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THE MAGAZINE OF CANADIAN ENERGY GEOSCIENTISTS

# RESERVOIR

CSPG
Canada's Energy Geoscientists

cspg.org

# The search is on...

APEGA is inviting applications from geoscientist members interested in being elected to serve on Council.
Applications close **Thursday, September 22, at 4:30 p.m.**

This year, we are looking for councillor and executive applicants who demonstrate a combination of required competencies and experience.

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- Answer six simple questions

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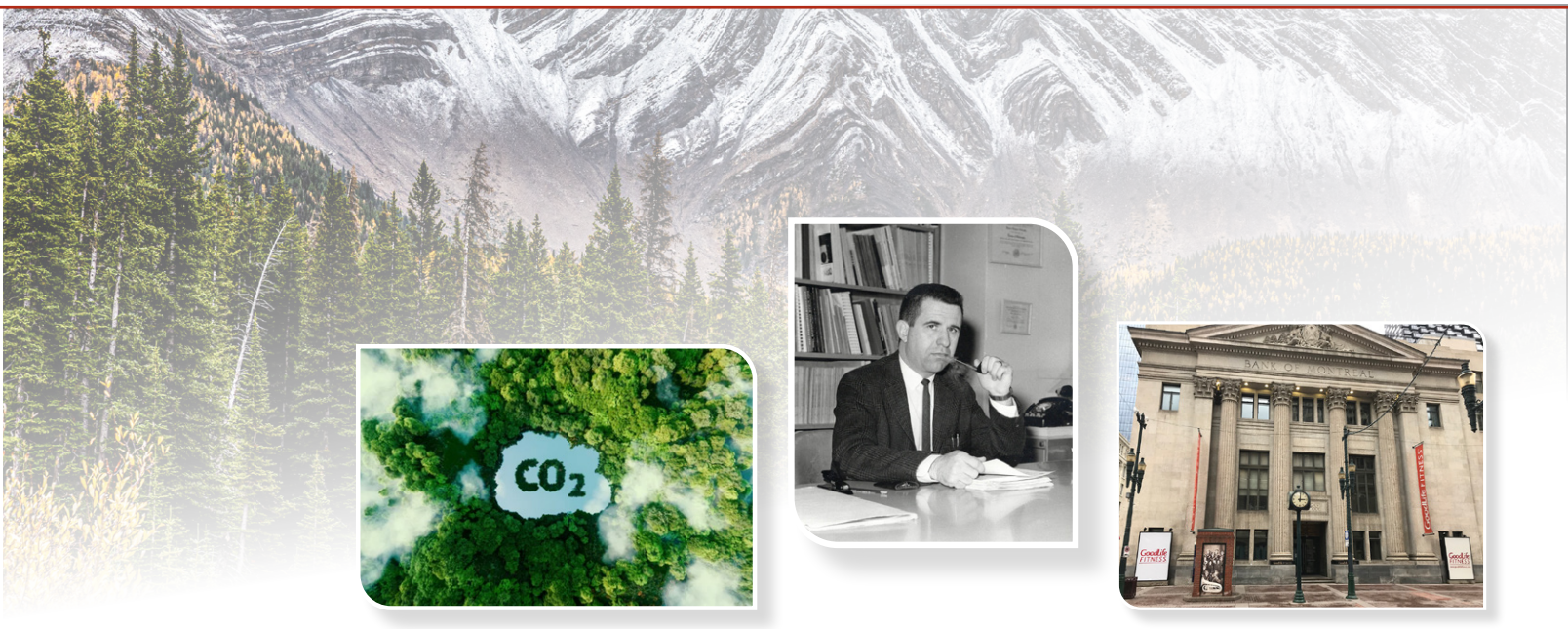
# In This Issue



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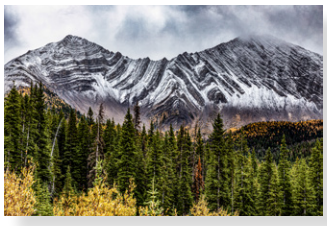

**FOOTWALL DEFORMATION, ALBERTA. BEST PHOTO.**

Strata in the footwall of the Lewis Thrust outcrop in the southeastern corner of Peter Lougheed Provincial Park. As seen looking south towards the Highwood Ridge, beds of the Morrissey, Mist Mountain and Elk formations of the Jurassic Kootenay Group display complex fold and fault patterns accentuated by a light dusting of snow. The overlying Early Cretaceous Cadomin Formation occurs just to the west followed by outcrops of the Lewis Thrust Sheet as old as the upper part of the Mississippian Livingstone Formation.

**Photo by: John Andersen**

# FROM THE EDITOR

**TOM SNEDDON**, PROFESSIONAL GEOLOGIST (ALBERTA), PROFESSIONAL GEOSCIENTIST

**I hope you will be dedicated readers of the Reservoir and continue to contribute technical and professional articles to our illustrious e-zine.**

It's Autumn again and the trail to Sentinel Pass and its larch forest is crammed with eager outdoor photographers and hikers. This is the season when geological field trips are in full force, but everyone else is more inclined toward enjoying the entire landscape and a lot of carbonates and siliciclastics are simply a backdrop.

Welcome to Canadian Well Logging Society Members who voted to join us in July. I hope you will be dedicated readers of the Reservoir and continue to contribute technical and professional articles to our illustrious e-zine. We all use petrophysics in our daily work and It is great to have you on the rig.

Our interest in the fine details of sedimentary rocks begins when the snow flies and this year you can get up close and personal with the selection, evaluation and monitoring of carbon dioxide storage reservoirs with Ross Crain's lead article, the second of a series, on the Petrophysics in the Green Economy.

The following Go Take a Hike column by the far-travelled Tako Koning takes us to Downtown Calgary to explore our favourite Manitoba product, Tyndall Stone, to discover Ordovician fossils. A topic we all love to explain to any available elevator waiting room visitor in some detail. Learn more from Tako.

This is the awards season, and we also feature the 2021 nominations for prominent (and deserving) CSPG Members.

A formal CSPG President passed back in April of 2022 and two other former Presidents, Colin Yeo and Ian McIlwraith remind us of his enormous contribution to our Profession made by Dr. Gordon Williams. It is with pride and admiration that the In Memory column is dedicated to Dr. Williams and is published in this edition of the Reservoir.

The Fall convention season is beginning, and the Spring/Summer sessions are now history. The co-chairs of the Core Conference do the wrap on historically our favourite conclusion to the GeoConvention (next, of course, to the Core Melt Down). Covid lockdowns are now history, and we can return to our roots!

Our continuing Woodmac series deals with the business side of geoscience in this issue.

After 2 years of inactivity, get out there and enjoy the recreational and educational sides of the Professions – then write it up for future editions of the Reservoir! ■

*Tom Sneddon*

**PUBLICATIONS INFORMATION**

The RESERVOIR is published 6 times per year by the Canadian Society of Petroleum Geologists. The purpose of the RESERVOIR is to publicize the Society's many activities and to promote the geosciences. We look for both technical and non-technical material to publish.

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# FROM THE BOARD

**SIMON HAYNES**, CSPG PRESIDENT-ELECT

## WHAT'S IN A NAME?

As I write this, it is mid-summer in Alberta. The Calgary Stampede is over, and many people I know are away on extended family vacations (some a lot further afield this year, with the absence of Covid-induced restrictions). It finally feels like life is returning to some semblance of "normal". Oil prices have been at their highest sustained levels since November 2014, and activity in our industry is once again picking up. Change is in the air.

