Seamus	1880-1885	Sst	Sandstone with calcite cement, occasional bitumen, high porosity	5.69
S2005	Cuttings	Seamus	2000-2005	Lst	Limestone with frequent bitumen, abundant clear calcite	>4
S2140	Cuttings	Seamus	2135-2140	Lst	Fractures with abundant calcite and occasional bitumen	64
S2295	Cuttings	Seamus	2290-2295	Sst	Quartz sandstone with siliceous and calcite cement, high porosity	2
S2505	Cuttings	Seamus	2500-2505	Sst	Quartz, feldspar sandstone with calcite cement and calcite stringers	>4
S2595	Cuttings	Seamus	2590-2595	Lst	Abundant white crystalline calcite in fractures	>20
S2605	Cuttings	Seamus	2600-2605	Lst	Abundant white crystalline calcite in fractures	44.8
S2775	Cuttings	Seamus	2770-2775	Dol	Sucrosic dolomite, trace bitumen	15
S2865	Cuttings	Seamus	2860-2865	Dol	Sucrosic dolomite, poor porosity, frequent saddle dolomite, some bitumen	0
S2895	Cuttings	Seamus	2890-2895	Dol	Sucrosic dolomite, frequent saddle dolomite veinlets	0
S3085	Cuttings	Seamus	3080-3085	Dol	Large vug, sucrosic dolomite, lots of saddle dolomite/clear calcite	3
S3120	Cuttings	Seamus	3115-3120	Dol	Sucrosic dolomite, lots of saddle dolomite/clear calcite, trace bitumen	1
S3150	Cuttings	Seamus	3145-3150	Dol	Sucrosic dolomite, poor to fair porosity	1

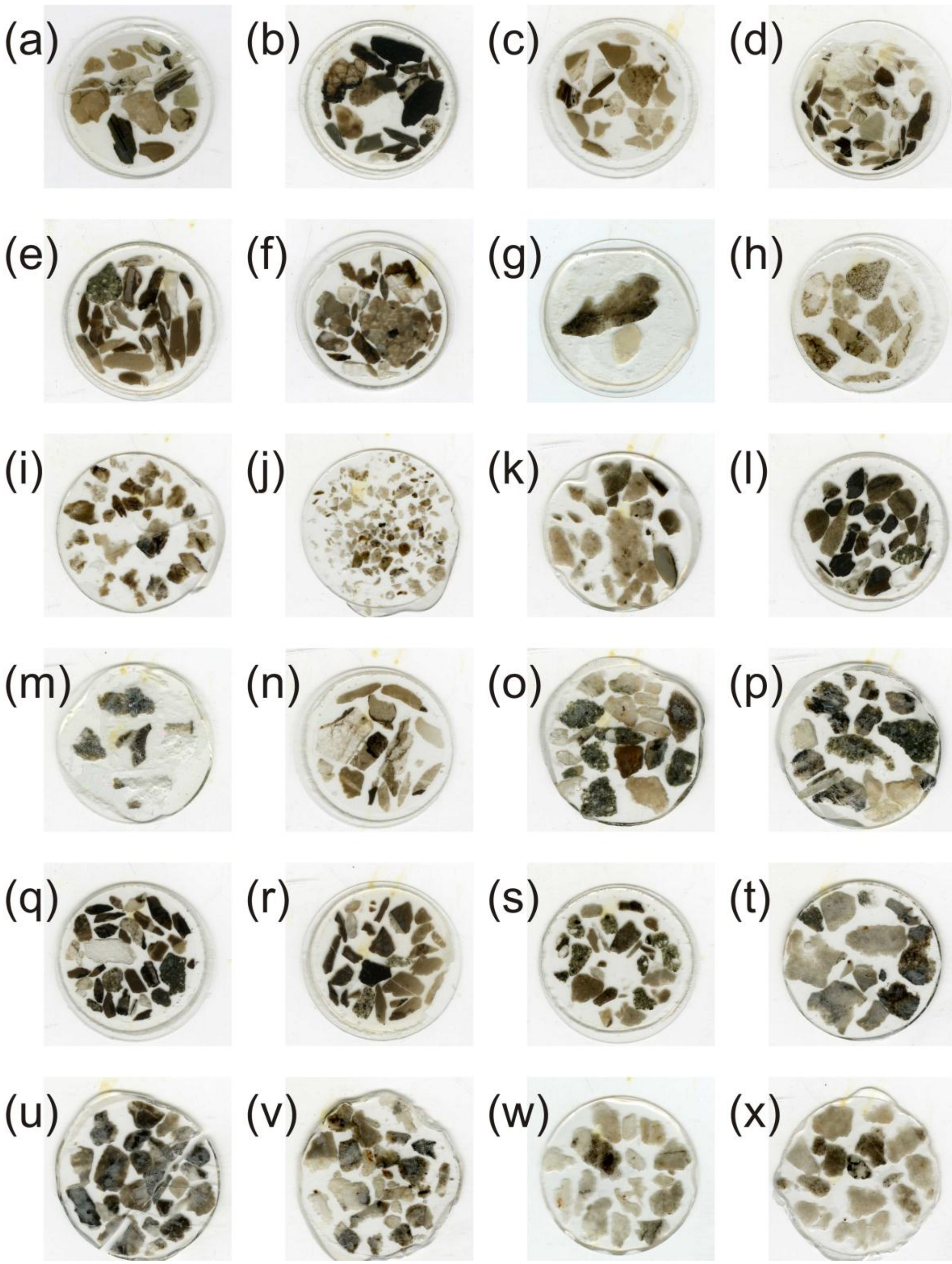

Figure 4: Scanned photographs of wafers from Nalcor et al. Seamus. (a) S715; (b) S720; (c) S810; (d) S940; (e) S1050; (f) S1105a; (g) S1105b; (h) S1320; (i) S1420; (j) S1860; (k) S1885; (l) S2005; (m) S2140a; (n) S2140b; (o) S2295; (p) S2505; (q) S2595; (r) S2605; (s) S2775; (t) S2865; (u) S2895; (v) S3085; (w) S3120; (x) S3150.

7. Fluid Inclusion Petrography

Five main fluid inclusion types are recorded. Their recognition is based on their optical characteristics at room temperature and their phase behaviour on cooling. In the case of Type 1 (petroleum bearing) inclusions their presence is determined using UV microscopy. Fluid inclusions in all samples display a range of morphologies from ellipsoidal to irregular shapes, and rare negative crystal shapes. Inclusions are recorded in a variety of settings, including clusters of inclusions (primary) and trails of inclusions (secondary) along annealed fractures.

Type 1 inclusions are petroleum-bearing fluid inclusions and are recorded in calcite and quartz vein material from all wells. The degree of fill (F) of the Type 1 inclusions varies greatly between samples with both monophase (L) and two-phase (L +V) inclusions common. However the ratio of vapour to liquid remains relatively constant within fluid inclusion assemblages and therefore it is unlikely that these inclusions underwent any significant post-entrapment modifications. The liquid phase in Type 1 inclusions is typically clear or light brown in colour in transmitted ordinary light and is fluorescent under UV light (Figs. 5, 6). The fluorescence colour is generally related to the API gravity of the hydrocarbon fluids (Bodnar, 1990). Type 1 inclusions in all samples have blue-green fluorescence colours, which correspond to a relatively light oil (API gravity = ~35-50°). However, the complex controls on fluorescence in hydrocarbons often leads to variations in the relationship between fluorescence colour and API gravity in inclusions (George et al., 2001). Therefore the fluorescence colours recorded here can only be taken as a general guide to oil maturity. In an attempt to better determine the composition of petroleum fluids, and to correlate between wells, samples with populations of Type 1 inclusions were saved for Ultraviolet Fluorescence Microspectroscopy (see below)

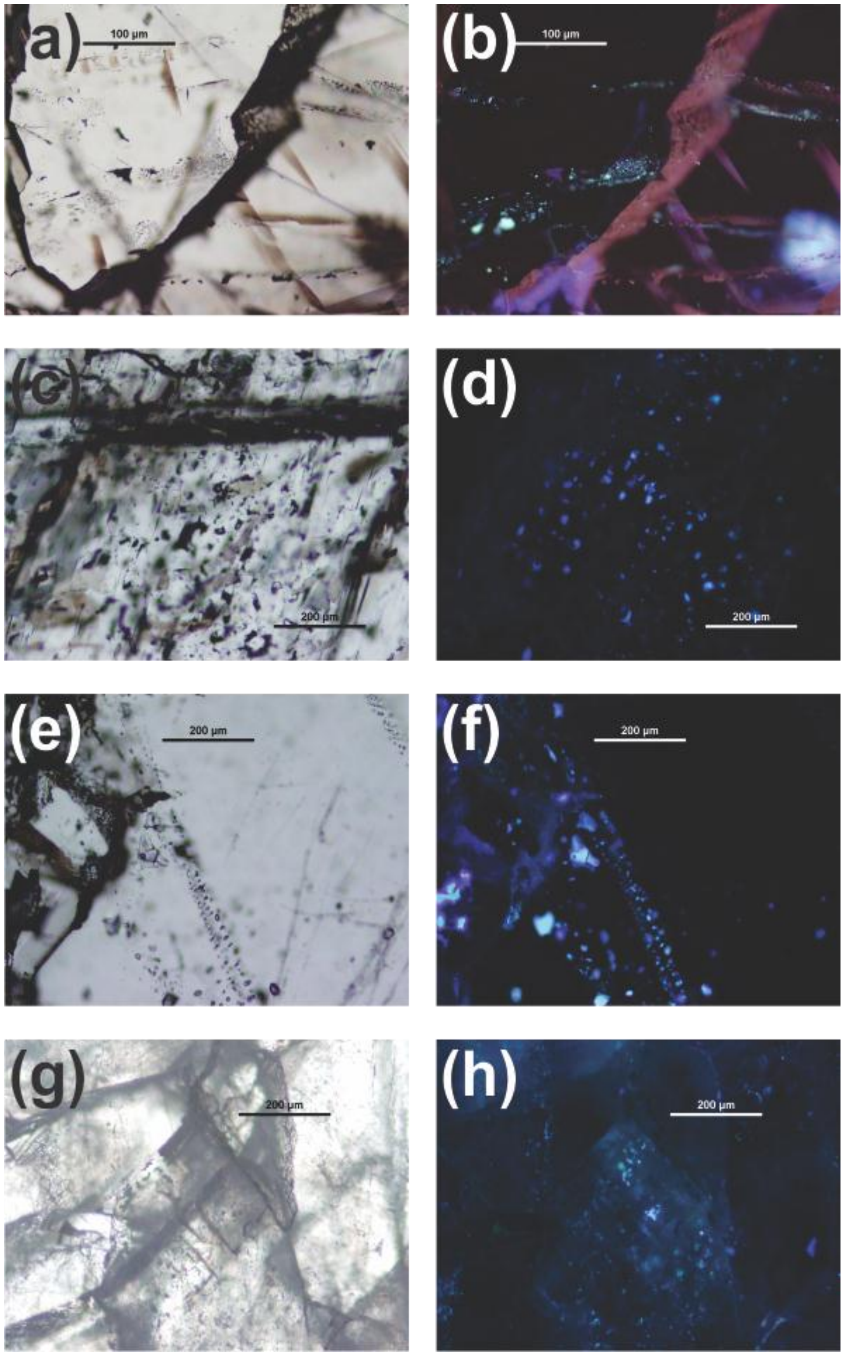

Figure 5: Photomicrographs of Type 1 inclusions. (a) Clusters of Type 1 inclusions in sample CE570.3; (b) Same view under UV light; (c) Two-phase Type 1 inclusions in calcite vein from sample CE927.2; (d) Same view under UV light showing blue fluorescence; (e) Large, liquid rich two-phase Type 1 inclusions in sample CE949.2; (f) Same view under UV light; (g) Two-phase Type 1 inclusions in sample CE1054.2; (h) Same view under UV light

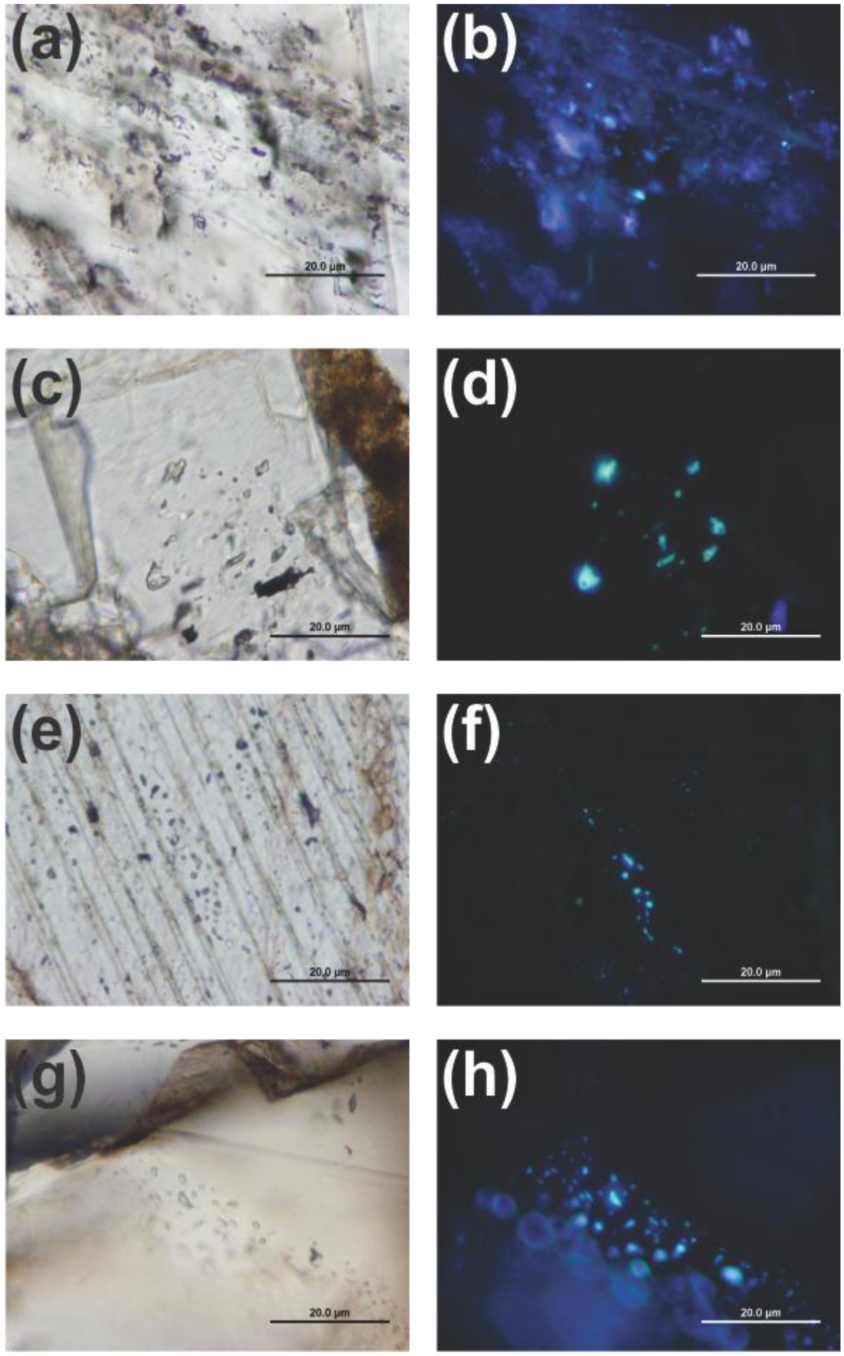

Figure 6: Photomicrographs of Type 1 inclusions. (a) Calcite hosted Type 1 inclusions in sample F990; (b) Same view under UV light; (c) Two-phase Type 1 inclusions in sample S810; (d) Same view under UV light showing green fluorescence; (e) Type 1 inclusions in sample S940; (f) Same view under UV light; (g) Cluster of Type 1 inclusions in sample S2140; (h) Same view under UV light

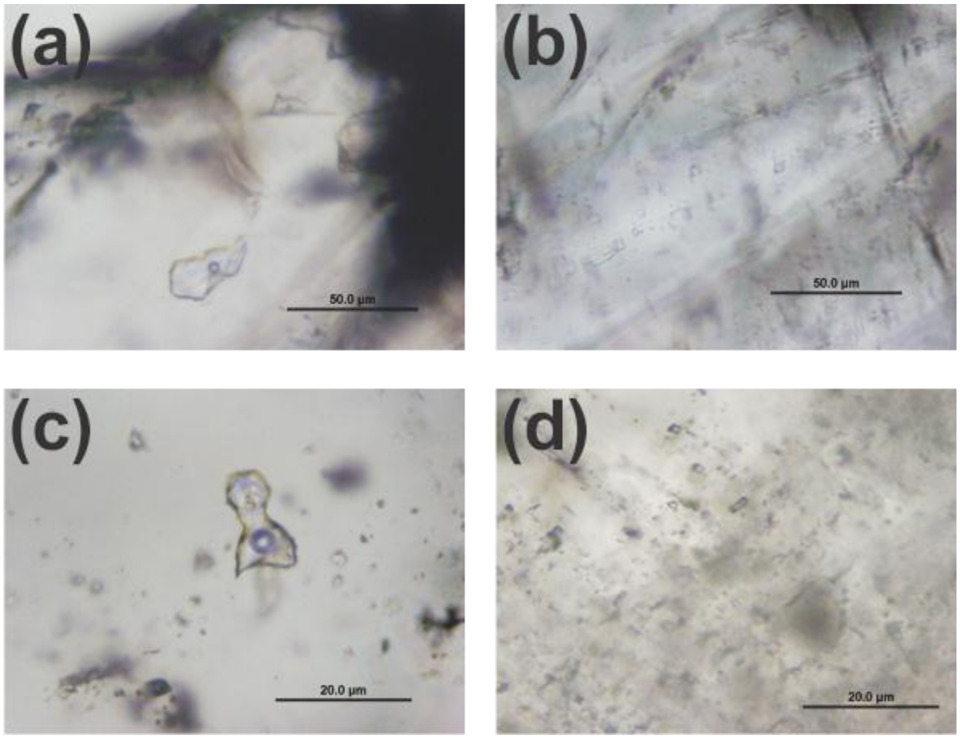

Figure 7: Photomicrographs of Type 2 inclusions. (a) Large, two-phase Type 2 inclusion in sample CE415.; (b) trail of two-phase Type 2 inclusions in calcite from sample CE607.; (c) Large, two-phase Type 2 inclusion in sample F1530; (d) Cluster of Type 2 inclusions in sample F2755.