As geoscientists, we understand that change is normal, whether catastrophic or gradual. Looking at the history of our Society, it has always been one of adaptation and evolution.

- In 1973, after nearly half a century, the Alberta Society of Petroleum Geologists voted to change its name to the Canadian Society of Petroleum Geologists (CSPG),
- In 2011, the CSPG Board of Directors (BOD) added the tagline "Canada's Energy Geoscientists" to our Society,
- In January 2021, the CSPG BOD unanimously voted to change the name of our scientific journal to the "Bulletin of Canadian Energy Geoscience",
- In October 2021, the Board of the Canadian Society of Petroleum Geologists met online for its annual strategy session and voted unanimously to investigate the rebranding of the Society.
- On July 6th, 2022, the Canadian Well Logging Society voted overwhelmingly to join the CSPG as a technical division, and,
- The Society's vision is, and has been for many years, "To be the premier community of energy geoscientists"

Our organization has demonstrated a strong history of foresight, adaptation, grace under pressure, and most importantly, endurance. The energy industry is cyclical in nature, yet the CSPG has retained a strong, loyal membership base for almost a century. This fall, members of the CSPG will be asked to vote on changing the name of our Society. This is the first of a series of articles and updates that will address this rebranding effort, and what it will mean for the membership.

Over the last decade, the societal pressures we have faced as an organization, an industry, and often individually, to abandon petroleum as a primary energy source have been immense. We all know people and companies who have pivoted their focus to alternative energy sources as investment in traditional oil and gas firms dried up, and layoffs mounted. But consider this - In 1980, the global population was 4.4 billion, and is now projected to hit 8 billion by next year. Instead of engaging in a debate of whether we need "this-or-that" with respect to various energy resources, we need to adopt the understanding that our modern world requires "this-and-that". In short, we are going to need all of it. And as energy geoscience continues to grow and expand, so will our fields of research, industry investment focus, and future job roles. We owe it to our membership to make the necessary changes to reflect this growth and adaptation. The energy transition has been in full swing, hand-in-hand with the CSPG's evolution, for years now, and it is time for our membership to consider a name which better reflects where we are heading.

**The new name we are proposing for our organization is the "Canadian Energy Geoscience Association" or CEGA. To provide some background on why this name, we considered each word carefully.**

The new name we are proposing for our organization is the "Canadian Energy Geoscience Association" or CEGA. To provide some background on why this name, we considered each word carefully.

**Canadian** – retained as a key component of our membership identity, reflecting where we work, study, and live.

**Energy** – while remaining true to our roots in petroleum, recognizing the expanding focus on alternative resources for our individual and company members, and society.

**Geoscience** – our technical organization's core scientific branch, which has become increasingly interdisciplinary and inclusive.

**Association** – reflects our holistic nature as "a group of people gathered for a common purpose" rather than a society.

CEGA is also a natural extension of the CSPG's tagline "Canada's Energy Geoscientists" which we introduced over a decade ago.

Change can be difficult, and we understand that there will be some reluctance to do so. But times and societal attitudes are shifting, particularly with respect to oil and gas. Despite popular perception, petroleum will continue to play a key role in terms of supplying enough energy, and providing reliable security in an environmentally responsible manner, for decades to come. As a technical organization, we will need to provide support to our members for an ever-increasing range of skills.

This fall, you are not simply being asked to vote on if we should change our name. We are asking for your opinion, to fully consider our future direction, and what sort of organization you want us to become. There is much to be gained by reinventing ourselves, acknowledging our legacy, and considering what the next generation of energy geoscientists are going to look like and the skills they will need to succeed.

We have been the Canadian Society of Petroleum Geologists for 39 years. This year, we will decide together whether to continue to display the courage to reinvent our society to reflect the world we serve. We look forward to hearing your opinions, answering your questions as best we can, and seeing where our membership wishes to go.

Sincerely,

*Simon Haynes*

# Call for Nominations

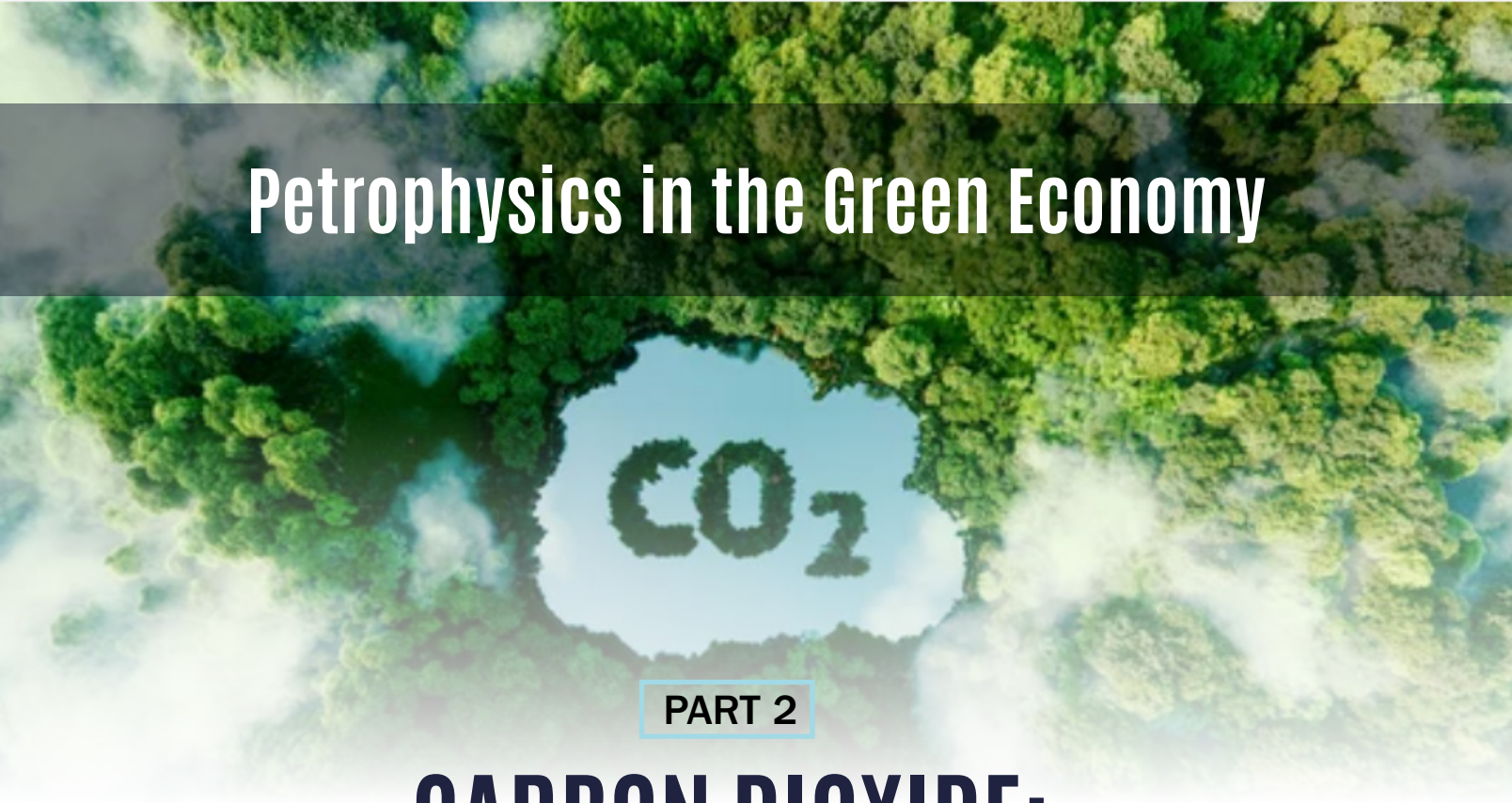
## 2023 CSPG Board of Directors


The CSPG is seeking nominations for its 2023 Board of Directors.

The available positions are:

**President Elect** – *who will continue to serve as President in the 2nd year and Past President in the 3rd year*
**Finance Director Elect** – *who will continue to serve as Finance Director in the 2nd year*
**Three Directors at Large** - *who will each serve a 2-year term on the Board of Directors*

**FIND OUT MORE TODAY!**




# Petrophysics in the Green Economy

PART 2

# CARBON DIOXIDE: Storage and Monitoring

E.R. CRAIN, P.ENG.

## INTRODUCTION

Selection, evaluation, and monitoring carbon dioxide storage reservoirs is a multi-disciplined task, in which petrophysics plays a vital role. Most of the discussion about CO2 also applies to natural gas (CH4) and hydrogen (H2) storage reservoirs. This article describes the special properties of CO2, storage reservoir criteria, the role of petrophysics, followed by visual and quantitative log analysis methods, and an example from a CO2 monitoring project using the fast neutron cross section measurement.

Carbon dioxide (CO2) is a chemical compound occurring as a colorless non-combustible gas with a density about 153% of that of dry air. It has a sharp and acidic odour and taste at high concentrations (eg carbonated water), but at atmospheric concentrations it is odourless and tasteless. Because CO2 is heavier than air, it can collect in low or enclosed spaces, asphyxiating occupants due to lack of oxygen.

CO2 has no liquid phase at pressures below 518 kPa. At 101 kPa, the gas deposits directly to a solid (dry ice) at temperatures below –78.5°C; the solid sublimes to gas above this temperature. Liquid CO2 forms only at pressures above 518 kPa. The density of dry ice increases with decreasing temperature and ranges between 1550 and 1700 kg/m3 below –78 °C.

Most elements and simple compounds can exist in the gas, liquid or solid phase depending on temperature and pressure. A few can exist in a fourth phase, as a supercritical fluid when above a critical temperature and pressure. The critical point for CO2 is 31.1 C and 7.38 MPa, above which the distinction between the gas and liquid phase disappears, entering the supercritical fluid phase. A supercritical fluid behaves like a gas, moving easily through porous media, but has densities more like liquids. Density of supercritical CO2 is 600 to 800 kg/m3.

Geological CO2 storage makes use of these special supercritical properties, allowing for efficient transportation and injection of CO2 into underground reservoirs.

## SOURCES AND USES OF CARBON DIOXIDE

Carbon dioxide occurs naturally in our atmosphere in trace amounts, about 412 ppm by volume, compared to pre-industrial levels of 280 ppm. CO2 is one of several green house gases (GHGs) that are implicated in global warming and climate change. Reducing CO2 emissions and CO2 capture and storage (CCS) to mitigate these issues are goals of industry and government.

Natural sources of CO2 include volcanoes, forest fires, hot springs, geysers, dissolution of carbonate rocks, and decay of organic matter, including landfills and backyard compost. It is soluble in water and occurs naturally in groundwater and all surface water bodies.

Human sources include combustion of wood, peat and other organic fuels, fossil fuels, and unwanted by-product of many industrial processes, such as manufacture of cement, steel, and plastics. Agriculture and food processing is a large CO2 emitter, mostly unrecognized because it is so dispersed across the planet.

Major uses of carbon dioxide are as a feedstock for synthetic fuels and other chemicals. It is used in welding, fire extinguishers, pressurizing agents, enhanced oil recovery (EOR), and as a solvent. It is the key ingredient in carbonated drinks. The solid form (dry ice) is used as a refrigerant and as an abrasive in a much less messy form of sand-blasting.

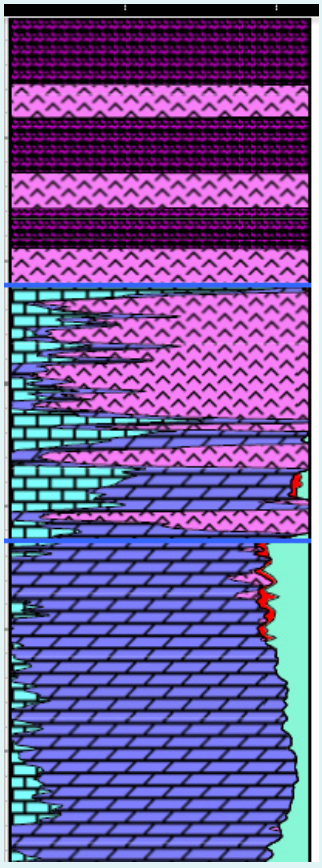


FIGURE 2: Porosity-lithology depth plot showing evaporite caprock and porous carbonate suitable for a CO2 storage reservoir

Carbon dioxide is essential for all plant life, which generates the oxygen essential for human existence. However, too much of a good thing is turning into a bad thing, so we must learn to reduce emissions and to store what we can't reduce in a safe place, instead of into the atmosphere.

## CARBON STORAGE IN GEOLOGICAL FORMATIONS

Geological sequestration refers to the storage of CO2 underground in depleted oil and gas reservoirs, saline-water bearing formations, or deep, un-minable coal beds. The storage capacity of these reservoirs worldwide is enormous, estimated as large as 20,000 Giga tonnes of CO2.

As CO2 is captured from an industrial source, such as a cement plant, steel mill, or oil refinery, it is compressed to about 10 MPa so that it becomes a supercritical fluid. In this form, the CO2 is easy to transport via pipeline to the storage location. The CO2 is then injected into an underground porous reservoir, where it will remain as a stable supercritical fluid.

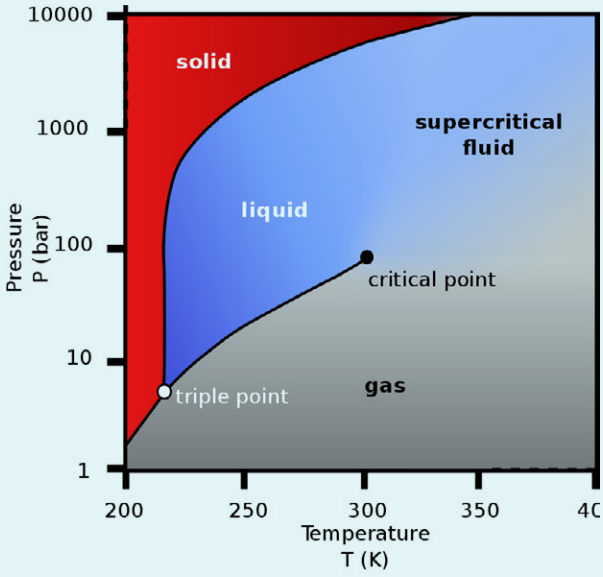



FIGURE 1: Phase diagram of carbon dioxide (Wikipedia)

At these storage conditions, the density of supercritical CO2 is 600 to 800 kg/m3, lighter than water, so it will rise to the top of the reservoir and be trapped by the caprock above the reservoir. As more CO2 is injected, it will spread laterally until the reservoir has been filled to its capacity.