Type 2 inclusions are non-fluorescent aqueous inclusions (Fig. 7). Both monophase (liquid only; L) and two-phase (liquid + vapour; L + V) Type 2 inclusions have been noted, and they are recorded in calcite and quartz vein material, authigenic cements around detrital grains in sandstones, and in carbonates (calcite and dolomite). Their degree of fill (F = vol. of liquid/ [vol. of liquid + vapour]) ranges between ~0.90 and 1. Some Type 2 inclusions display clathrate melting at temperatures > 0°C, consistent with the presence of dissolved $CH_4 \pm CO_2$ in the aqueous fluids.

Type 3 inclusions are monophase vapour at room temperature and are characterized by their behaviour at low temperatures (Figs. 8, 9). When they are frozen to < -120°C Type 3 inclusions separate into a liquid and vapour phase, with no freezing seen upon further cooling to > -180°C. This indicates that these inclusions are dominantly CH_4 rich, with lesser amounts of CO_2, C_2H_6, C_3H_8 and other gases (exact proportion of gases is likely variable between samples, see below). Type 3 inclusions are non-fluorescent and are hosted in quartz and calcite vein material and rarely in quartz cements around detrital quartz grains (S2775) and saddle dolomite (F2480).

Type 4 inclusions are classified as "wet gas" and are likely an intermediate fluid type between Type 1 and Type 3 inclusions. Type 4 inclusions are either monophase liquid or vapour at room temperature and upon freezing to < -65°C separate into a liquid and vapour phase (Fig. 10). They are recognised in quartz and calcite vein material from all three wells and have a very weak blue fluorescence at room temperature.

Type 5 inclusions are only recorded in quartz vein material in a single sample (F1530) and consist of an aqueous liquid and a hydrocarbon vapour phase (Fig. 8c, d). Upon freezing the vapour phase separates in liquid and vapour CH_4 (± other gases) at ~ -110°C. The presence of aqueous fluids and CH_4 in the same inclusions indicates simultaneous trapping of two immiscible fluids.

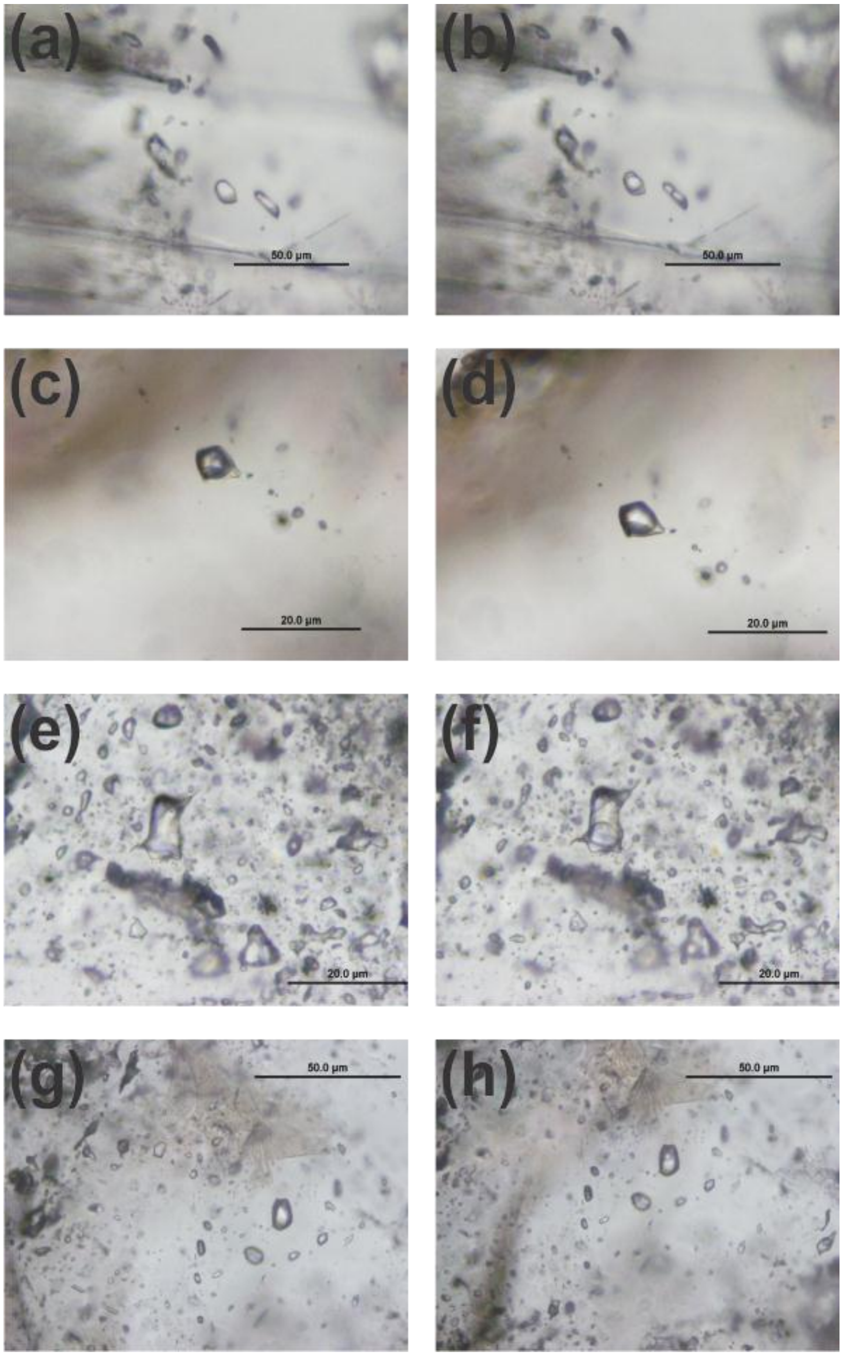

Figure 8: Photomicrographs of Type 3 inclusions. (a) Calcite-hosted Type 2 and Type 3 inclusions at room temperature in sample CE918.2; (b) Same view at -120°C; (c) Three-phase Type 5 inclusions at -120°C in sample F1530; (d) Same view at room temperature; (e) Calcite-hosted Type 3 inclusions at room temperature in sample F1800; (f) Same view at -120°C; (g) Cluster of quartz-hosted Type 3 inclusions in sample F2065; (h) Same view at -120°C.

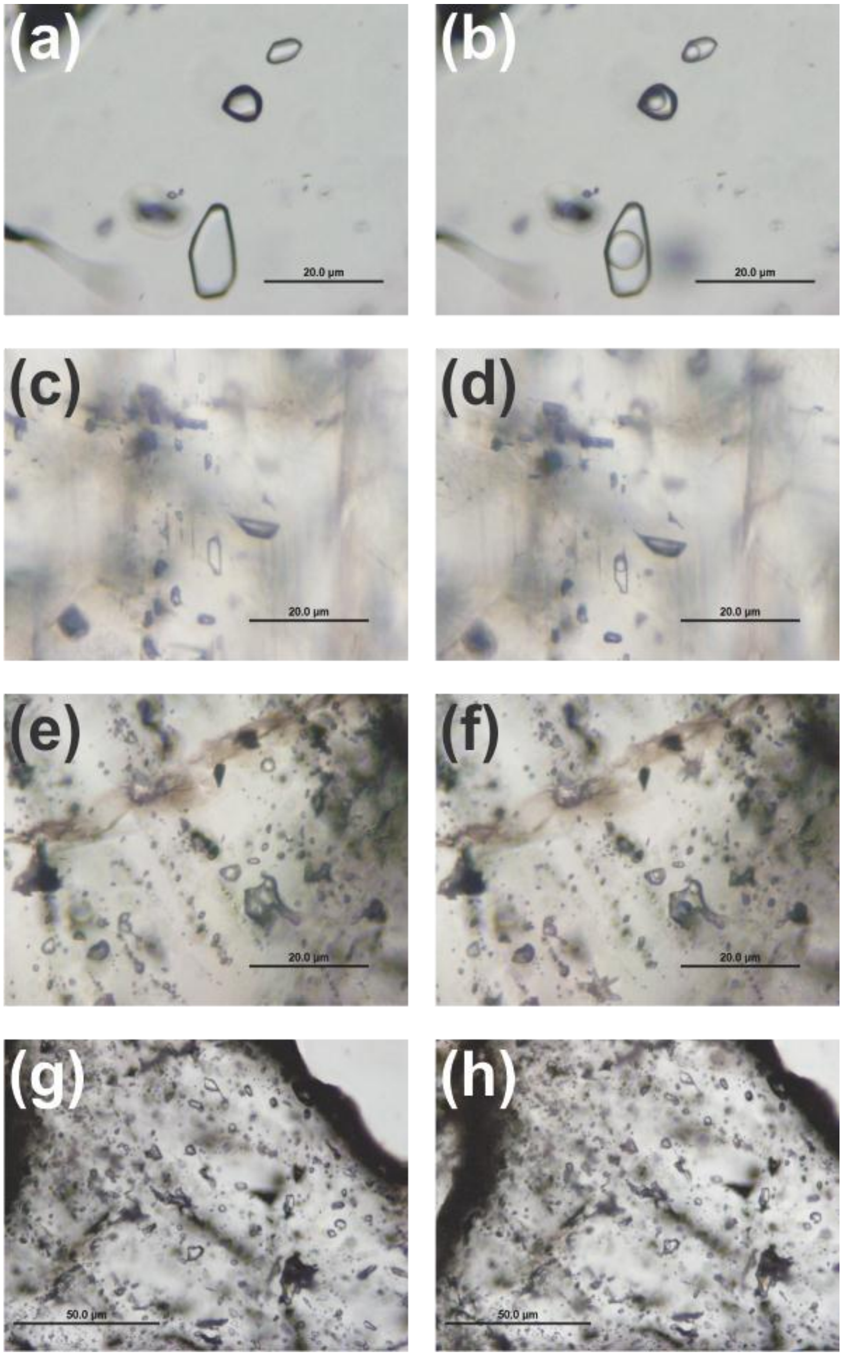

Figure 9: Photomicrographs of Type 3 inclusions. (a) Large, quartz-hosted Type 3 inclusions at room temperature in sample S2005; (b) Same view at -120°C; (c) Calcite-hosted Type 3 inclusions from sample S2295; (d) Same view at -120°C; (e) Quartz-hosted Type 3 inclusions at room temperature in sample S2505; (f) Same view at -120°C; (g) Quartz-hosted Type 3 inclusions in sample S2595; (h) Same view at -120°C.

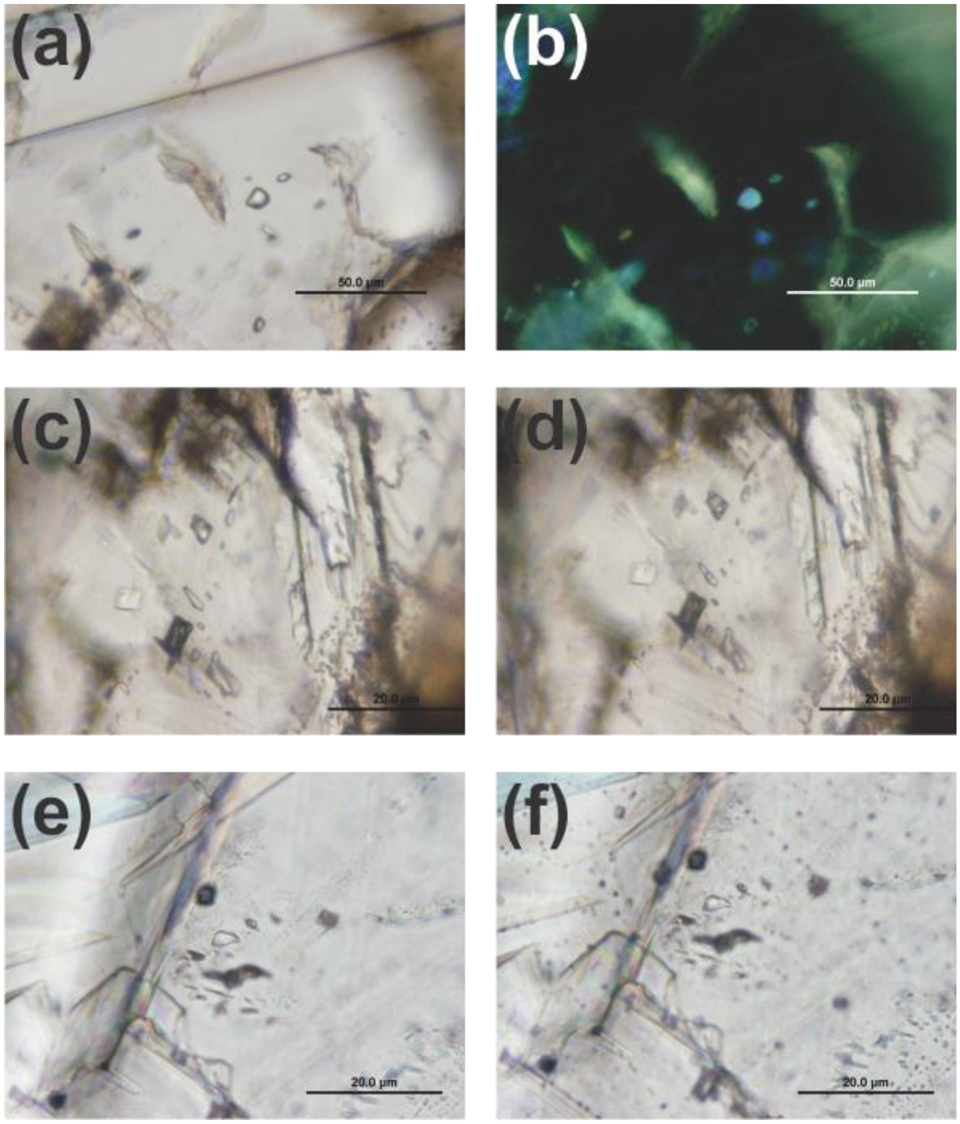

Figure 10: Photomicrographs of Type 4 inclusions. (a) Cluster of Type 4 inclusions in sample CE949.2; (b) Same view under UV light, showing weak fluorescence; (c) Cluster of Type 4 inclusions in sample F1495; (d) Same view at -70°C; (e) Calcite-hosted Type 4 inclusions at room temperature in sample S810; (f) Same view at -70°C.

8. Fluid Inclusion Microthermometry

8.1. Contact Exploration: Parson's Pond #1

Fluid inclusions were recorded in all samples (Table 4). However due to the small size of inclusions and poor clarity in some samples, microthermometric data was only recorded in calcite vein material from 13 of the 15 samples. The microthermometric data from each sample is summarized in Table 5, with detailed results presented in Appendix 1.

Table 4: Relative abundances of fluid inclusion types in samples from Contact Exploration Inc. Parson's Pond #1. xxx = abundant. xx = common. x = rare.