A good reservoir for carbon dioxide storage is one with medium to high porosity and permeability, with no faults or fractures, and a well defined structural or stratigraphic trap. The seal or caprock is usually a thick shale, an evaporite such as halite or anhydrite, or a subsurface lava flow like basalt.

If there are faults or fractures, there is a strong possibility that the CO2 could migrate to other reservoirs, causing economic loss to others, or a leak to the surface, which could be dangerous to life in the surrounding area.

The dominant monitoring technique to date is time-lapse 3-D seismic imaging to locate the CO2 plume in the reservoir. Well logs run periodically in monitoring wells are also widely used.

## PETROPHYSICS FOR CARBON STORAGE PROJECTS

Petrophysics has a large role to play in the green economy. Hundreds of thousands of legacy wells have been drilled in the past, in search of fossil fuels. These wells penetrate reservoirs which may find new life by defining potential storage for carbon capture and storage (CCS). The competent petrophysicist can analyze these old wells with key suitability criteria in mind, to validate mechanical earth models (MEM), which tend to be more heavily weighted towards seismic inputs. Seismic can give a good overview of the reservoir, but only petrophysics can fill in the details that can determine success or failure of the project.

Identifying a container for CO2 is the most important step in the process; a suitable site ensures the injected CO2 will stay where it is supposed to be for the foreseeable future.

The key criteria for which petrophysical analysis can provide ground truth for the reservoir model are: shale characterization, porosity, permeability, mobility and saturations. Including legacy wells means better definition of the areal extent of the potential container. Once the container has been selected and the most porous and permeable zones selected for injection well locations, the petrophysicist will run logs to evaluate the well for fractures and casing / cement integrity. In the final phase, the petrophysicist will evaluate the monitor wells to assess how well the CO2 has entered the pore space.

Due to the risk to life from a CO2 leak to surface, there is no room for amateurs or novices in this work. Expert petrophysical advice should be sought and be acted upon at every stage in the project development and operation.

Here are the stages in the development of a carbon storage reservoir that require competent petrophysical analysis, coupled with other geoscience and reservoir engineering work.

### PHASE 1: Find a Suitable Storage Reservoir

**Criteria:** thick competent caprock, no faults or fractures, no barriers to vertical flow (shale or anhydrite interbeds), thick porous and permeable reservoir (saline water bearing or depleted oil or gas zone), structural or stratigraphic trap (area, volume, spill point), economics, proximity to CO2 source.

**Action Items:** prepare complete reservoir study, integrating geological, geophysical, and petrophysical analysis (with mechanical properties calculations) on all available wells (including entire caprock sequence), prepare structural maps and cross sections, pore volume calculations, depth-pressure-temperature profiles.

### PHASE 2: Locate and Evaluate Injection Well(s)

**Action Items:** select injection well location(s) based on reservoir model, drill through best porosity to optimize CO2 injection rate, run and analyze full log suite, run resistivity image log to find unexpected fractures, run ultra- sonic cement integrity log to find leaks or channels, repair as needed. Run Pulsar (induced gamma ray spectroscopy with fast neutron cross section) for comparison to same log in monitor wells.

### PHASE 3: Run Baseline Well Logs In Monitor Wells

**Action Items:** In open hole run resistivity image log to find unexpected fractures. In cased hole, run ultra- sonic cement integrity log to find leaks, repair as needed. Before CO2 injection begins, run baseline logs over storage reservoir, entire caprock, and 1000 meters above caprock.

**Option 1:** Pulsar log, generically known as the advanced pulsed neutron log, which includes gamma ray (GR), neutron porosity (TPHI), capture cross section (SIGMA), and fast neutron cross section (FNXS). Best for quantitative CO2 analysis. Also capable of elemental capture and inelastic spectroscopy for matrix rock and fluid identification.

**Option 2:** Standard pulsed neutron (TDT) log which includes gamma ray, neutron porosity, capture cross section.

**Option 3:** Gamma ray, shear and compressional sonic, neutron porosity, cased hole density**, cased hole resistivity** (** = optional but desirable)

### PHASE 4: Run Time Lapse Logs to Monitor CO2 Plume Development

**Action Items:** run same logs as Stage 3, use visual analysis rules in text below to determine if CO2 has reached this monitor well. Run monitor logs over same interval as baseline logs. Look for evidence of leaks through and above caprock.

## VISUAL LOG ANALYSIS RULES FOR CO2

If CO2 is present at a monitor well, then the time-lapse log data in the CO2 plume will be different than the baseline log, in which no CO2 was present.

These rules are based on the log response to CO2 compared to water-filled porosity, highlighted in Table 1.

**For Pulsar log:**

gamma ray (GR) will be unchanged from baseline values
neutron porosity from Pulsar (TPHI) will be much lower or negative
capture cross section (SIGMA) will be much lower
fast neutron cross section (FNXS) will be lower

See Figure 3 to estimate approximate CO2 saturation using TPHI and FNXS. FNXS is a measurement independent of hydrogen index

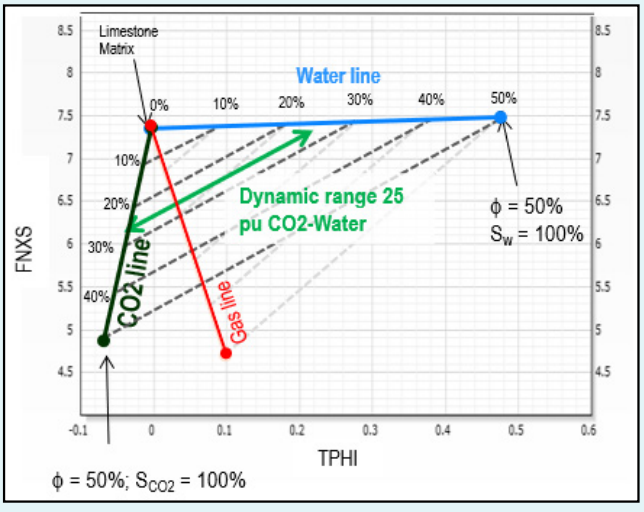



FIGURE 3: TPHI vs FNXS crossplot for estimating carbon dioxide saturation Sco2

which primarily responds to the atomic density of the formation; it provided an additional method for CO2 detection and quantification, and it enables solving for more complex scenarios when integrated to other rock properties, such as neutron porosity.