Sample Name	Sample Depth	Host Mineral	Gas Show	Fluid Inclusion Types			
				Petroleum 1	Aqueous 2	CH_4/CO_2 3	Wet Gas 4
CE368.4	368.4	Core	0.0144		xxx		
CE415.2	415.2	Core	0.0394		xxx		
CE569.7	569.7	Core	n/a	x			
CE570.3	570.3	Core	< 1%	xxx	x		
CE588.9	588.9	Core	0.0585		xx		
CE605.3	605.3	Core	0.013		xx		
CE607.4	607.4	Core	0.013		xxx		
CE917.4	917.4	Core	1-2%	xx	xxx	xxx	
CE918.2	918.2	Core	1-2%		xxx	xxx	
CE922.7	922.7	Core	0.025	xx	xxx	xxx	
CE927.2	927.2	Core	~1%	xxx	xx		
CE949.2	949.2	Core	2-3%			x	xx
CE950.4	950.4	Core	3-4%		xx		
CE955.5	955.5	Core	1-2%	xxx	x		
CE1054.2	1054.2	Core	2-3%	xx			

Type 1

Type 1 inclusions were recorded in nine samples (Table 4, Fig. 11). They range in size from <2 to >50µm, and both two-phase (L + V petroleum) and monophase liquid Type 1 inclusions were observed. Fluorescence colours of Type 1 inclusions range from light blue to green, representing a range of petroleum compositions (see below for detailed discussion). Fluid inclusion homogenization temperatures were recorded in two-phase Type 1 inclusions in seven samples (Table 5). T_h values range from between 49.7 and 118°C (mean = 71.0°C; standard deviation = 18.4°C). In addition monophase Type 1 inclusions in other samples indicate homogenisation temperatures of <50°C. No phase changes were recorded on cooling of Type 1 inclusions.

In sample CE922.7 two generations of calcite veining are recorded, with Type 1 inclusions recorded in both vein generations (Fig. 11). Type 1 inclusions in early and late calcite have different fluorescent colours and homogenization temperatures (Table 5), consistent with multiple petroleum charge events.

Type 2

Type 2 inclusions were recorded in 12 samples (Table 4). They range in size from >20 to <2µm, and are two-phase (L + V) at room temperature. Upon cooling Type 1 inclusions freeze below -50°C. First ice melting temperatures were recorded at -22.9 ± 1.0°C, indicating a composition of H_2O + NaCl ± KCl. $T_m$ice values of -5.97 ± 1.54°C were used to calculate fluid salinities of 9.10 ± 1.86 eq. wt% NaCl. Homogenization temperatures generally range between 75 and 125°C (Fig. 12), with a mean of 98.8°C (± 11°C).

Table 5: Summary of microthermometric data from Contact Exploration Inc. Parson's Pond #1. $T_m$ice = last ice melting temperature. T_h = homogenization temperature

Sample Number	Type	n	Tmice		Salinity		Th		Notes
			mean	stdev	mean	stdev	mean	stdev	
CE368.4	2	17	-4.62	0.56	7.33	0.80	97.6	7.2	In calcite vein
CE415.2	2	24	-4.77	0.27	7.55	0.38	105.6	7.4	In calcite vein
CE569.7	1								Monophase and rare two-phase petroleum inclusions in calcite vein
CE570.3	1	14					88.7	2.8	In calcite vein
CE605.3	2	9	-5.10	0.35	8.00	0.47	103.9	6.8	In calcite vein
CE607.4	2	15	-11.38	0.51	15.35	0.50	94.4	12.5	In calcite vein
	1	10					60.2	6.7	In calcite vein
CE917.4	2	28	-5.89	0.51	9.06	0.68	96.5	6.8	In calcite vein
	3	9					-66.6	1.6	In calcite vein
CE918.2	2	16	-6.54	0.69	9.89	0.90	99.6	9.2	In calcite vein
	3	13					-68.1	3.0	In calcite vein
	1	6					70.7	8.7	In calcite vein
CE922.7	1	9					38.5	3.9	Early calcite veinlet
	2	10	-6.08	0.26	9.32	0.34	102.8	16.5	Late calcite vein
	3	6					-72.6	2.9	Late calcite vein
CE927.7	1	26					54.3	2.5	In calcite vein
	2	15	-5.83	0.38	8.99	0.50	98.2	12.4	In calcite vein
	1	22					52.1	10.7	In calcite vein
CE949.2	3	2					-73.9	1.2	In calcite vein
	4	31					1.3	13.5	In calcite vein
CE950.4	1	4					111.7	7.4	In calcite vein
	2	4					73.8	6.0	In calcite vein
CE955.5	1	23					71.1	12.6	In calcite vein
	2	11	-9.16	0.36	13.02	0.41	84.9	12.4	In calcite vein
CE1054.2	1								Monophase petroleum inclusions in calcite vein
Type 1		**61**					**71.0**	**18.4**	
Type 2		**126**	**-5.97**	**1.54**	**9.10**	**1.86**	**98.8**	**11.0**	
Type 3		**30**					**-68.9**	**3.5**	
Type 4		**23**					**-1.5**	**11.9**	

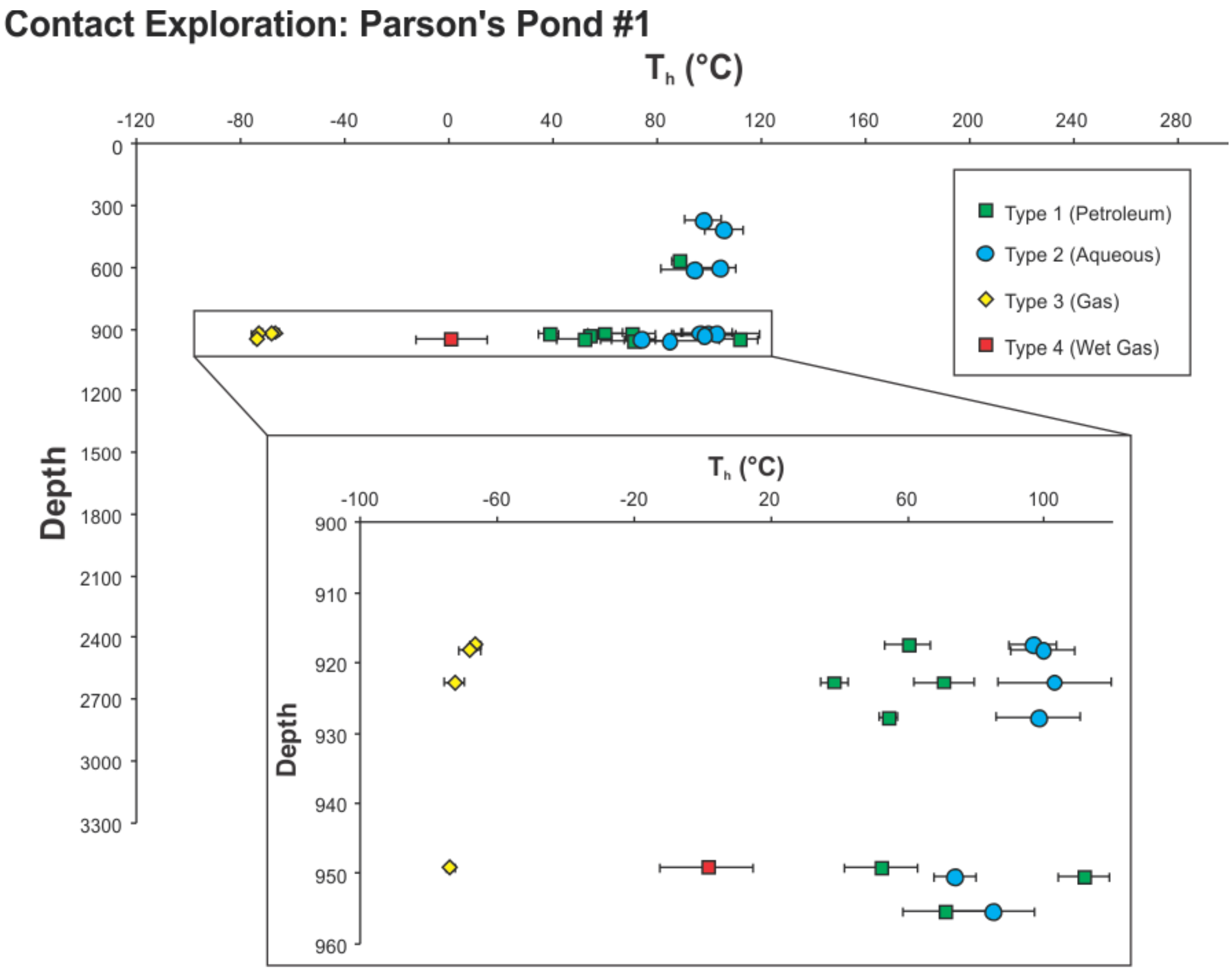

Figure 11: Homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Contact Exploration Inc. Parson's Pond #1 plotted against depth. Symbols represent mean T_h values, error bars represent standard deviation

Type 3

Type 3 inclusions are recorded in four samples. They are monophase at room temperature, and upon cooling to below -100°C they separate into a separate liquid and vapour phase. Homogenization temperatures in Type 3 inclusions range from -75.1 to -63.7°C (Fig. 12), which are above the homogenization temperature for pure CH_4 (-82.7°C), indicating the presence of other gases and/or hydrocarbons.

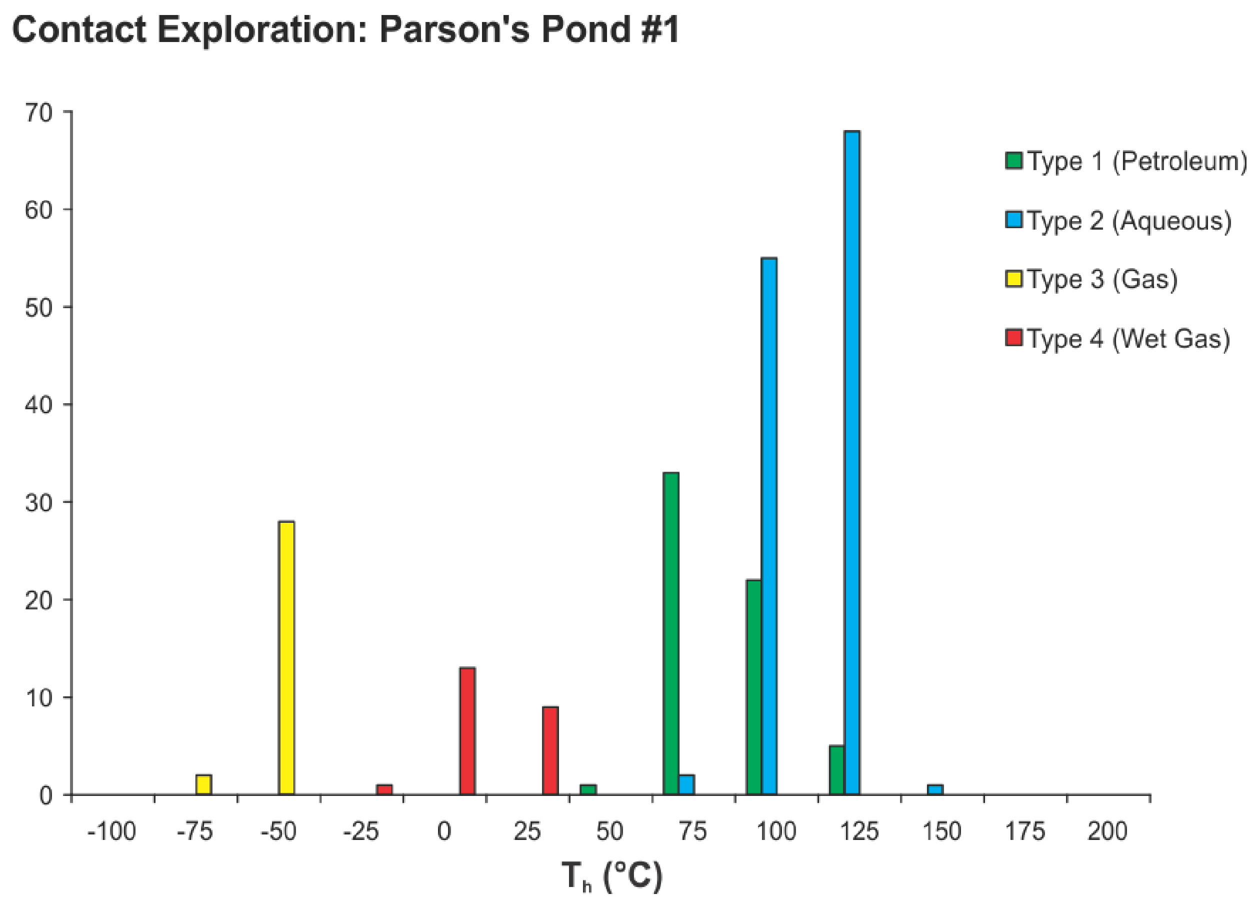

Figure 12: Frequency distribution histogram for homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Contact Exploration Inc. Parson's Pond #1.

Type 4

Type 4 inclusions are only recorded in sample CE949.2 and have petrographic and microthermometric characteristics intermediate between Type 1 and Type 3 inclusions. They are monophase at room temperature, with a very weak blue fluorescence (visible only using camera). Upon freezing they separate into a liquid and vapour phase, and have a wide range of homogenization temperatures (generally -14 to 11.4°C; Fig 12).

8.2. Nalcor et al. Finnegan

Fluid inclusions were recorded in all samples (Table 6), with microthermometric data collected from 13 samples. In other samples, clarity was poor and/or fluid inclusions were too small to collect accurate microthermometric data. The microthermometric data from each sample is summarized in Table 7, with detailed results presented in Appendix 1.

Type 1

Type 1 inclusions were recorded in calcite vein material in two samples (F800 and F990). They range in size from 15 to <2µm and have a blue to blue-green fluorescence. Type 1 inclusions are monophase or two-phase (liquid + vapour) at room temperature, with a vapour bubble appearing on slight cooling. Homogenization temperatures range from 2.9 to 42.1°C (mean = 14.8°C, standard deviation = 10.8°C). No phase changes were recorded on cooling of Type 1 inclusions.

Type 2

Type 2 inclusions were recorded in all samples except F990 (Table 6; Fig. 13). They are hosted in calcite and quartz vein material, authigenic quartz cements and in quartz and carbonates from the autochthonous sequences. However, due to the small size (commonly <3µm) and poor clarity, microthermometry was only possible on two-phase (liquid + vapour) Type 2 inclusions from quartz and calcite vein material in six samples and quartz and calcite from two samples from the autochthonous sediments (Table 7). The majority of Type 2 inclusions are low salinity (1.43 ± 0.92 eq. wt% NaCl) and NaCl appears to be the dominant salt (eutectic temperature of ~-22°C). In sample F2755, Type 2 inclusions have a much higher salinity (29.19 ± 0.46 eq. wt% NaCl), and first ice melting occurs at ~-50°C, indicating that these fluids are $CaCl_2$ rich brines. Type 2 inclusions have a wide range of homogenization temperatures (49.5 to 269.5°C), with a mean of 166.1°C (± 61.7°C).

Table 6: Relative abundances of fluid inclusion types in samples from Nalcor et al. Finnegan. xxx = abundant. xx = common. x = rare.

Sample Name	Sample Depth	Host Mineral	Gas Show	Fluid Inclusion Types: Petroleum 1	Aqueous 2	CH_4/CO_2 3	Wet Gas 4
F765	760-765	Cuttings	>6		xx		
F800	790-800	Cuttings	>6	xx	x		
F990	985-995	Cuttings	38.83	xxx			
F1145	1145-1150	Cuttings	64		xx		
F1165	1160-1165	Cuttings	8		xx		
F1495	1490-1495	Cuttings	1.5-2		x		xx
F1530	1520-1530	Cuttings	>4		xxx	xx	
F1800	1795-1800	Cuttings	0		xx	xx	
F1885	1875-1885	Cuttings	2.5		xx	xxx	
F1970	1965-1970	Cuttings	2		xx	xxx	
F2045	2040-2045	Cuttings	2.5		x		
F2060	2055-2065	Cuttings	20		xx	xxx	
F2065	2055-2065	Cuttings	20		xx	xx	
F2135	2130-2135	Cuttings	1.8		x	xx	
F2225	2220-2225	Cuttings	1		x	xxx	
F2480	2475-2480	Cuttings	1.5		x	x	
F2575	2565-2575	Cuttings	0		xx		
F2615	2605-2615	Cuttings	0		xx		
F2755	2750-2755	Cuttings	0		xx		
F2790	2785-2790	Cuttings	0		xx		
F2915	2910-2915	Cuttings	0.25		xx		

Table 7: Summary of microthermometric data from Nalcor et al. Finnegan. $T_m$ice = last ice melting temperature. T_h = homogenization temperature

Sample Number	Type	n	Tmice		Salinity		Th		Notes
			mean	stdev	mean	stdev	mean	stdev	
F765	2								Rare, small (<2µm) aqueous inclusions in calcite vein material
F800	1								Abundant monophase petroleum inclusions in calcite vein material
F990	1	15					14.8	10.8	In calcite vein material
F1145	2	4	-1.77	0.06	3.01	0.09	115.0	4.6	In calcite vein material
F1165	2								Monophase aqueous inclusions in calcite vein material
F1495	4	10					-53.8	4.2	In calcite vein material
	2	4					193.8	5.7	In calcite and quartz vein material
F1530	3	8					-84.3	5.6	In calcite and quartz vein material
	5	1					42.7		In quartz vein material
F1800	2	3	-1.07	0.06	1.85	0.10	207.0	0.0	In calcite and quartz vein material
	3	15					-79.9	9.4	In calcite and quartz vein material
F1885	2	6	-1.37	0.12	2.35	0.19	219.7	3.0	In calcite and quartz vein material
	3	20					-84.2	4.2	In calcite and quartz vein material
F1970	2								Small (<2µm) aqueous inclusions in quartz overgrowths
	3	16					-91.9	4.0	In calcite and quartz vein material
F2045	2								Small (<2µm) aqueous inclusions in quartz overgrowths
F2060	2	5	-2.02	0.28	3.42	0.45	207.3	24.2	In calcite and quartz vein material
	3	27					-88.6	5.1	In calcite and quartz vein material
F2065	2	6	-1.80	0.52	3.06	0.85	236.9	31.8	In calcite and quartz vein material
	3	8					-90.9	2.9	In calcite and quartz vein material
F2135	2								Small (<2µm) aqueous inclusions in quartz overgrowths
	3	5					-89.8	1.3	In calcite vein material
F2225	3	19					-83.5	12.4	In calcite and quartz vein material

Table 7 (cont.): Summary of microthermometric data from Nalcor et al. Finnegan. $T_m$ice = last ice melting temperature. T_h = homogenization temperature

Sample Number	Type	n	Tmice		Salinity		Th		Notes
			mean	stdev	mean	stdev	mean	stdev	
F2480	2, 3								Small (<2µm) inclusions, commonly aqueous with rare gas (Th ~-60oC) in calcite and dolomite
F2575	2	7	-4.35	0.35	6.95	0.50	54.9	4.3	In quartz
	2								Rare, small (<2µm) aqueous inclusions in calcite, dolomite and quartz
F2615	2								Rare, small (<2µm) aqueous inclusions in calcite and dolomite
F2755	2	12	-30.83	0.72	29.19	0.46	144.8	3.3	In calcite and dolomite
F2790	2								Small (<2µm) aqueous inclusions in calcite and dolomite
F2915	2								Small (<2µm) aqueous inclusions in quartz overgrowths
Type 1		**15**					**14.8**	**10.8**	
Type 2		**46**	**-5.87**	**10.19**	**6.79**	**9.21**	**166.1**	**61.7**	
Type 3		**118**					**-86.3**	**7.9**	
Type 4		**10**					**-53.8**	**4.2**	
Type 5		**1**					**42.7**		

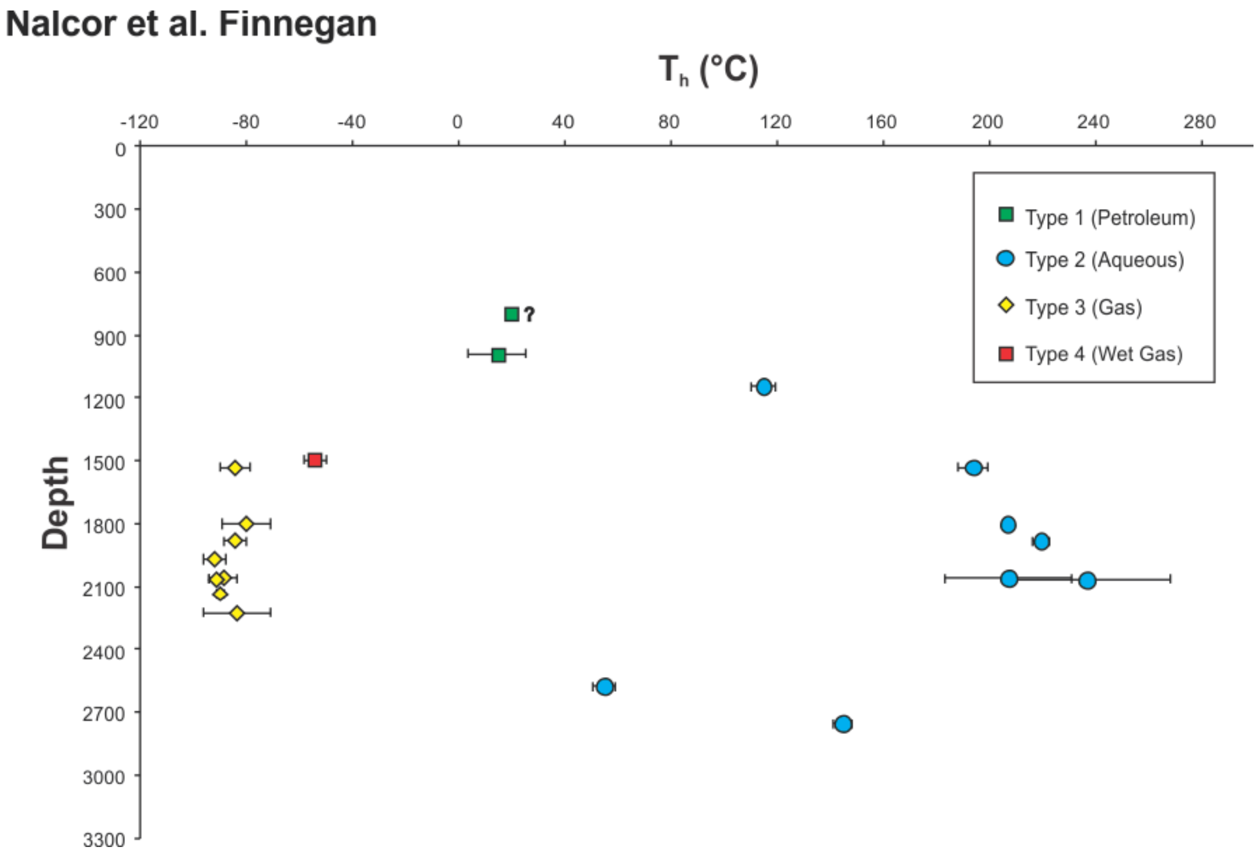

Figure 13: Homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Nalcor et al. Finnegan plotted against depth. Symbols represent mean T_h values, error bars represent standard deviation

Type 3

Type 3 gas inclusions are common in quartz and calcite vein material in eight samples, and are restricted to samples from depths of 1530 to 2225m (Table 6). These inclusions range in size from >20 to <2µm, and separate into a liquid and vapour phase upon cooling to >100°C. Homogenization temperatures of Type 3 inclusions range from -96.7 to -58.4°C, indicating their composition is not pure CH_4 (T_h = -82.7°C). In addition small (<3µm) gas inclusions were recorded in calcite and sucrosic dolomite from sample F2480, with T_h values of ~ -60°C..

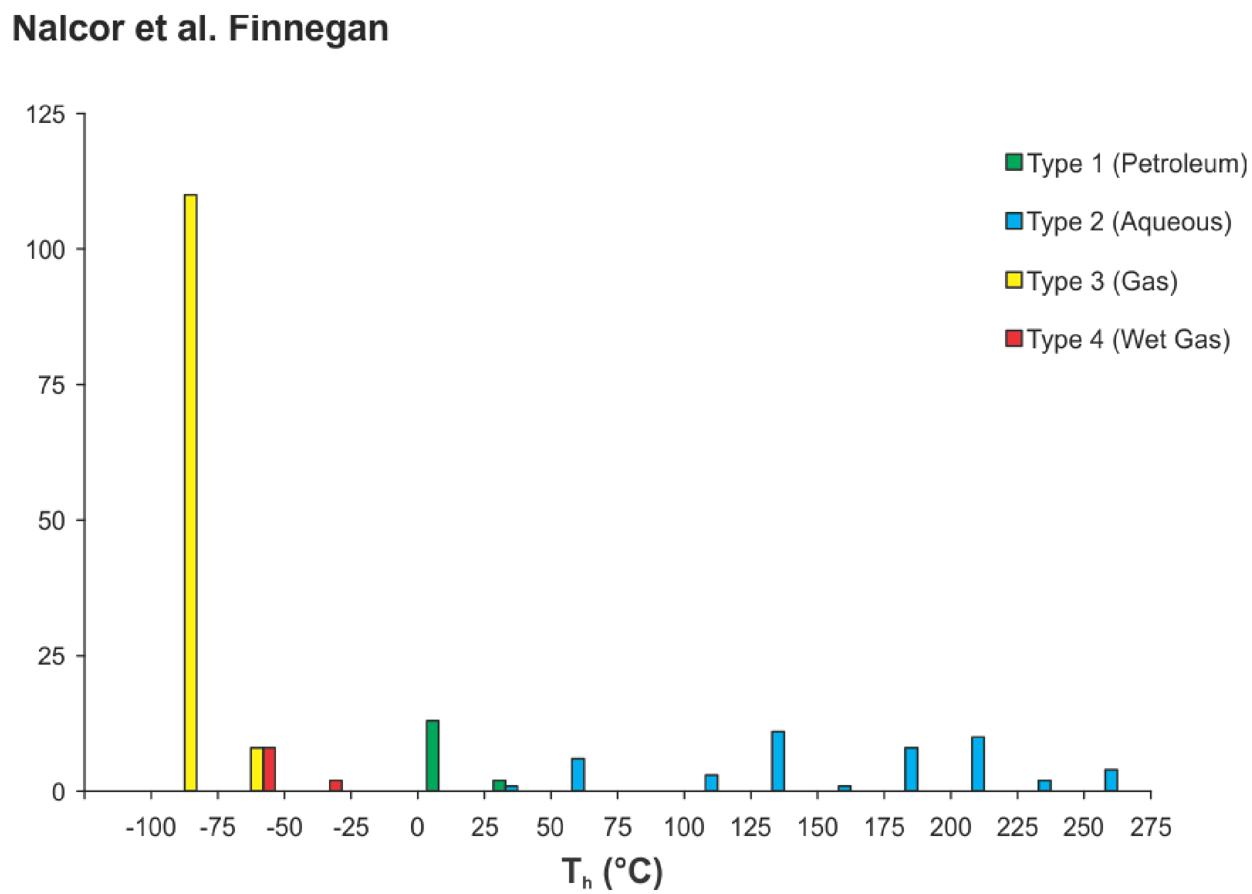

Figure 14: Frequency distribution histogram for homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Nalcor et al. Finnegan.

Type 4

Type 4 inclusions were recorded in calcite vein material from a single sample (F1495). Like other Type 4 inclusions they are monophase at room temperature and have a very weak blue fluorescence (visible only using camera). However, upon freezing they do not separate into a liquid and gas phase till >-60°C, and their Th values (-53.8 ± 4.2°C) are much lower than Type 4 inclusions in other wells (Fig. 14). This indicates that Type 4 inclusions in this sample are more similar to Type 3 gas inclusions than Type 1 petroleum inclusions.

8.3. Nalcor et al. Seamus

Microthermometric data was collected from 14 of the 22 samples (Tables 8, 9). In other samples, fluid inclusions were observed, but collection of fluid inclusions data was impossible due to the small size of inclusion (<2µm) or poor clarity of the sample. The microthermometric data from each sample is summarized in Table 9, with detailed results presented in Appendix 1.

Type 1

Type 1 inclusions were recorded in six samples and are hosted in calcite and quartz vein material. They were generally found in samples from 810 to 1320m (Table 8; Fig. 15), but Type 1 inclusions were recorded in a single sample from below this depth (S2140). At room temperatures Type 1 inclusions may be monophase liquid or two-phase (L + V) and range in size from 20 to <2µm. They were recognised based on their fluorescence under UV light. Many have a characteristic blue-green fluorescence, with rarer blue fluorescing Type 1 inclusions and some FIA showing a range of fluorescence colours (see below). T_h values were recorded in two-phase Type 1 inclusions in five samples, with values ranging from 23.5 to 101.3°C (mean = 49.9°C, standard deviation = 25.9°C). No phase changes were recorded on cooling of Type 1 inclusions.

Type 2

Type 2 aqueous inclusions were found throughout the well at all depths (Table 8; Fig. 15), and were recorded in all but one sample (S1105). Type 2 inclusions were recorded in calcite and quartz vein material, authigenic sandstone cements and in dolomite and calcite in the autochthonous carbonates. Both monophase and two-phase (L+V) aqueous inclusions were recorded and they are generally small (<5µm) with rare Type 1 inclusions up to 20µm. Due to the small size of Type 2 inclusions, and poor clarity in some samples, fluid inclusion microthermometry was only possible for Type 2 inclusions in six samples. Fluid salinities of 7.32 ± 0.49 eq. wt% NaCl were calculated for Type 2 inclusions in samples S1420 and S2295. A wide range of homogenization temperatures were recorded (Fig. 16), with values ranging from 109 to 187°C.

Table 8: Relative abundances of fluid inclusion types in samples from Nalcor et al. Seamus. xxx = abundant. xx = common. x = rare.

Sample Name	Sample Depth	Host Mineral	Gas Show	Fluid Inclusion Types Petroleum 1	Aqueous 2	CH_4/CO_2 3	Wet Gas 4
S715	710-715	Cuttings	0.8		x		
S720	715-720	Cuttings	4.18		x		
S810	805-810	Cuttings	4.2	xx	x		xx
S940	935-940	Cuttings	6.06	xx	xx		
S1050	1045-1050	Cuttings	20.5	x	xx	xx	
S1105	1100-1105	Cuttings	3.7	xx			xx
S1320	1315-1320	Cuttings	3.8	xx	xx		
S1420	1415-1420	Cuttings	2.5		xx	xx	
S1860	1855-1860	Cuttings	1.4		xx		
S1885	1880-1885	Cuttings	5.69		xx		
S2005	2000-2005	Cuttings	>4		xx	xxx	
S2140	2135-2140	Cuttings	64	xx	xx		
S2295	2290-2295	Cuttings	2		xx	xx	
S2505	2500-2505	Cuttings	>4		x	xx	
S2595	2590-2595	Cuttings	>20		x	xx	
S2605	2600-2605	Cuttings	44.8		x	xx	
S2775	2770-2775	Cuttings	15		x	xx	
S2865	2860-2865	Cuttings	0		xx		
S2895	2890-2895	Cuttings	0		xx		
S3085	3080-3085	Cuttings	3		xx		
S3120	3115-3120	Cuttings	1		xx		
S3150	3145-3150	Cuttings	1		xx	?	