**For pulsed neutron (TDT) logs:**

gamma ray (GR) will be unchanged from baseline values
neutron porosity from TDT (TPHI) will be much lower or negative
capture cross section (SIGMA) will be much lower

The following rules are for conventional logs run through casing:

gamma ray (GR) will be unchanged from baseline values
shear sonic (DTS) will be unchanged
compressional sonic (DTC) will be higher
resistivity (RESD) will be higher
density (DENS) will be lower (density porosity (PHID) will be higher)
neutron porosity (PHIN) will be much lower or negative

# QUANTITATIVE METHODS FOR CO2 LOG ANALYSIS

## CO2 LOG ANALYSIS EXAMPLE

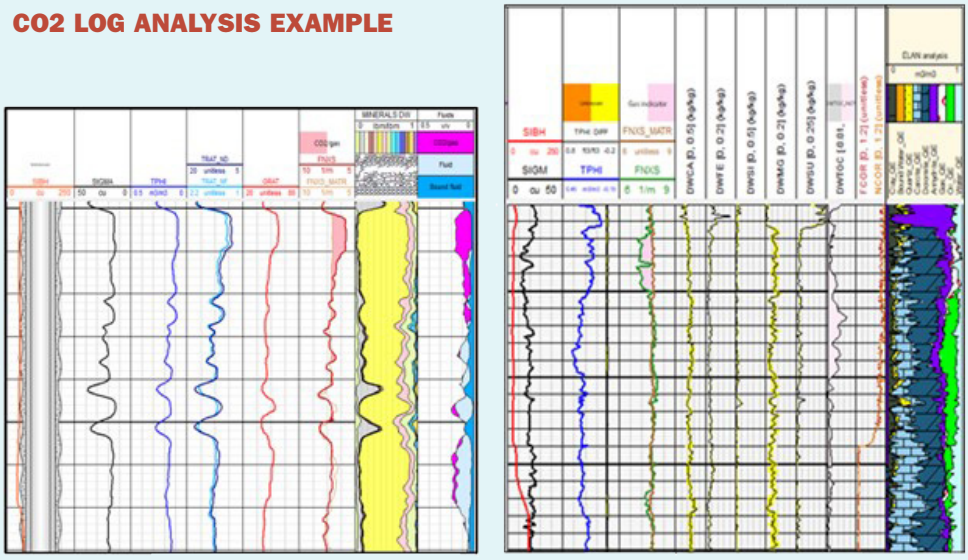


**FIGURE 4: Examples of CO2 detection and quantification at current reservoir condition. Different gas indicators are presented, including Sigma, Neutron count rates and porosity, Fast Neutron Cross Section, and its deviation from Fast Neutron Cross Section of matrix components in presence of gas. SIGMA, TPHI, FNXS end points calculated based on gas density and composition. Lithology and porosity are measured based on induced gamma ray spectroscopy combined to TPHI and FNXS, eliminating the need for open hole logs.**

Quantitative analysis of carbon dioxide saturation (Sco2) is possible using capture cross section (SIGMA), neutron porosity (TPHI), or fast neutron cross section (FNXS) using the classic log response equation by substituting CO2 parameters for the hydrocarbon terms. CO2 has zero hydrogen index so TPHI reads total porosity only if the zone is 100% wet. For a zone filled with super-critical CO2, TPHI will read near zero porosity. SIGMA and FNXS also have very different properties for CO2 compared to those for water, so all three terms can be used as CO2 saturation indicators. See Table 1.

Here is the log response equation for the SIGMA measurement with only CO2 and water in the porosity:

1: SIGMA = PHIe * Sw * SIGw (water term)
+ PHIe * (1 - Sw) * SIGco2 (carbon dioxide term)
+ Vsh * SIGsh (shale term)
+ (1 - Vsh - PHIe) * Sum (Vi * SIGi) (matrix term)

Where:

SIGco2 = log reading in 100% carbon dioxide
SIGi = log reading in 100% of the ith component of matrix rock
SIGMA = log reading
SIGsh = log reading in 100% shale
SIGw = log reading in 100% water
PHIe = effective porosity (fractional)
Sco2 = carbon dioxide saturation in reservoir (fractional)
Sw = water saturation in reservoir (fractional)
Vi = volume of ith component of matrix rock
Vsh = volume of shale (fractional)
WS(ppm) = water salinity NaCl equivalent (parts per million)

This equation is solved for Sw by assuming all other variables are known or previously calculated:

2: SIGw = 22.0 + 0.000404 * WS(ppm)

3: SIGm = Sum (Vi * SIGi)

4: PHIe = TPHI from baseline log before CO2 injection OR from open hole logs

5: SWtdt = ((SIGMA - SIGm) - PHIe * (SIGco2 – SIGm) - Vsh * (SIGsh - SIGm))
/ (PHIe * (SIGw - SIGco2))

6: Sco2 = 1 - SWtdt

Similarly for FNXS:

7: FNXSm = Sum (Vi * FNXSi)

8: SWfnxs = ((FNXS-FNXSm)-PHIe*(FNXSco2-FNXSm)-Vsh*(FNXSsh-FNXSm))
/ (PHIe * (FNXSw - FNXSco2))

9: Sco2 = 1 - SWfnxs

And for TPHI:

10: TPHIm = Sum (Vi * TPHIi)

11: SWtphi = ((TPHI-TPHIm)-PHIe*(TPHIco2-TPHIm)-Vsh*(TPHIsh-TPHIm))
/ (PHIe * (TPHIw - TPHIco2))

12: Sco2 = 1 – SWtphi

The FNXS model has the best resolution for CO2 monitoring. FNXS values for helium and nitrogen are reported to be similar to CO2 so the Pulsar log can be used to evaluate helium wells through casing. Other uses include monitoring natural gas and hydrogen storage reservoirs.

**TABLE 1:** NUCLEAR PROPERTIES FOR PULSAR LOGS

| Material | Sigma (c.u.) | TPHI | FNXS (1/m) |
|---|---|---|---|
| Quartz | 4.55 | –0.03 | 6.84 |
| Calcite | 7.08 | 0.00 | 7.51 |
| Dolomite | 4.70 | 0.03 | 8.51 |
| Orthoclase | 15.82 | –0.05 | 6.33 |
| Albite | 7.65 | –0.04 | 6.69 |
| Anhydrite | 12.45 | –0.03 | 7.14 |
| Pyrite | 90.53 | 0.01 | 6.60 |
| Bituminous Coal | 15.79 | 0.68 | 7.72 |
| Dry Illite | 20.79[a] | 0.22 | 8.06 |
| Wet Illite | 21.00 [a] | 0.34 | 8.02 |
| Dry Smectite | 14.36 [a] | 0.29 | 8.36 |
| Wet Smectite | 19.23 [a] | 0.68 | 8.60 |
| Kerogen (CH 1.3g/cc) | 20.18 | 0.98 | 9.07 |
| $CH_4$ (0.05 g/cc) | 2.50 | –0.05 | 0.67 |
| $CH_4$ (0.15 g/cc) | 7.50 | 0.21 | 2.01 |
| $CH_4$ (0.25 g/cc) | 12.50 | 0.47 | 3.36 |
| Oil ($C_3H_8$ 0.5g/cc) | 18.21 | 0.78 | 5.44 |
| Oil ($C_3H_8$ 0.6g/cc) | 21.85 | 0.97 | 6.53 |
| Diesel ($CH_{1.8}$ 0.89 g/cc) | 23.30 | 1.08 | 7.98 |
| $CO_2$ (0.6 g/cc) | 0.03 | –0.12 | 2.24 |
| Water 0 ppm | 22.2 | 1.00 | 7.800 |
| Water 200,000 ppm | 97.2 | 0.90 | 7.36 |

## Search for contributors to go take a hike series

The go take a hike series has been published in the CSPG Reservoir since at least 2009 and resulted in the publication of a book compiling the hikes in 2019. The series is ongoing and is managed by Philip Benham his email is benham.philip@gmail.com. He is seeking for new contributors to the series whether you be a student who has an interesting thesis which can be voted to a go take a hike article or whether be converted to an article. Or perhaps you are an avid hiker and you have some interest and knowledge in the geology of a region and you would like to convert it to an article as well. We are looking for hikes which are diverse both in terms of the geology but also in terms of the geography while we focus on Alberta we also will except hikes from other provinces or even articles on international destinations. If you're interested in writing an article and or you have questions please contact Philip Benham and he can provide an example template on how to create the article.


## ACKNOWLEDGEMENTS

Thanks to Chiara Cavalleri of Schlumberger for contributing content for this article, including Figures 3 and 4, and Table 1. Thanks also to Sandra Bleue for acting as research assistant on the Pulsar log and the fast neutron cross section (FNXS) measurement.


## REFERENCES


Fast Neutron Cross-Section Measurement Physics and Applications
Tong Zhou, David Rose, et al
SPWLA 57th Annual Symposium, 25 – 29 June 2016

CO2 Data, Phases, Sources, Uses
Various Wikipedia pages

# PATRICIA J. LEE
# TRAILBLAZER AWARD

COLLABORATION

VISION

INNOVATION

## ABOUT THE AWARD

All CSPG members will be eligible for this award both as Teams or as Individuals. The award will celebrate trailblazers based on their: Innovation, Vision and Collaboration.

These values are embodied in Patricia J. Lee's cross-disciplinary creativity, work ethic and perseverance that led to a 2 TCF Caroline (Devonian Swan Hills) gas discovery in 1986 (only 8 years after starting her career), her subsequent successes in the Foothills, her ascent to Chief Geoscientist of Shell Canada and continuous engagement as a mentor.

**Important Note:** CSPG members from all genders are eligible for this award. For a multidisciplinary team to be considered, at least one individual from the team must be a CSPG member

## NOMINATION PROCESS

1. A sponsor must submit an award nomination form outlining the contributions of the nominee.

2. The nomination requires the names and contact information for three referees who can comment on the nominee's qualifications along with a description of the nature of their relationship to the nominee. These people will be contacted by the committee for telephone references.

3. Nomination forms must be received by CSPG by November 1, 2022.

4. Unsuccessful candidates will be automatically reconsidered for three additional years providing they continue to meet the award criteria. Sponsors will have the opportunity to update the information for the nomination.

## SUBMIT YOUR NOMINATION TODAY!

# CSPG GRADUATE THESIS AWARDS

## CALL FOR NOMINATIONS

**DEADLINE: NOV 1ST, 2022**

## ABOUT THE AWARDS

**Ph. D. AWARD**

Win $5,000, a framed certificate, and a one-year CSPG membership for the Doctoral thesis that makes the most significant contribution to Canadian sedimentary geology in 2022.

**M. Sc. AWARD**

Win $4,000, a framed certificate, and a one-year CSPG membership for the Masters thesis that makes the most significant contribution to Canadian sedimentary geology in 2022.

## ELIGIBILTY REQUIREMENTS

Eligible theses are either produced in a Canadian university, regardless of project location, or deal with a Canadian sedimentary/energy topic, regardless of the university of origin. Theses entered for the 2022 awards must have been submitted to a recognized university and must have formed part of the requirements for degrees awarded at the Fall 2021 or spring 2022 convocations.

Please submit an electronic copy (pdf) of the thesis for judging to:
Canadian Society of Petroleum Geologists (CSPG), Graduate Thesis Awards Committee
c/o Andre Chow | amcchow@gmail.com

## SUBMIT YOUR NOMINATION TODAY!

# STANLEY SLIPPER GOLD MEDAL


## CALL FOR NOMINATIONS

**DEADLINE: NOV 1**

## ABOUT THE AWARD

The Stanley Slipper Gold Medal is amongst the highest honours awarded by the Canadian Society of Petroleum Geologists (CSPG). The Stanley Slipper Gold Medal was established in 1989 and is named for Mr. Stanley E. Slipper (1890-1982) who was the Alberta Society of Petroleum Geologists' first President and a pioneer of early exploration efforts in Alberta.

The medal is presented annually for outstanding contributions to petroleum exploration and development either in Canada or by Canadian-based petroleum geologists working internationally. In contrast to other CSPG awards, the Stanley Slipper Award recognizes, in part, accomplishments in business and in the broader petroleum industry through the application of the knowledge of petroleum geology.

## NOMINATION PROCESS

Nominees must be recognized as having made significant contributions in one or more of the following areas:

- initiating and/or leading exploration or development programs
- making significant discoveries on new or existing exploration trends
- applying new technologies to exploration and exploitation
- teaching and/or training of petroleum geologists

Nominators should provide a letter with compelling evidence to support the nominee's professional and career achievements. The letter should target 250 words. Submit the nomination letter to the CSPG office by November 1st. Review the full nomination guidelines online today!

## SUBMIT YOUR NOMINATION TODAY!

# Dr. Gordon D. Williams

P.Geo, Ph.D., FGC, FEC (Hon.), DFGAC

**MAY 22, 1933 – APRIL 26, 2022**

The consummate Professional Geologist, educator, mentor, leader, a great facilitator and enabler, a friend of many, and always with his dry humour, Dr. Gordon Williams led the quest for geoscience professional recognition across Canada while educating generations of petroleum explorationists. The consummate Professional Geologist, educator, mentor, leader, a great facilitator and enabler, a friend of many, and always with his dry humour, Dr. Gordon Williams led the quest for geoscience professional recognition across Canada while educating generations of petroleum explorationists.

## Early Days

Fate conspired to make Gordon Williams a geologist. He was a student at Brandon College (former affiliate of the University of Manitoba) and, as a member of the Science Club, went on a field trip to the Virden oilfield. The district manager for California Standard, operator of the field, was Don Allan (the son of Dr. John A. Allan who established the Geology Department at the University of Alberta), who offered Gordon a part-time job as a geological assistant. Upon graduation, Gordon joined Cal Standard to do field work in the Crowsnest Pass. His party chief was Jerry Henderson (later President of Chevron Canada), along with Clint Dahlstrom, renown structural geologist, and others. With his interest in geology piqued by field work, and encouraged by his former principal at Brandon College, Gordon began his Masters' degree in geology at the University of Alberta in 1956. A year later, based on Gordon's high marks, the Chairman of the Geology Department encouraged Gordon to pursue his Ph.D. degree. In 1960, Gordon would become the first Ph.D. student in Geology to graduate from U of A, having completed his thesis on the Mannville Formation in central Alberta. He then joined Standard Oil of Indiana and worked there for 18 months, but his real interests lay in academia.

## A Gifted and Practical Teacher

Gordon was always keen to learn and transfer his knowledge to others. His greatest thrill was watching students as they first understood a new concept or learned a new skill. But he was also practical and wanted to prepare his students for the reality of working in a cyclical industry that could impact them economically and professionally. He encouraged them to be generalists with skills that are valuable to potential employers with the ability to move into new areas when presented with an opportunity. Right from the beginning as a teacher, he espoused the advantages of life-long learning and continuous professional development.