Table 9: Summary of microthermometric data from Nalcor et al. Seamus. $T_m$ice = last ice melting temperature. T_h = homogenization temperature

Sample Number	Type	n	$T_m$ice mean	$T_m$ice stdev	Salinity mean	Salinity stdev	T_h mean	T_h stdev	Notes
S715	2								Rare, small (<2µm) aqueous inclusions in calcite vein material
S720	2								Rare, small (<2µm) aqueous inclusions in calcite vein material
S810	1	5					98.0	2.4	In calcite vein material
	1								Small, monophase (?) petroleum inclusions in calcite vein material
	4	2					-4.0	2.8	In calcite vein material
S940	1	4					40.0	1.0	In calcite vein material
	1, 2								Small petroleum and aqueous inclusions in calcite vein material
S1050	1	1					38.9		In calcite vein material
	2	3					146.3	3.7	In calcite vein material
	3	6					-74.7	1.4	In calcite vein material
S1105	1	10					41.3	18.4	In calcite vein material
	4	6					-13.6	5.3	In calcite vein material
S1320	1, 2								Monophase petroleum and aqueous inclusions in calcite vein material
S1420	2	8	-5.20		8.14		131.7	22.3	In calcite vein material
	3	8					-64.7	4.8	In calcite vein material
S1860	2								Small (<2µm) aqueous inclusions in calcite vein material
S1885	2								Small (<2µm) aqueous inclusions in calcite vein material
S2005	3	24					-73.0	11.8	In quartz vein material
S2140	1	7					35.2	1.4	In quartz vein material
	1								Monophase petroleum inclusions in quartz vein material
S2295	2	6	-4.50	0.22	8.14	0.31	184.1	3.0	In calcite vein material
	3	14					-92.2	4.6	In calcite vein material

Table 9 (cont.): Summary of microthermometric data from Nalcor et al. Seamus. $T_m$ice = last ice melting temperature. T_h = homogenization temperature

Sample Number	Type	n	$T_m$ice		Salinity		T_h		Notes
			mean	stdev	mean	stdev	mean	stdev	
S2505	3	18					-94.7	5.2	In calcite and quartz vein material
S2595	2	5					124.7	4.6	In calcite vein material
	3	21					-95.8	4.8	In quartz vein material
S2605	2								Small (<2μm) aqueous inclusions in calcite vein material
	3	5					-71.8	2.8	In calcite vein material
S2775	3	4					-84.4	0.8	In calcite vein material
	2, 3								Small (<2μm) aqueous and possible gas inclusions in quartz overgrowths
S2865	2								Small (<2μm) aqueous inclusions in calcite and dolomite
S2895	2								Small (<2μm) aqueous inclusions in calcite and dolomite
S3085	2	4					129.1	3.6	In calcite and dolomite
	2								Small (<2μm) aqueous inclusions in calcite and dolomite
S3120	2	4					160.5	3.3	In calcite and dolomite
	2								Small (<2μm) aqueous inclusions in calcite and dolomite
S3150	2								Small (<2μm) aqueous inclusions in calcite and dolomite
Type 1		**28**					**49.8**	**25.4**	
Type 2		**29**	**-4.62**	**0.34**	**7.32**	**0.49**	**144.6**	**24.5**	
Type 3		**100**					**-84.2**	**13.4**	
Type 4		**8**					**-11.2**	**6.4**	

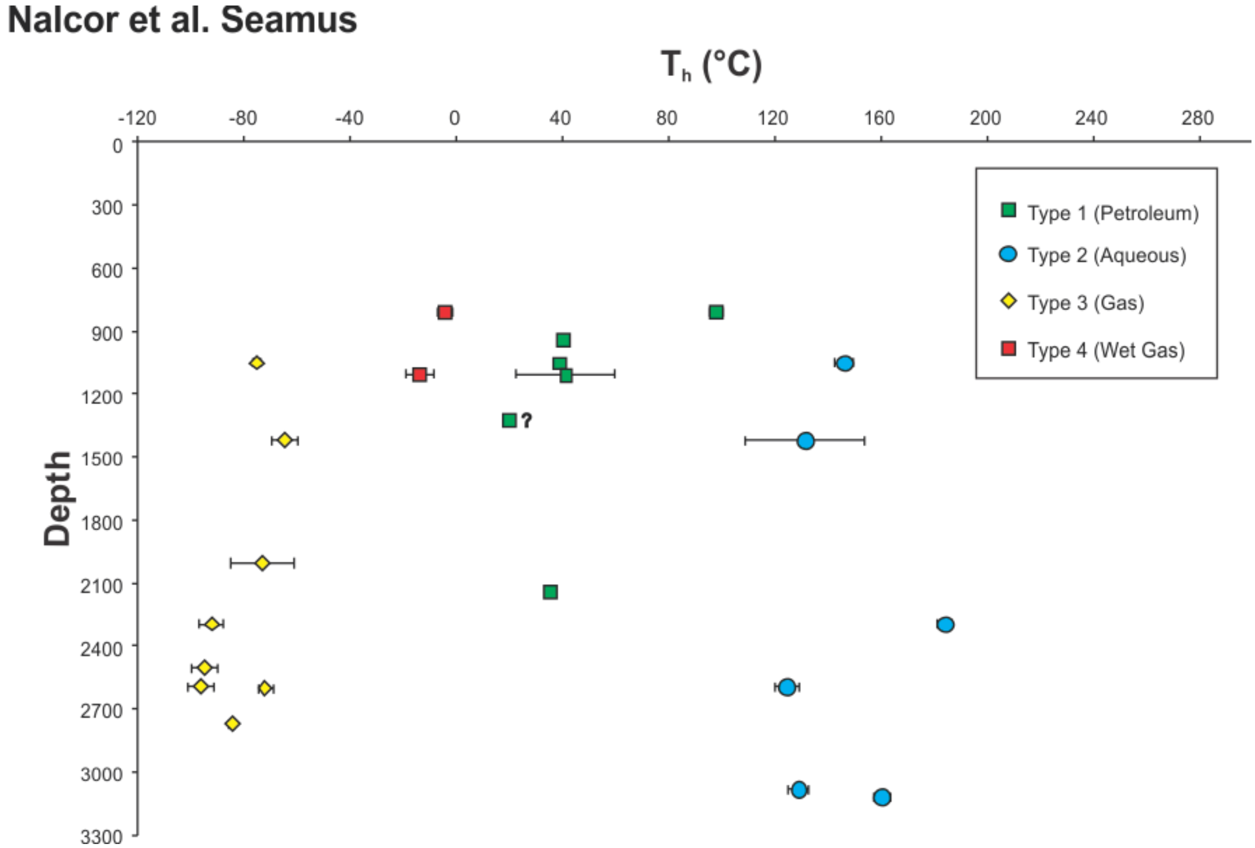

Figure 15: Homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Nalcor et al. Seamus plotted against depth. Symbols represent mean T_h values, error bars represent standard deviation

Type 3

Type 3 gas inclusions were recorded in quartz and calcite vein material in eight samples from 1050 to 2775m (Table 8). In addition some small, possible Type 3 inclusions were recorded in quartz overgrowth in sample S2775, indicating the presence of gas during the cementation of these sandstones. Type 3 inclusions range in size from >20 to <2µm, with rare inclusions up to 100µm. Upon cooling Type 3 inclusions separate into a liquid and vapour phase at a range of temperatures from -70 to -120°C. Homogenization temperatures range from -101.7 to -55.9°C (mean = -84.2°C; standard deviation = 13.4°C), which are different from what is the expected value for pure CH_4 (-82.7°C).

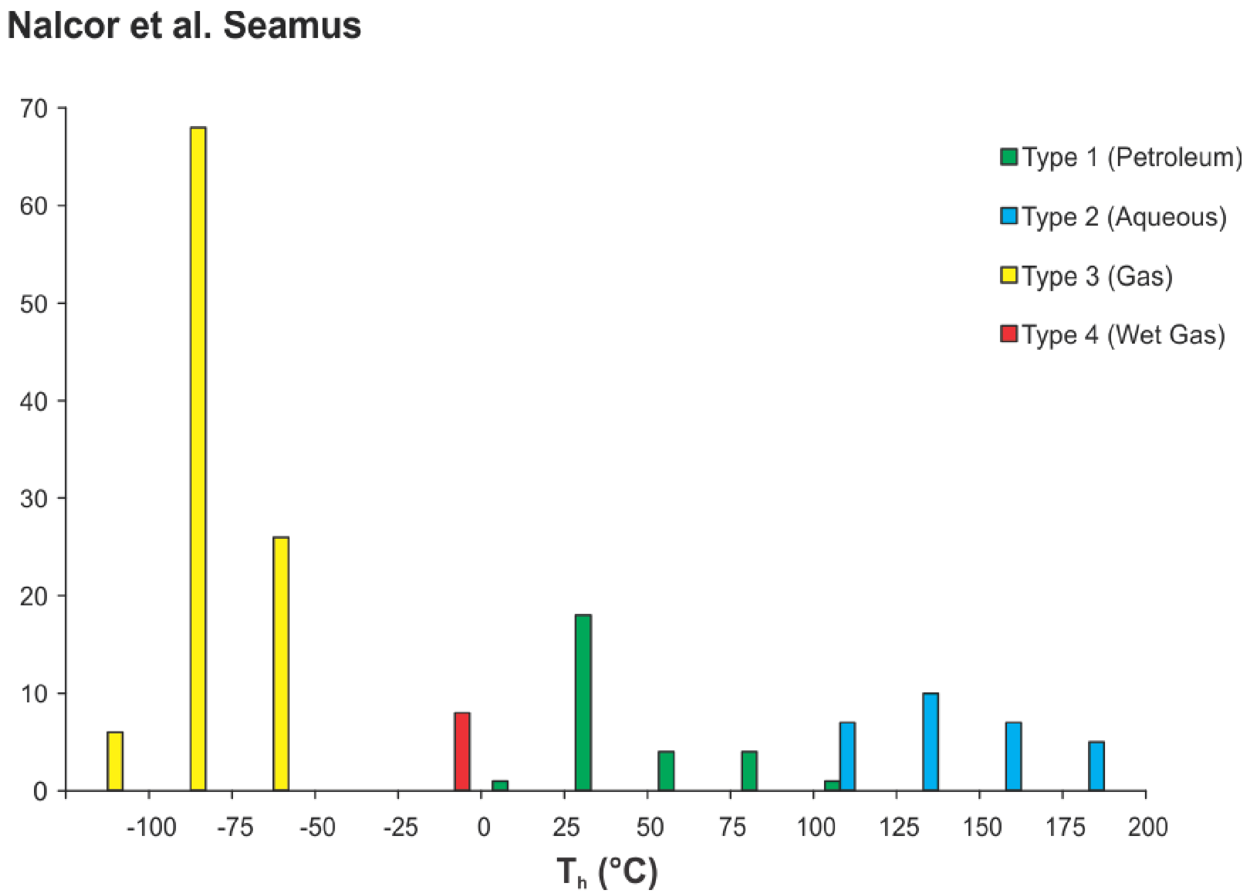

Figure 16: Frequency distribution histogram for homogenization temperatures of Type 1, Type 2, Type 3 and Type 4 inclusions from Nalcor et al. Seamus.

Type 4

Type 4 inclusions were recorded in two samples (S810 and S1105) and are associated with Type 1 inclusions. They are distinguished due to their very weak fluorescence (blue) and monophase nature at room temperature. Upon cooling Type 4 inclusions separate into a liquid and vapour phase, with T_h values of -19.8 to -2°C.

9. Ultraviolet fluorescence microspectroscopy

Following detailed petrography and fluid inclusion microthermometry, samples with Type 1 inclusions were selected for ultraviolet fluorescence microspectroscopy. In total Type 1 inclusions were analysed in 17 samples; 10 from Contact Exploration Inc. Parson's Pond #1, 2 from Nalcor et al. Finnegan, and 5 from Nalcor et al. Seamus. Based on spectral shape, maximum intensity, λ_{max}, $Q_{650/500}$ and $Q_{510/430}$, Type 1 inclusions have been separated into three main populations (Figs. 17, 18, 19, and 20).

Table 10: Summary of λ_{max}, $Q_{650/500}$ and $Q_{510/430}$ from Type 1a, 1b and 1c inclusion.

Sample Number	Type	λ_{max} (nm)		$Q_{650/500}$		$Q_{510/430}$	
		mean	stdev	mean	stdev	mean	stdev
CE569.7	1a	493.4	0.6	0.13	0.01	1.90	0.14
CE570.3	1a	493.6	0.8	0.13	0.02	2.22	0.12
CE917.4	1a	491.2	1.9	0.13	0.02	1.48	0.18
F800	1a	493.7	0.0	0.15	0.03	1.98	0.16
S810	1a	492.7	0.7	0.19	0.08	1.72	0.01
S940	1a	490.7	1.0	0.45	0.15	1.50	0.18
CE1054.2	1b	491.5	0.7	0.07	0.01	1.67	0.27
CE922.7 (early)	1b	490.4	0.4	0.04	0.00	1.36	0.10
CE949.2	1b	490.4	0.6	0.04	0.01	1.34	0.21
CE950.4	1b	491.0	0.9	0.04	0.01	1.68	0.44
CE955.5	1b	492.2	0.9	0.04	0.01	2.07	0.37
F990	1b	490.8	0.7	0.04	0.01	1.37	0.19
S1105	1b	492.1	0.2	0.04	0.01	1.96	0.16
S1320	1b	492.1	0.3	0.04	0.03	1.99	0.19
S2140	1b	490.6	0.2	0.09	0.02	1.46	0.05
CE917.4	1c	455.8	25.1	0.06	0.03	0.82	0.16
CE922.7 (late)	1c	447.5	20.7	0.05	0.01	0.80	0.11
CE927.7	1c	449.0	21.3	0.06	0.05	0.75	0.10
CE949.2	1c	465.4	26.9	0.05	0.04	0.72	0.17
S940	1c	437.1	0.2	0.30	0.19	0.60	0.04
CE1054.2	Biodegraded Oil	492.4	2.3	0.09	0.03	1.62	1.03
CE927.7	Water Washed	485.3	20.5	0.09	0.09	1.78	0.71
S810	Biodegraded Oil	492.4	2.3	0.51	0.77	2.05	0.53

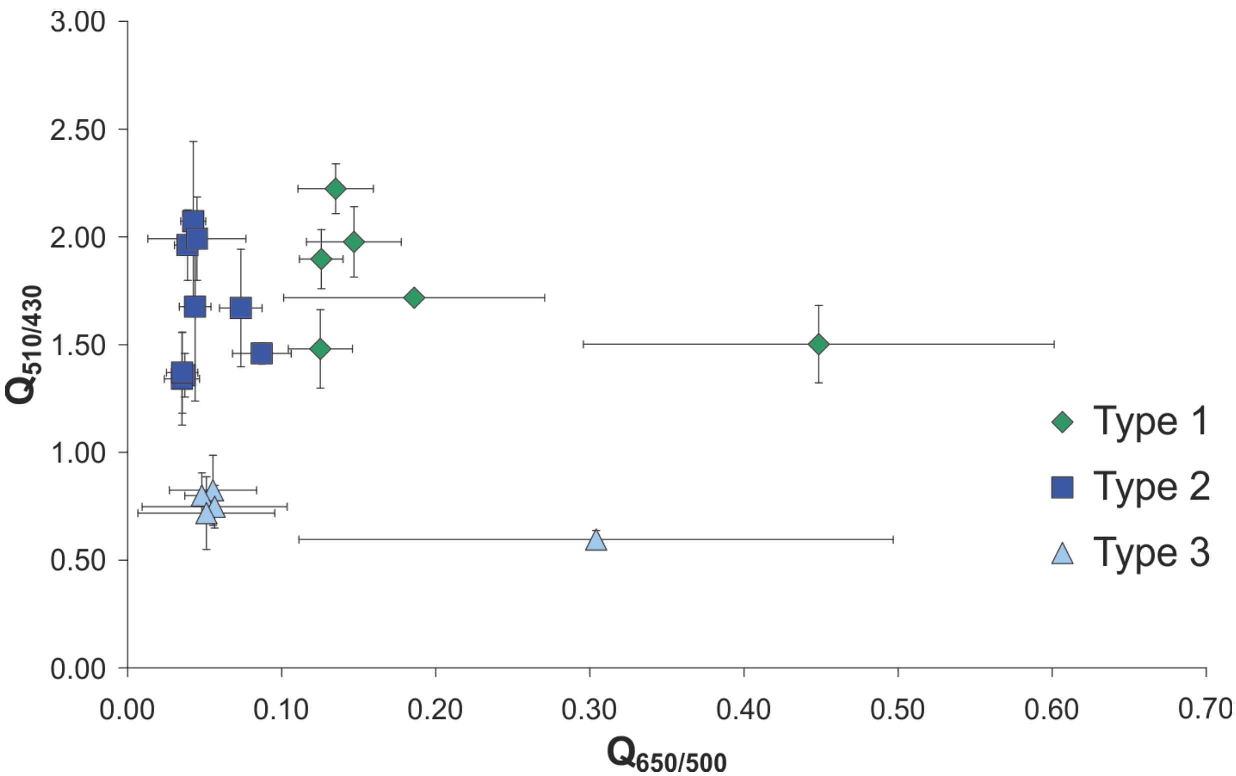

Figure 17: Comparison of Q values

- *Type 1a:* These inclusions have a green-blue fluorescence under UV light, and were recorded in samples CE569.7, CE570.3, CE917.4, F800, S810 and S940 (Table ?). They are characterized by a pronounced peak (λ_{max}) at 490-495nm (Fig. 18). When plotted on a bivariate plot of $Q_{650/500}$ vs. $Q_{510/430}$ (Fig. 17) these inclusions have relatively high $Q_{650/500}$ (>0.10) and $Q_{510/430}$ (>1.3). Type 1a inclusions in sample S940 are characterised by high $Q_{650/500}$ values (0.45 ± 0.15). This may be related to a different petroleum composition or to the relative intensity fluorescence (see below).
- *Type 1b:* Type 1b inclusions were recorded in nine samples (CE922.7, CE949.2, CE950.4, CE955.5, CE1054.2, F990, S1105, S1320, and S2140). They have a blue fluorescence under UV light and their spectral shape has a pronounced peak at 490 to

495nm (Fig. 19). However, unlike Type 1a inclusions have an asymmetric spectral shape, with a sharp drop in intensity above 500nm. Therefore, Type 1b inclusions have very low $Q_{650/500}$ values (<0.15) and high $Q_{510/430}$ values (>1.5).

- *Type 1c:* Type 1c inclusions have a light blue fluorescence and were recorded in samples CE917.4, CE922.7, CE927.7, CE949.2, and S940. Their spectra is characterised by maximum intensity from 430-435nm or relatively equal intensity peaks at approx. 435nm and 490nm (Fig. 20). On a bivariate plot of $Q_{650/500}$ vs. $Q_{510/430}$ (Fig. 17) Type 1c inclusions have low $Q_{510/430}$ values (<1).

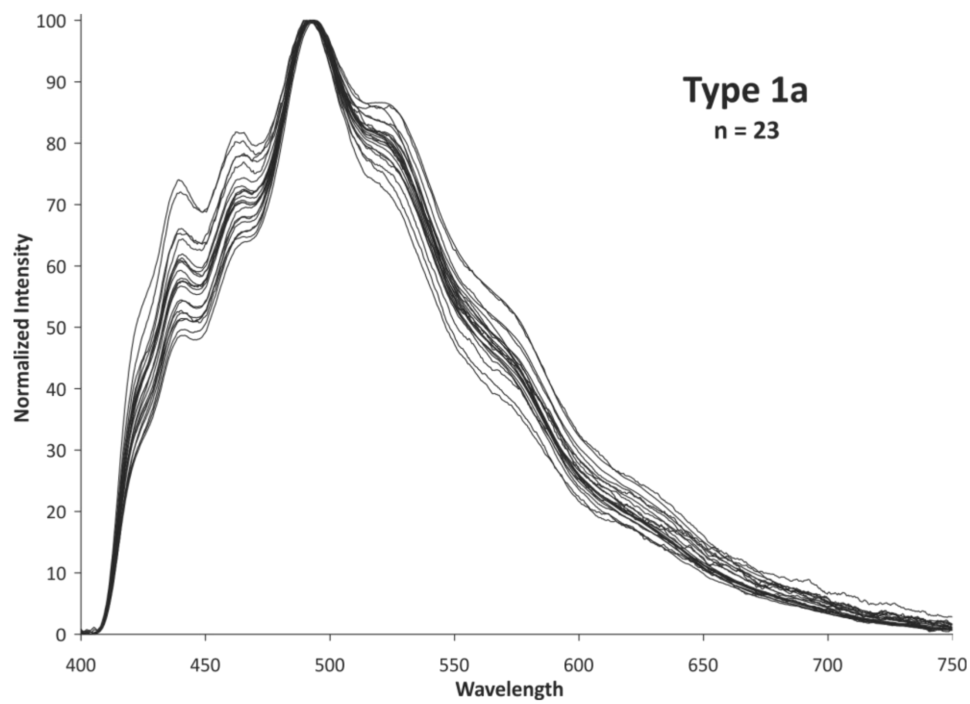

Figure 18: Wavelengths from Type 1a inclusions

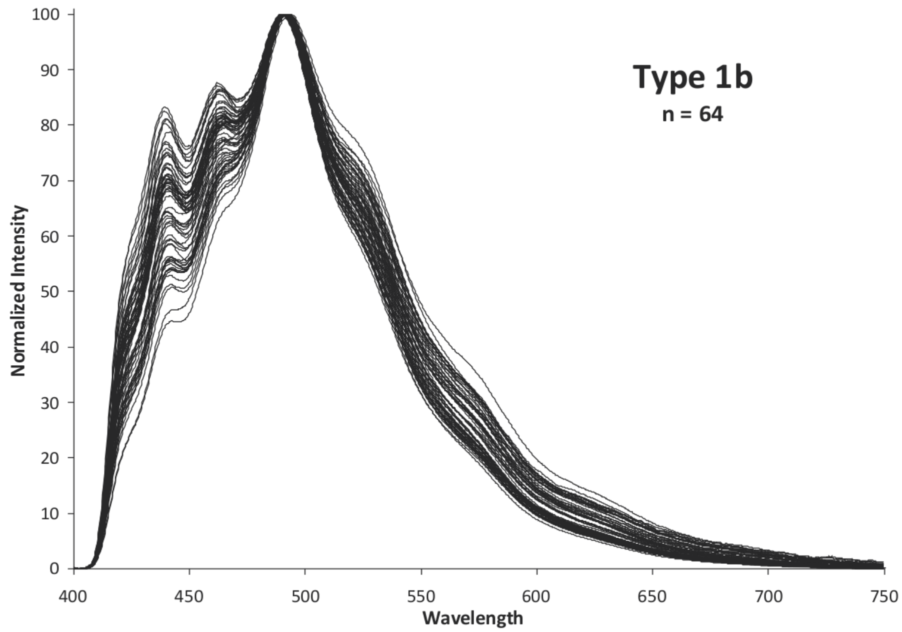

Figure 19: Wavelengths from Type 1b inclusions

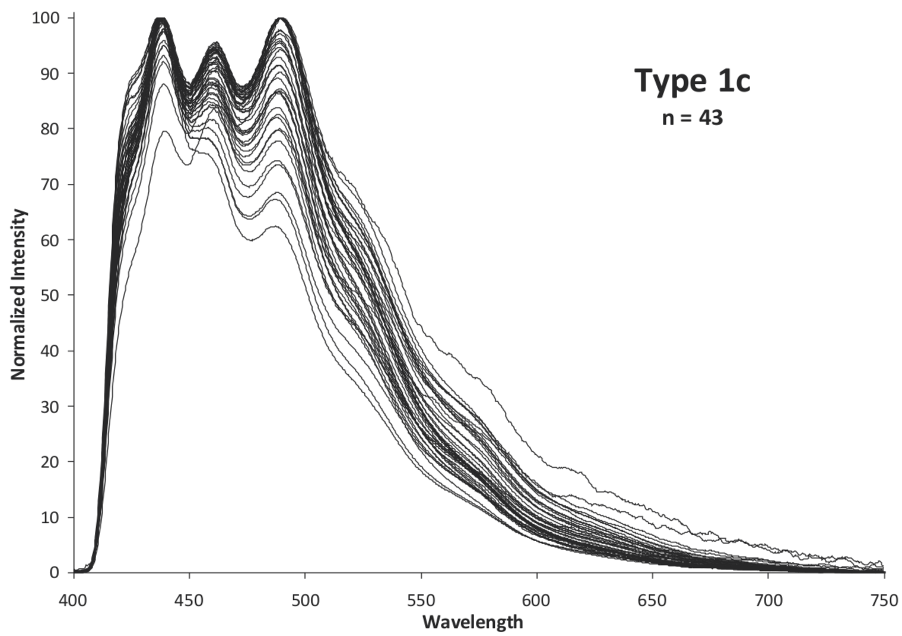

Figure 20: Wavelengths from Type 1c inclusions

Other processes have also been recorded based on ultraviolet fluorescence microspectroscopy. A number of FIA in sample CE927.7 have a wide range in λ_{max}, $Q_{650/500}$ and $Q_{510/430}$. Some of these inclusions contain an aqueous phase and therefore these variations are believed to be due to water washing. In samples CE1054.2 and S810 some FIA contain Type 1 inclusions with a range of fluorescence colours (brass to light blue), with a correspondingly wide range in λ_{max}, $Q_{650/500}$ and $Q_{510/430}$. This is interpreted to represent in situ biodegradation of oil after trapping.

10. Discussion

10.1. Petroleum and gas migration at Parson's Pond

Fluid inclusion analysis of core and cuttings samples from Parson's Pond has identified abundant evidence for petroleum and gas migration in all wells. All petroleum bearing fluid inclusion (Type 1) and the vast majority of gas inclusions (Type 3) are hosted in quartz and calcite vein material. This indicates that petroleum and gas migration at Parson's Pond is fracture controlled. This supports previous analysis by Contact Exploration, who conducted an assessment of five fracture zones in Contact Exploration Inc. Parson's Pond #1 and suggested the possibility the Lower Head Formation sandstones formed a fractured reservoir. Although only gas flow was encountered during the drilling of this well, the presence of abundant petroleum bearing fluid inclusions in calcite veins from three of these horizons (914-918m, 921.5 to 928m, and 1054-1058m) indicates that fractured reservoirs were charged with hydrocarbons during their post-diagenetic history.

With the exception of sample S2775, no petroleum or gas inclusions have been recorded in diagenetic sandstone cements. This indicates that no petroleum or gas was present during the cementation of these sandstones. The presence of monophase aqueous inclusions in sandstone cements indicates that cementation occurred at low temperatures, prior to the deep burial of these sandstones, and that they were essentially tight prior to hydrocarbon generation.

Gas-bearing inclusions were only recorded in a single dolomite sample (F2470) from potential autochthonous carbonate reservoirs in Nalcor et al. Finnegan and Seamus. Sample F2470 is from the Aguathuna Formation in the St. George Group, which has significant reservoir potential (Cooper et al. 2001). However, due to the scarcity of gas inclusions and absence of petroleum inclusions in samples from St. George Group it is unlikely that significant hydrocarbons were present during early dolomitization or late-stage hydrothermal dolomitization and calcite precipitation.

10.2. Distribution and composition of hydrocarbon-bearing fluid inclusions

Hydrocarbon (petroleum and gas) bearing fluid inclusions in all three wells show a wide range of compositions. The two end member fluids (least mature and most mature) are represented by the green fluorescing Type 1a inclusions and pure CH_4 Type 3 inclusions, respectively. Ultraviolet microfluorescence data from produced oils from the Jeanne D'Arc basin indicate that the $Q_{650/500}$ values can be related to the API gravity of the oils, particularly at $Q_{650/500}$ values of >0.10 (Fig. 21; Stasiuk and Snowdon, 1997; Gillespie pers. comm.). Using this linear relationship it was possible to calculate the API gravity of Type 1a inclusions. With the exception of sample S940, Type 1a inclusions have $Q_{650/500}$ values of 0.13 to 0.19, corresponding to API gravities of 33.89 to 31.73°. These values may underestimate the API gravity of the live oils contained in Type 1a inclusions, but give an approximation of the end member API gravity. The composition of Type 3 inclusions in sample S2005 was determined via Raman spectroscopy (at NUI, Galway, Ireland), and confirms that the most mature end member contains pure CH_4, with no other gases present (Fig. 22). Other hydrocarbon inclusions (Type 1, Type 3 and Type 4) represent hydrocarbon compositions intermediate to these types.

Evidence for multiple hydrocarbon migration events is particularly evident in sample CE922.7. Two generations of calcite veining have been recognised in this sample, with distinct population of Type 1 inclusions (based on fluorescence colours, T_h and UV microfluorescence). Early calcite contains abundant Type 1b inclusions, with blue-green fluorescence, relatively low T_h

values (38.5 ± 3.9°C) and high $Q_{510/430}$ values (1.36 ± 0.10). Type 1c inclusions in later calcite have a lighter blue fluorescence colour, higher homogenization temperatures (70.7 ± 8.7°C) and low $Q_{510/430}$ values (0.80 ± 0.11). This is consistent with an early charge of mature hydrocarbons at low temperatures, with a later charge of lighter hydrocarbons at higher temperatures.

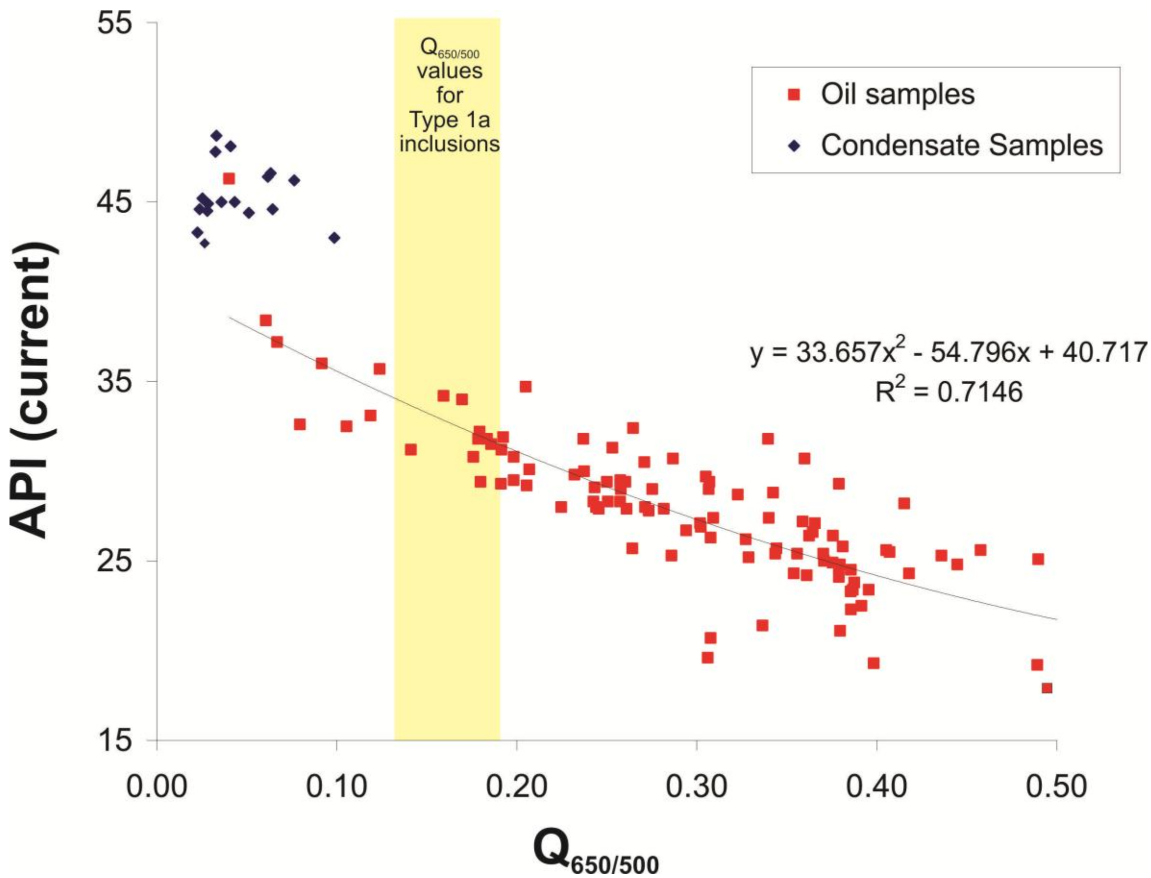

Figure 21: Relationship between API gravity and $Q_{650/500}$ of produced oils from the Jeanne D'Arc Basin (derived from Gillespie et al., PEEP data). Yellow box shows range of $Q_{650/500}$ values for Type 1a inclusions

In all three wells, the distribution of Type 1 and Type 3 inclusions shows a consistent distribution with depth (Figs. 11, 13, 15). Type 1 inclusions are generally confined to intermediate depths; from 569.7 to 1054m in Contact Exploration Inc. Parson's Pond #1, 800 to 990m in Nalcor et al. Finnegan, and 810 to 1320m (plus a single sample at 2140m) in Nalcor et al. Seamus. Calcite and quartz vein material from deeper depths show abundant evidence for gas migration, but no evidence for petroleum migration. This may be related to increased temperatures with depth, with the transition from the oil to the gas window occurring at approximately 1000-1500m.

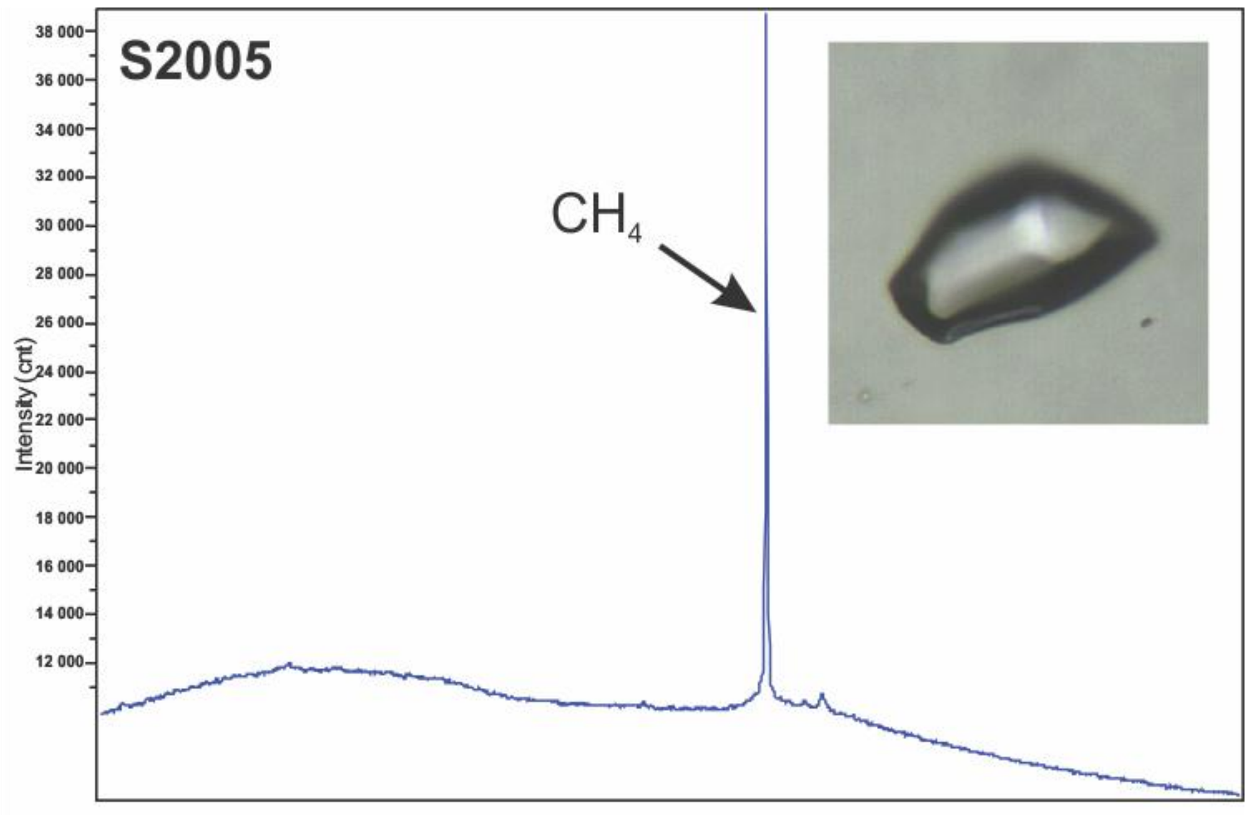

Figure 22: Laser Raman spectrum for Type 3 gas inclusion in sample S2005, showing presence of almost pure CH_4.