In 1961, Gordon accepted a professorship at the University of Alberta, then in 1963 he took a position at the University of Queensland in Brisbane, Australia, to develop a petroleum geology program. In 1966, Dr. Charlie Stelck, Department Chairman, asked him to return to the University of Alberta to help primarily with the administration of a growing department. As it turned out, personal matters made the decision easy, and Gordon returned to U of A where he stayed until 1985. During that time, he taught and supervised many undergraduate and graduate students, served as Department Chairman for over three years and continued to pursue independent research. Also, for several years he chaired the CSPG – University of Alberta Department of Extension Advisory Council for the National Conference on Earth Sciences in Banff, in many respects the precursor to the CSPG Gussow Conference.

Later after a short stint in industry with Suncor Energy, and a five-year hiatus in private practice with his consulting company (Summus Resource Evaluations Ltd.), including being Vice-President and partner of the Canadian Petroleum Training School of Business, Gordon returned to academic life taking up the post of Dean, Science and Technology, at Mount Royal College. He retired in 1995 and returned to private practice once again.

But Gordon never really left teaching. In his private practice, he focused on teaching petroleum geology,

subsurface methods, stratigraphy, and computer applications in petroleum exploration, both in Canada and internationally. From 1989 to 2015, he was a sessional instructor in the Petroleum Land Management Program at The University of Calgary's Haskayne School of Business. The conclusion to his sessional course, Introduction to Petroleum Land Management, was an evening challenging the students to play the famous "Oil and Gas Game".

This game was developed by John Cox, Wayne Lannan and Gordon. It was a unique physical simulation model which tied together most of the upstream (exploration and development) segments of the oil and gas industry in western Canada. Students learned to use geologic reports and seismic data to acquire mineral rights through purchase or negotiations. Students could drill simulated exploration and development wells in the physical model and experience the thrill of discovery or the disappointment of a dry hole. The model even included building and operating oil and gas facilities. The team with the most money at the end of the evening was the winner. However, the key to success in the game, as in the real world, included understanding the geology and geometry of the oil and gas plays, developing successful corporate and exploration strategies (including use of joint ventures) and estimating risk and return.

It was a remarkable example of experiential learning and was so popular that some oil companies in Calgary, and internationally, used the game in their educational programs, which sometimes included management. It was also used to teach some Alberta First Nations community leaders the essentials of the industry.

Gordon never stopped teaching and he left behind generations of petroleum industry practitioners and executives with the knowledge and experience to find and develop oil and gas reserves. He enabled people to do great things.

## A Leader in Geoscience Professionalism: Persistence, Patience and Practicality

Geologists are a fiercely independent group who traditionally have resisted licensure and regulation. They argue geoscientists should be judged on their results, not on their knowledge and experience. Years ago, Gordon faced this resistance head-on. He believed that geology was a rigorous and virtuous profession, that geology programs at universities were not accredited across the country and that practitioners must be licensed by their peers, not universities (nor technical organizations), to protect the public interest. He knew regulating the practice of geology would be complex and expensive because of the small number of geologists so he concluded that its professional affairs should be administered by a larger regulator. From his experience as both a professor and industry practitioner, he knew geologists in the petroleum industry were closely aligned with their engineering colleagues, and he believed APEGA, the current regulator, was therefore best positioned to regulate the practice of geology within Alberta. To Gordon this was obvious, but there was strong opposition from within the geological community. As always, he was up for the challenge.

It was no small feat, but Gordon created a consensus among a widely divided geoscience community. On October 7, 1980, Gordon organized a panel discussion in front of 800 geoscientists at the Calgary Convention Centre to hear the pros and cons of geoscience regulation and who should regulate geoscience. From that meeting, the CSPG – CSEG Professional Registration Committee was formed, and Gordon was selected as Chairman. Over the next year, the Committee confirmed that both geologists and geophysicists wanted to be regulated and that APEGA was the most appropriate body to do that. Initially, geoscientists wanted the CSPG and CSEG to regulate them professionally, but the Committee found that the cost and complexity of doing this was just too much. In a conciliatory move, a hallmark of Gordon's skill as a negotiator, the Committee formed a permanent CSPG-CSEG-APEGA Liaison Committee to maintain direct and open dialogue with APEGA Council that operated until 2013. The CSPG and CSEG never again raised the issue of regulating geoscience. The matter was settled, at least in Alberta.

Well liked, life-affirming and easy going, the champion of geoscience professionalism in Canada is gone and we will miss him.

Gordon didn't stop there. He saw a burgeoning movement developing across Canada to begin licensing geoscientists, either by jointly regulating them with engineers or through separate acts, and he saw an opportunity to enhance geoscientist professional mobility. The key was developing a common syllabus for geology, geophysics and environmental geoscience and instituting standard registration practices in each jurisdiction. However, he first had to help professional geoscience committees in various provinces get their members on board with registration and prepare to work patiently through government departments to bring in the legislation. He worked tirelessly with each group and faced setbacks with stoicism and a resolve to continue. While others began to lose hope, Gordon remained steadfast in his vision.

Initially, the work of creating a national coordinating body of independent provincial and territorial regulators was done by the National Registration Committee of the Canadian Geoscience Council. With his good friend and colleague, Dr. Hugh Miller, Gordon compiled a draft national syllabus for geology and presented it to the department heads for geology from Canadian universities where it was soundly rejected. Recognizing this was an insurmountable problem, the ever-practical Gordon transferred the committee from the Canadian Geoscience Council to the newly formed Canadian Council of Professional Geoscientists (CCPG), which was supported by APEGA and the Canadian Council of Professional Engineers. A standards committee was formed at CCPG where national standards for geology, geophysics and environmental geoscience were developed. The Canadian Council of Professional Geoscientists, later to become Geoscientists Canada, was incorporated under the Canada Business Corporation Act in 1997.

Gordon served as the Founding Member and then President from 1996 to 1999, and again as President from 2003 to 2004, as four additional provinces began geoscience regulation. Gordon's vision was pan-Canadian geoscientist mobility and, to accomplish this, he knew academic and experience requirements would have to be standardized among all jurisdictions and ensuring reciprocal practice arrangements with other jurisdictions. Perhaps Gordon's most significant contribution to achieving his vision was the creation of the Geoscience Knowledge and Experience Requirements for Professional Registration in Canada. Again, with his good friend Dr. Hugh Miller, they analyzed the honours bachelor science degrees in geology from across Canada and created a syllabus to be used by academic reviewers in each jurisdiction. Similarly, a syllabus for practical geological experience was created. Gordon recruited and organized experts in both geophysics and environmental geoscience to develop academic and experience syllabi. These syllabi are now recognized by registrars as a true national standard and have even been upheld by the courts. Today, because of Gordon's work, geoscientists can work anywhere in the country and be recognized as professionals just like engineers, lawyers, and doctors.

For his vision, dedication and hard work on professional licensure and the creation of the CCPG, Gordon was a most worthy recipient of APEGA's prestigious L. C. Charlesworth Professional Service Award, the GAC's J. Willis Ambrose Medal, the rarely given CSPG President's Special Recognition Award, Geoscientist's Canada's Canadian Professional Geoscientist Award, and in 2021, Brandon University's "Distinguished Alumni Award for Career Achievement".

## The Presidencies: Duty Calls

As much as Gordon was driven by promoting professionalism in the geosciences, he also believed it was an obligation to give something back to the profession. Although strictly a learned society, Gordon viewed the CSPG as an

essential vehicle for furthering technical development of geoscientists once they graduated, which is an essential element of being a professional. Gordon joined the CSPG in 1960, when he first started working at Cal Standard as it was an expectation that all geologists would become members. He first served on the CSPG Board as a Director in 1977. In 1980, he chaired the very important Professional Registration Committee for which he was given the President's Award for his work. In 1984, Gordon was elected Vice-President of the CSPG, served as President in 1985 and Past-President in 1986.