10.3. Implication for petroleum and gas exploration at Parson's Pond

These data are consistent with a complex hydrocarbon charge history at Parson's Pond, with multiple petroleum charge events of multiple compositions. The distribution of petroleum and gas inclusions indicate that the vast majority of hydrocarbon migration is fractured controlled, and no hydrocarbons were present during the cementation of the essentially tight sandstones of the Lower Head Formation and Cow Head Group. Previous studies have shown that the shales of the Green Point Formation (Cow Head Group) are the most likely source for the petroleum present in the Parson's Pond area (Macauley, 1987). These shales are distributed throughout the allochthonous sequence and it is likely that hydrocarbons were generated at multiple times during progressive burial and heating. This is supported by evidence from sample CE922.7, with early, low temperature migration of relatively immature hydrocarbon followed by the migration of more mature hydrocarbons at higher temperatures. In addition, the distribution of petroleum and gas-bearing inclusions with depth suggests that deeper levels are gas-prone, with petroleum confined to relatively shallow depths.

Fluid inclusions indicate that hydrocarbons were not present in significant amounts during dolomitization of the St. George Group Carbonates in the underlying autochthonous sequence. This does not necessarily mean that these carbonate reservoirs were never charged with hydrocarbons. Analysis of sucrosic and hydrothermal dolomite from the major exposed reservoir at Port aux Choix, western Newfoundland found no evidence of hydrocarbon charge during dolomitization, and filling of the reservoir postdates porosity enhancement during dolomitization (Conliffe et al. 2011). However, as current data indicates that hydrocarbons were generated from shales of the overlying allochthonous sequence, and without evidence of the juxtaposition of these shales with potential carbonate reservoirs, it remains unresolved if these reservoirs were ever filled.

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APPENDIX 1: Microthermometric data

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE368.4	1	1	2	0.95		-3.3	5.41	95.3	L
CE368.4	1	2	2	0.95				95.2	L
CE368.4	1	3	2	0.95				90.7	L
CE368.4	2	1	2	0.95				112.9	L
CE368.4	2	2	2	0.95				96	L
CE368.4	2	3	2	0.95		-5.3	8.28	101	L
CE368.4	3	1	2	0.9	-22	-4.8	7.59	101	L
CE368.4	3	2	2	0.9				105	L
CE368.4	3	3	2	0.9		-5.1	8.00	102.5	L
CE368.4	3	4	2	0.9		-4.8	7.59	105	L
CE368.4	3	5	2	0.9		-4.6	7.31	102.5	L
CE368.4	4	1	2	0.95				87.8	L
CE368.4	4	2	2	0.95		-4.6	7.31	89	L
CE368.4	4	3	2	0.95		-4.6	7.31	87.8	L
CE368.4	5	1	2	0.95		-4.5	7.17	103.4	L
CE368.4	6	1	2	0.95				93.8	L
CE368.4	6	2	2	0.95				91	L
CE415.2	1	1	2	0.95		-5	7.86	102	L
CE415.2	1	2	2	0.95	-22.9	-5.2	8.14	102	L
CE415.2	1	3	2	0.95	-22.3	-4.7	7.45	111.3	L
CE415.2	1	4	2	0.95				101.6	L
CE415.2	1	5	2	0.95	-24.6	-4.4	7.02	80.6	L
CE415.2	1	6	2	0.95				105	L
CE415.2	2	1	2	0.95		-5	7.86	105.6	L
CE415.2	2	2	2	0.95				114	L
CE415.2	2	3	2	0.95		-5.1	8.00	105.6	L
CE415.2	2	4	2	0.95		-4.9	7.73	114	L
CE415.2	3	1	2	0.95				101.6	L
CE415.2	3	2	2	0.95				98	L
CE415.2	3	3	2	0.95		-4.8	7.59	104	L
CE415.2	3	4	2	0.95		-4.4	7.02	104	L
CE415.2	4	1	2	0.95		-4.6	7.31	110.6	L
CE415.2	4	2	2	0.95		-4.5	7.17	113	L
CE415.2	4	3	2	0.95				113	L
CE415.2	4	4	2	0.95		-4.5	7.17	108.9	L
CE415.2	4	5	2	0.95		-4.5	7.17	116.2	L
CE415.2	5	1	2	0.95		-5	7.86	104.5	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE415.2	5	3	2	0.95		-5	7.86	110	L
CE415.2	5	4	2	0.95				98	L
CE415.2	5	5	2	0.95				106	L
CE570.3	1	1	1	0.95				87.6	L
CE570.3	1	2	1	0.95				94.8	L
CE570.3	1	3	1	0.95				87.6	L
CE570.3	1	4	1	0.95				92.6	L
CE570.3	2	1	1	0.95				87.3	L
CE570.3	2	2	1	0.95				89	L
CE570.3	2	3	1	0.95				91	L
CE570.3	2	4	1	0.95				91.2	L
CE570.3	3	1	1	0.95				87.7	L
CE570.3	3	2	1	0.9				88.6	L
CE570.3	3	3	1	0.95				84.6	L
CE570.3	3	4	1	0.95				87.1	L
CE570.3	3	5	1	0.95				87.1	L
CE570.3	3	6	1	0.95				85.4	L
CE605.3	1	1	2	0.95	-23.1			101.2	L
CE605.3	1	2	2	0.95				96.4	L
CE605.3	1	3	2	0.95				102.5	L
CE605.3	1	4	2	0.95				98.9	L
CE605.3	1	5	2	0.95				94.3	L
CE605.3	2	1	2	0.95		-5.5	8.55	110.3	L
CE605.3	2	2	2	0.95				107.6	L
CE605.3	2	3	2	0.95		-4.9	7.73	112	L
CE605.3	2	4	2	0.95		-4.9	7.73	112	L
CE607.4	1	1	2	0.95				105.2	L
CE607.4	1	2	2	0.95		-11.8	15.76	103.5	L
CE607.4	1	3	2	0.95		-12	15.96	92.4	L
CE607.4	1	4	2	0.95				94	L
CE607.4	1	5	2	0.95				94	L
CE607.4	2	1	2	0.95				102.3	L
CE607.4	2	2	2	0.95				109.7	L
CE607.4	2	3	2	0.95				108	L
CE607.4	2	4	2	0.95				108	L
CE607.4	2	5	2	0.95				104.8	L
CE607.4	3	1	2	0.95		-11.3	15.27	77.9	L
CE607.4	3	2	2	0.95				78	L
CE607.4	3	3	2	0.95		-10.9	14.87	78	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE607.4	3	4	2	0.95		-10.9	14.87	79.4	L
CE607.4	3	5	2	0.95				80.6	L
CE917.4	1	1	2	0.95		-6.3	9.60	93.9	L
CE917.4	1	2	2	0.95		-6.3	9.60	93.9	L
CE917.4	1	3	2	0.95				89.7	L
CE917.4	1	4	2	0.95		-6.5	9.86	89.7	L
CE917.4	1	5	2	0.95				92.1	L
CE917.4	2	1	2	0.95		-6.2	9.47	88.3	L
CE917.4	2	2	2	0.95		-6.2	9.47	96.1	L
CE917.4	2	3	2	0.95		-6.5	9.86	94.7	L
CE917.4	2	4	2	0.95		-6.4	9.73	88.3	L
CE917.4	2	5	2	0.95		-6.4	9.73	86.4	L
CE917.4	2	6	2	0.95		-6.2	9.47	89.1	L
CE917.4	3	1	1	0.95				53.4	L
CE917.4	3	2	2	0.95		-4.2	6.74	94.6	L
CE917.4	3	3	2	0.95				101.1	L
CE917.4	4	1	2	0.95	-23.8	-5.9	9.08		
CE917.4	4	2	2	0.95		-5.9	9.08		
CE917.4	4	3	2	0.95	-23.8	-5.8	8.95		
CE917.4	4	4	2	0.95		-5.8	8.95		
CE917.4	5	1	2	0.95		-6	9.21	105.7	L
CE917.4	6	1	2	0.95	-22.1	-5.5	8.55	104	L
CE917.4	6	2	2	0.95		-5.5	8.55	106.3	L
CE917.4	6	3	2	0.95		-5.5	8.55	101.7	L
CE917.4	6	4	2	0.95	-22.1	-6	9.21	104	L
CE917.4	6	5	2	0.95	-22.1	-6	9.21	104	L
CE917.4	6	6	2	0.95		-5.9	9.08	101.7	L
CE917.4	7	1	3					-66	V
CE917.4	8	1	2	0.95		-5.7	8.81	91	L
CE917.4	8	2	2	0.95				94.3	L
CE917.4	9	1	3					-67.5	V
CE917.4	9	2	3					-69	V
CE917.4	9	3	3					-66.9	V
CE917.4	9	4	3					-68.4	V
CE917.4	10	1	3					-65.1	V
CE917.4	10	2	3					-64.7	V
CE917.4	10	3	3					-66.8	V
CE917.4	10	4	3					-64.7	V
CE918.2	1	1	2	0.95	-22.7	-7	10.49	86.4	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE918.2	1	2	2	0.95		-6.8	10.24	91.6	L
CE918.2	1	3	2	0.95	-22.8	-6.8	10.24	86.4	L
CE918.2	1	4	2	0.95		-7	10.49	90	L
CE918.2	1	5	2	0.95		-6.8	10.24	94.7	L
CE918.2	1	6	2	0.95		-6.2	9.47	90	L
CE918.2	2	1	2	0.95	-25	-5.7	8.81	97.8	L
CE918.2	2	2	2	0.95		-4.9	7.73	104	L
CE918.2	2	3	2	0.95		-5.7	8.81	103.6	L
CE918.2	3	1	2	0.95		-7.2	10.73	112.9	L
CE918.2	3	2	2	0.95		-7.2	10.73	102	L
CE918.2	3	3	2	0.95				106	L
CE918.2	3	4	2	0.95		-7	10.49	106	L
CE918.2	3	5	2	0.95		-7	10.49	109.4	L
CE918.2	4	1	3					-70.8	V
CE918.2	4	2	3					-71.2	V
CE918.2	5	1	3					-73.4	V
CE918.2	5	2	3					-71	V
CE918.2	5	3	3					-69.8	V
CE918.2	6	1	3					-64.6	C
CE918.2	6	2	3					-67.9	V
CE918.2	6	3	3					-68	V
CE918.2	6	4	2	0.95		-6.2	9.47		
CE918.2	6	5	2	0.95				112.6	L
CE918.2	7	1	3					-67.4	V
CE918.2	7	2	3					-68	V
CE918.2	7	3	3					-63.7	V
CE918.2	7	4	3					-64.8	V
CE918.2	7	5	3					-64.8	V
CE922.7	1	1	2	0.95		-6.2	9.47	86.6	L
CE922.7	1	2	2	0.95		-6.5	9.86	89	L
CE922.7	1	3	2	0.95		-5.8	8.95	84.1	L
CE922.7	1	4	2	0.95		-5.9	9.08	90.4	L
CE922.7	1	5	2	0.95		-5.9	9.08	89.1	L
CE922.7	2	1	2	0.95				120.3	L
CE922.7	2	2	2	0.95		-6.2	9.47	109.8	L
CE922.7	2	3	2	0.95				121.6	L
CE922.7	2	4	2	0.95				111.5	L
CE922.7	2	5	2	0.95				125.6	L
CE922.7	2	6	3					-68.5	V

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE922.7	2	7	3					-69.4	V
CE922.7	3	1	3					-74.5	L
CE922.7	3	2	3					-75.1	L
CE922.7	3	3	3					-75.1	L
CE922.7	3	4	3					-73	L
CE922.7	4	1	1	0.95				59.7	L
CE922.7	4	2	1	0.95				63.2	L
CE922.7	5	1	1	0.9				80.5	L
CE922.7	5	2	1	0.9				81	L
CE922.7	5	3	1	0.95				69.6	L
CE922.7	5	4	1	0.95				69.9	L
CE927.7	1	1	1	0.95				56.1	L
CE927.7	1	2	1	0.95				57	L
CE927.7	1	3	1	0.95				57	L
CE927.7	1	4	1	0.95				56.7	L
CE927.7	1	5	1	0.95				56	L
CE927.7	1	6	1	0.95				54	L
CE927.7	2	1	1	0.95				52.7	L
CE927.7	2	2	1	0.95				57.3	L
CE927.7	2	3	1	0.95				57	L
CE927.7	2	4	1	0.95				54.3	L
CE927.7	2	5	2	0.95	-21.6	-6.3	9.60	81.3	L
CE927.7	2	6	2	0.95		-5.9	9.08	84.6	L
CE927.7	2	7	2	0.95		-6.2	9.47	79	L
CE927.7	3	1	1	0.95				52.3	L
CE927.7	3	2	1	0.95				523	L
CE927.7	3	3	1	0.95				57.5	L
CE927.7	3	4	1	0.95				54.1	L
CE927.7	4	1	1	0.95				50.2	L
CE927.7	4	2	1	0.95				52	L
CE927.7	4	3	1	0.95				57	L
CE927.7	4	4	1	0.95				54.8	L
CE927.7	4	5	1	0.95				57	L
CE927.7	4	6	1	0.95				54.8	L
CE927.7	4	7	1	0.95				56.3	L
CE927.7	5	1	2	0.95		-5.4	8.41	101.4	L
CE927.7	5	2	2	0.95		-5.7	8.81	102.3	L
CE927.7	5	3	2	0.95		-5.4	8.41	101.4	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE927.7	5	4	2	0.95		-5.4	8.41	98.7	L
CE927.7	6	1	2	0.95		-5.6	8.68		
CE927.7	6	2	2	0.95		-5.6	8.68		
CE927.7	6	3	2	0.95		-5.7	8.81		
CE927.7	6	4	2	0.95		-5.6	8.68		
CE927.7	7	1	1	0.95				50.5	L
CE927.7	7	2	1	0.95				51	L
CE927.7	7	3	1	0.95				49.7	L
CE927.7	7	4	1	0.95				53.8	L
CE927.7	7	5	1	0.95				51	L
CE927.7	8	1	2	0.95		-5.7	8.81	113.2	L
CE927.7	8	2	2	0.95		-6	9.21	110	L
CE927.7	8	3	2	0.95		-6.5	9.86	110	L
CE927.7	8	4	2	0.95		-6.5	9.86		
CE949.2	1	1	3					-74.7	L
CE949.2	1	2	3					-73	L
CE949.2	2	1	4					-6.3	L
CE949.2	2	2	4					-6.3	L
CE949.2	2	3	4					-6	L
CE949.2	2	4	4					-6	L
CE949.2	3	1	4					3.2	L
CE949.2	3	2	4					7.4	L
CE949.2	3	3	4					-3	L
CE949.2	3	4	4					-6.3	L
CE949.2	3	5	4					-41.4	L
CE949.2	4	1	4					9.8	L
CE949.2	4	2	4					11.4	L
CE949.2	4	3	4					10.9	L
CE949.2	4	4	4					10.9	L
CE949.2	4	5	4					11.4	L
CE949.2	4	6	4					9.7	L
CE949.2	4	7	4					11.4	L
CE949.2	5	1	4					-5.8	L
CE949.2	5	2	4					-7.4	L
CE949.2	5	3	4					-5.8	L
CE949.2	5	4	4					-5.8	L
CE949.2	6	1	4					-14	V
CE949.2	6	2	4					-4.7	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
CE949.2	6	3	4					-2.8	L
CE950.4	1	1	2	0.95				66.3	L
CE950.4	1	2	2	0.95				80.4	L
CE950.4	1	3	2	0.95				76.2	L
CE950.4	1	4	2	0.95				72.1	L
CE955.4	1	1	1	0.95				77.8	L
CE955.4	1	2	1	0.95				87.1	L
CE955.4	1	3	1	0.95				86.4	L
CE955.4	1	4	1	0.95				82.4	L
CE955.4	1	5	1	0.95				83	L
CE955.4	2	1	1	0.95				64.6	L
CE955.4	2	2	1	0.95				64.7	L
CE955.4	2	3	1	0.9				77.8	L
CE955.4	2	4	1	0.95				65.2	L
CE955.4	2	5	1	0.95				65.3	L
F990	1	1	1					42.1	L
F990	1	2	1					6.1	L
F990	1	3	1					2.9	L
F990	1	4	1					6.8	L
F990	1	5	1					14.3	L
F990	1	6	1					14.3	L
F990	2	1	1					14.3	L
F990	2	2	1					18.7	L
F990	2	3	1					21.6	L
F990	2	4	1					21.6	L
F990	2	5	1					30.4	L
F990	3	1	1					4.5	L
F990	3	2	1					7.6	L
F990	3	3	1					8.1	L
F990	3	4	1					8.1	L
F1145	1	1	2	0.85		-1.8	3.06	111	L
F1145	1	2	2	0.85		-1.8	3.06		
F1145	1	3	2	0.85				120	L
F1145	1	4	2	0.85		-1.7	2.90	114	L
F1495	1	1	4					-52.3	L
F1495	1	2	4					-53.6	L
F1495	1	3	4					-48.1	L
F1495	1	4	4					-47.6	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
F1495	2	1	4					-58.1	L
F1495	2	2	4					-56.3	L
F1495	2	3	4					-52.1	C
F1495	2	4	4					-52.1	V
F1495	2	5	4					-58.9	L
F1495	2	6	4					-58.9	L
F1530	1	1	5	0.3				42.7	V
F1530	2	1	3					-80.8	V
F1530	2	2	3					-79.1	V
F1530	2	3	3					-77.5	V
F1530	2	4	2						L
F1530	2	5	2					188.4	L
F1530	2	6	2					190.7	L
F1530	2	7	2					194.6	L
F1530	2	8	2					201.5	L
F1530	3	1	3					-91	V
F1530	3	2	3					-91	V
F1530	3	3	3					-90.1	V
F1530	3	4	3					-81.6	V
F1530	3	5	3					-83.4	V
F1800	1	1	3					-80	L
F1800	1	2	3					-79.1	L
F1800	1	3	3					-79.1	L
F1800	1	4	3					-81	L
F1800	2	1	2			-1	1.74	207	L
F1800	2	2	3					-91.3	L
F1800	2	3	3					-91.3	L
F1800	2	4	3					-90	L
F1800	2	5	3					-90	L
F1800	2	6	3					-92	L
F1800	2	7	2			-1.1	1.91	207	L
F1800	2	8	2			-1.1	1.91	207	L
F1800	3	1	3					-76.7	L
F1800	3	2	3					-78	L
F1800	3	3	3					-68.1	L
F1800	3	4	3					-68.1	L
F1800	3	5	3					-67	L
F1800	3	6	3					-67	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
F1885	1	1	2	0.9		-1.5	2.57	223	L
F1885	1	2	2	0.9		-1.3	2.24	223	L
F1885	1	3	2	0.9		-1.3	2.24	217	L
F1885	1	4	2	0.9				217	L
F1885	1	5	2	0.9				217	L
F1885	1	6	2	0.9				221	L
F1885	2	1	3					-79.6	V
F1885	2	2	3					-78	V
F1885	2	3	3					-78	V
F1885	2	4	3					-81.4	V
F1885	2	5	3					-86.4	V
F1885	2	6	3					-85.8	V
F1885	3	1	3					-82.6	V
F1885	3	2	3					-83	V
F1885	3	3	3					-78.2	V
F1885	3	4	3					-79	V
F1885	4	1	3					-87.5	V
F1885	4	2	3					-87.5	V
F1885	4	3	3					-86.3	V
F1885	4	4	3					-86.3	V
F1885	4	5	3					-85	V
F1885	4	6	3					-85	V
F1885	5	1	3					-92	V
F1885	5	2	3					-92	V
F1885	5	3	3					-86.9	V
F1885	5	4	3					-84	V
F1970	1	1	3					-89.3	L
F1970	1	2	3					-87	L
F1970	1	3	3					-83.7	L
F1970	1	4	3					-87	L
F1970	1	5	3					-85.9	L
F1970	2	1	3					-93.1	L
F1970	2	2	3					-93	L
F1970	2	3	3					-92.6	L
F1970	2	4	3					-93	L
F1970	3	1	3					-94.3	L
F1970	3	2	3					-94.3	L
F1970	3	3	3					-95	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
F1970	3	4	3					-95	L
F1970	4	1	3					-96.3	L
F1970	4	2	3					-96.3	L
F1970	4	3	3					-95.1	L
F2060	1	1	3					-87	V
F2060	1	2	3					-87	V
F2060	1	3	3					-86.4	V
F2060	1	4	3					-86.4	V
F2060	1	5	3					-86.1	V
F2060	2	1	3					-90.4	V
F2060	2	2	3					-90.4	V
F2060	2	3	3					-89.3	V
F2060	2	4	3					-89.3	V
F2060	2	5	3					-88.4	V
F2060	2	6	3					-88.4	V
F2060	3	1	2	0.9		-2.3	3.87	233.4	L
F2060	3	2	2	0.9		-2.3	3.87	233.4	L
F2060	3	3	3					-67	V
F2060	3	4	3					-89.1	V
F2060	3	5	3					-92.6	V
F2060	3	6	3					-92	V
F2060	3	7	3					-89.4	V
F2060	4	1	2	0.9		-1.8	3.06	184.7	L
F2060	4	2	2	0.9		-2	3.39	189	L
F2060	4	3	3					-89.4	V
F2060	4	4	3					-88.5	V
F2060	4	5	3					-92.9	V
F2060	4	6	3					-91.8	V
F2060	4	7	3					-88.5	V
F2060	4	8	3					-88.1	V
F2060	5	1	2	0.9		-1.7	2.90	196	L
F2060	5	2	3					-96	V
F2060	5	3	3					-96.7	V
F2060	5	4	3					-86.7	V
F2060	5	5	3					-86.7	V
F2060	5	6	3					-88	V
F2065	1	1	3					-91.7	V
F2065	1	2	3					-88.1	V

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
F2065	1	3	3					-88.1	V
F2065	1	4	3					-87	V
F2065	1	5	2	0.9		-1.2	2.07	198.2	L
F2065	1	6	2	0.9				194	L
F2065	2	1	2	0.9		-2.1	3.55	261.5	L
F2065	2	2	2	0.9		-2.1	3.55	258	L
F2065	2	3	2	0.9				258	L
F2065	2	4	2	0.9				251.4	L
F2065	2	5	3					-94	V
F2065	2	6	3					-94	V
F2065	2	7	3					-94	V
F2065	2	8	3					-90.5	V
F2135	1	1	3					-88.6	L
F2135	1	2	3					-91.2	L
F2135	1	3	3					-91.3	L
F2135	1	4	3					-89	L
F2135	1	5	3					-89	L
F2225	1	1	3					-80.7	L
F2225	1	2	3					-80.7	L
F2225	1	3	3					-81.3	L
F2225	1	4	3					-94.9	L
F2225	1	5	3					-93.1	L
F2225	1	6	3					-60.2	L
F2225	1	7	3					-60.2	L
F2225	1	8	3					-58.4	L
F2225	2	1	3					-81.8	L
F2225	2	2	3					-83	L
F2225	2	3	3					-83	L
F2225	2	4	3					-80.1	L
F2225	2	5	3					-80.1	L
F2225	3	1	3					-94.5	L
F2225	3	2	3					-94.5	L
F2225	3	3	3					-95	L
F2225	3	4	3					-95	L
F2225	3	5	3					-94.5	L
F2225	3	6	3					-96.1	L
F2575	1	1	2	0.9		-4.1	6.59	49.5	L
F2575	1	2	2	0.9				51.6	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
F2575	1	3	2	0.9				51.6	L
F2575	2	1	2	0.9		-4.6	7.31	54.6	L
F2575	2	2	2	0.9		-4.35	6.95	60.3	L
F2575	2	3	2	0.9		0.25	0.36	60.3	L
F2575	2	4	2	0.9				56.3	L
F2755	1	1	2	0.95				145	L
F2755	1	2	2	0.95				145	L
F2755	1	3	2	0.95				147	L
F2755	1	4	2	0.95				147	L
F2755	1	5	2	0.95				151	L
F2755	1	6	2	0.95				147	L
F2755	2	1	2	0.95		-31.2	29.43	145.3	L
F2755	2	2	2	0.95		-31.3	29.49	140	L
F2755	2	3	2	0.95		-30	28.66	140	L
F2755	2	4	2	0.95				142	L
F2755	2	5	2	0.95				142	L
F2755	2	6	2	0.95				146	L
S810	1	1	1	0.8				45.2	L
S810	1	2	1	0.9				95.1	L
S810	1	3	1	0.9				97	L
S810	1	4	1	0.9				97	L
S810	1	5	1	0.9				99.6	L
S810	1	6	1	0.9				101.3	L
S810	2	1	4					-2	V
S810	3	1	4					-6	V
S940	1	1	1	0.95				40	L
S940	1	2	1	0.95				38.7	L
S940	1	3	1	0.95				40	L
S940	1	4	1	0.95				41.2	L
S1050	1	1	2	0.95				147.8	L
S1050	1	2	2	0.95				149	L
S1050	1	3	2	0.95				142	L
S1050	1	4	1	0.95				38.9	L
S1050	2	1	3					-76.2	L
S1050	2	2	3					-73	L
S1050	2	3	3					-73	L
S1050	2	4	3					-74.9	L
S1050	2	5	3					-74.9	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
S1050	2	6	3					-76.2	L
S1105	1	1	1	0.9				55.2	L
S1105	1	2	1	0.9				55.2	L
S1105	1	3	1	0.9				68	L
S1105	1	4	1	0.9				69.2	L
S1105	2	1	1	0.99				23.5	L
S1105	2	2	1	0.99				27.4	L
S1105	2	3	1	0.99				27.9	L
S1105	2	4	1	0.99				29	L
S1105	2	5	1	0.99				29	L
S1105	2	6	1	0.99				28.1	L
S1105	3	1	4					-17.5	L
S1105	3	2	4					-19.8	L
S1105	3	3	4					-17.6	L
S1105	3	4	4					-8.6	L
S1105	3	5	4					-8.9	L
S1105	3	6	4					-9	L
S1420	1	1	2	0.97		-5.2	8.14	152.2	L
S1420	1	2	2	0.97				154	L
S1420	1	3	2	0.97				154	L
S1420	1	4	2	0.97				149.6	L
S1420	1	5	3					-68.6	L
S1420	1	6	3					-70	L
S1420	1	7	3					-68.6	L
S1420	1	8	3					-69	L
S1420	2	1	3					-59.6	L
S1420	2	2	3					-60.3	L
S1420	2	3	3					-58.7	L
S1420	3	1	2	0.99				113.4	L
S1420	3	2	2	0.99				109	L
S1420	3	3	2	0.99				109	L
S1420	3	4	2	0.99				112.1	L
S1420	3	5	3					-62.4	L
S2005	1	1	3					-60.1	L
S2005	1	2	3					-59.2	L
S2005	1	3	3					-59.2	L
S2005	1	4	3					-60.1	L
S2005	1	5	3					-57.7	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
S2005	1	6	3					-57.7	L
S2005	2	1	3					-66.3	L
S2005	2	2	3					-67.4	L
S2005	2	3	3					-55.9	L
S2005	2	4	3					-55.9	L
S2005	3	1	3					-84.7	L
S2005	3	2	3					-84.7	L
S2005	3	3	3					-84.7	L
S2005	3	4	3					-88	L
S2005	3	5	3					-86.9	L
S2005	3	6	3					-78.7	L
S2005	3	7	3					-77.6	L
S2005	4	1	3					-79	L
S2005	4	2	3					-79	L
S2005	4	3	3					-79	L
S2005	5	1	3					-84.8	L
S2005	5	2	3					-84.8	L
S2005	5	3	3					-80.1	L
S2005	5	4	3					-79.6	L
S2140	1	1	1	0.97				35.3	L
S2140	1	2	1	0.97				35.3	L
S2140	1	3	1	0.97				37	L
S2140	1	4	1	0.97				33.6	L
S2140	1	5	1	0.97				33.6	L
S2140	1	6	1	0.97				37	L
S2140	1	7	1	0.97				34.7	L
S2295	1	1	2	0.97				183.2	L
S2295	1	2	2	0.97		-4.4	7.02	183.2	L
S2295	1	3	2	0.97		-4.4	7.02	187	L
S2295	1	4	2	0.97		-4.4	7.02	187	L
S2295	1	5	2	0.97		-4.4	7.02		
S2295	2	1	3					-88.8	L
S2295	2	2	3					-87	L
S2295	3	1	3					-89.1	L
S2295	3	2	3					-88.6	L
S2295	4	1	3					-89.1	L
S2295	4	2	3					-89.1	L
S2295	5	1	3					-96.9	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
S2295	5	2	3					-96.9	L
S2295	5	3	3					-95.3	L
S2295	5	4	3					-89.7	L
S2295	5	5	3					-89.7	L
S2295	5	6	3					-90.2	L
S2295	6	1	3					-100.5	L
S2295	6	2	3					-99.7	L
S2295	6	3	2	0.9		-4.9	7.73	180	L
S2505	1	1	3					-84.5	L
S2505	1	2	3					-84.5	L
S2505	1	3	3					-96.8	L
S2505	1	4	3					-94	L
S2505	2	1	3					-88.8	L
S2505	2	2	3					-90	L
S2505	2	3	3					-90	L
S2505	2	4	3					-91.1	L
S2505	3	1	3					-97.8	L
S2505	3	2	3					-97.8	L
S2505	3	3	3					-98.2	L
S2505	3	4	3					-97	L
S2505	3	5	3					-97	L
S2505	4	1	3					-101.7	L
S2505	4	2	3					-99.1	L
S2505	4	3	3					-98.5	L
S2505	4	4	3					-98.5	L
S2505	4	5	3					-99.1	L
S2595	1	1	3					-100.2	L
S2595	1	2	3					-101.6	L
S2595	1	3	3					-99.7	L
S2595	1	4	3					-99.7	L
S2595	1	5	3					-100.2	L
S2595	1	6	3					-100.9	L
S2595	2	1	3					-99.7	L
S2595	2	2	3					-95.2	L
S2595	2	3	3					-94.7	L
S2595	2	4	3					-94.7	L
S2595	2	5	3					-95	L
S2595	2	6	3					-95.8	L

Sample Number	FIA	Inclusion	Type	Fill	Te (°C)	Tmice (°C)	Salinity (eq. wt% NaCl)	Th (°C)	to
S2595	3	1	2	0.95				127.3	L
S2595	3	2	2	0.95				119.6	L
S2595	3	3	2	0.95				119.6	L
S2595	3	4	2	0.95				128.4	L
S2595	3	5	2	0.95				128.4	L
S2595	4	1	3					-99.3	L
S2595	4	2	3					-96.5	L
S2595	4	3	3					-96.5	L
S2595	4	4	3					-95	L
S2595	4	5	3					-95	L
S2595	4	6	3					-95.7	L
S2595	5	1	3					-86.3	L
S2595	5	2	3					-84	L
S2595	5	3	3					-87.1	L
S2605	1	1	3					-76.3	L
S2605	1	2	3					-72	L
S2605	1	3	3					-72	L
S2605	1	4	3					-69.4	L
S2605	1	5	3					-69.4	L
S2775	1	1	3					-85.6	L
S2775	1	2	3					-83.7	L
S2775	1	3	3					-84.2	L
S2775	1	4	3					-84.2	L
S3085	1	1	2	0.95				127.6	L
S3085	1	2	2	0.95				132	L
S3085	1	3	2	0.95				132	L
S3085	1	4	2	0.95				124.6	L
S3120	1	1	2	0.95				161.2	L
S3120	1	2	2	0.95				158	L
S3120	1	3	2	0.95				158	L
S3120	1	4	2	0.95				164.9	L