Gordon had a great skill to enable and facilitate others to work better and achieve more. As was his style, President Gordon met with committee chairs to reaffirm their mandates, increase activity, and become more effective. He established the CSPG/CSEG/APEGA Liaison Committee and set up a Management Task Force to devise new management strategies for the Society. He was awarded CSPG Honorary Membership in 2005.

Fittingly, in 2007, the International Year of Planet Earth, Gordon was elected President of APEGA, the 10th geoscientist to fill that position in the previous 87 years. He had served 10 years on the Board of Examiners, 6 years on the Practice Review Committee and 4 years on the Discipline Committee. He entered office wanting to increase the licensure rate of geologists and geophysicists and to enhance the mobility of engineers and geoscientists, making it easier to work throughout the country. He made great effort to address the issue of short term, incidental practice within the geoscience community but recognized that any possible arrangement would be too costly for smaller jurisdictions, causing more problems than it solved. Above all, Gordon was a practical leader who knew some problems were just complex and confounding and therefore cannot be easily solved.

Gordon worked with the Association of Science and Engineering Technologists, ASET, to implement the One Act, Two Associations legislation. He began the process of introducing the Professional Geoscientist, P.Geo., title within APEGA, which would align APEGA's title with the rest of Canada. Gordon made significant inroads with many US states and other countries to recognize APEGA member credentials which would enhance their international mobility.

As a champion of inclusivity, throughout his years with APEGA, he portrayed engineers and geoscientists as being two sides of the same coin. He maintained there were far more similarities between the professions than differences. He always sought to find common ground.

## Later Years

A true teacher to the end, Gordon continued instructing at the University of Calgary until 2015. He maintained a great interest in geoscience professional matters, being briefed by current Geoscientists Canada Directors and offering advice and guidance right to the end. He never lost interest. His sixty plus years of professional advocacy enabled him to cut through the minutia and focus on the really important items so that meaningful progress could be made. Trivial matters should always be "someone else's problem" while critical issues needed to be tackled by committees, not to diffuse accountability but to get everyone's buy-in. Gordon knew how to get the most out of everyone and his expectations made people work that much harder. We were all better because of Gordon. His legacy is the people he left behind.

Well liked, life-affirming and easy going, the champion of geoscience professionalism in Canada is gone and we will miss him.

**Colin Yeo** *CSPG Past-President 2007 and APEGA President 2013*

**Ian McIlreath** *CSPG Past-President 1983 and GAC President 1993*

GO TAKE A HIKE

# Interested in Contributing?

The go take a hike series has been published in the CSPG Reservoir since at least 2009 and resulted in the publication of a book compiling the hikes in 2019. The series is ongoing and is managed by Philip Benham his email is benham.philip@gmail.com. He is seeking for new contributors to the series whether you be a student who has an interesting thesis which can be voted to a go take a hike article or whether be converted to an article. Or perhaps you are an avid hiker and you have some interest and knowledge in the geology of a region and you would like to convert it to an article as well. We are looking for hikes which are diverse both in terms of the geology but also in terms of the geography while we focus on Alberta we also will except hikes from other provinces or even articles on international destinations. If you're interested in writing an article and or you have questions please contact Philip Benham and he can provide an example template on how to create the article.

**Contact Philip Benham • benham.philip@gmail.com**

# 2022 CORE CONFERENCE WRAP-UP

**Nicholas Ayre and Michele Asgar-Deen; Co-Chairs 2022 CSPG Core Conference**

When we started planning the 2022 Core Conference, we really did not know in what format the conference would be run. Would the conference be online, hybrid or in-person? After two years of hosting this conference online we were eager to try to host an in-person event at the Alberta Energy Regulator's Core Research Centre. We kept a close eye on COVID numbers and took a gamble on the dropping case numbers.

Our theme "Creating Opportunities and Charting New Horizons." was a two-part theme that celebrated the resilience of the petroleum geoscientist and demonstrated how we can identify opportunities in new resources and energy forms. Our industry and geoscience community are adapting and innovating to meet the changes of future energy needs. As geoscientists we make ourselves more efficient and versatile by building on existing skill sets and exploring the potential in new ones. We wanted to organize an inclusive event that showcased the exciting changes in our industry yet celebrated the origins of our society.

Planning started last September, and we were fortunate to have attracted a fantastic line-up of presenters from industry, government and academia that provided presentations that covered four diverse themes. Over two days we had presentations that covered carbon capture and enhanced oil recovery, sedimentology and ichnology, reservoir development and a morning of presentations that spanned from the earliest oil play in North America to cutting edge geothermal and helium exploration. We had core from the Cambrian to the upper Cretaceous that encompassed carbonates, clastics, and volcanics. We are grateful for the support we received from our presenters who gave us not only their precious time but were also unstinting with their knowledge and diverse views on our industry.

Turnout was strong and exceeded our expectations as we attracted over 380 delegates. It was nice to see faces that were familiar and new. The positive momentum from the conference spilled over into the Meltdown which was held offsite at Kilkenny's where we continued to catch up on lost time from the previous two years.

Congratulations to Murray Gilhooly, Marian Warren and John Weissenberger who won the Pemberton Award for best overall presentation. Their presentation on the Banff Ferrier 'B' Pool was a wonderful example of an integrated Geological and Geophysical approach to exploring new potential in an established petroleum system. Anders Cowper with Murray Gingras and John-Paul Zonneveld as co-authors, won the Baillie Award for best student presentation and the $1000 dollar prize. Anders' presentation on the Milk River was concise, well delivered, and conveyed a thorough understanding of his subject matter.

This conference would not have been possible without the support of our sponsors and advertisers. We would like to thank the continued support of our title sponsor Tourmaline, our program book sponsor APEGA, our student sponsor PROGEO who covered the cost of entry for 10 student registrations, and AGAT for sponsoring our presentation room.

It has been a real team effort to pull together the 2022 conference.

**THANK YOU!**

We would also like to thank the AER Core Research Centre for pulling core and providing us access to their world class facility as well as our conference sponsors Spur, Stratum, Core Lab, ROGGI, Chinook Consulting, Freehold Royalties, AGAT, Crescent Point, Canadian Discovery, Advance Logic Technologies, Canpar Holdings, and Spectrum Geosciences for providing their generous support. ROGGI and Chinook returned as sponsors for the Core Meltdown and Stratum generously provided us BBQ lunches over the two days of the conference.

It has been a real team effort to pull together the 2022 conference. We had an amazing group of volunteers; Christa Williams from Canadian Discovery, Thomas Plumridge from Freehold Royalties, Daniela Becerra from Schlumberger, James Burr from Sinopec Canada, Lauren Eggie from Imperial Oil, Carolyn Furlong from the U of C, Scott MacKnight from Crescent Point Energy, Rob Paul, Maureen Stonehouse from Stone Consulting and Mark Radomski and Ozzy Ofoegbu from Cenovus. Throughout the course of the two days, members of our organizing committee hosted each of our four technical sessions. We would also like to take the opportunity to thank Emma MacPherson and Shaelyn Brown at the CSPG office for helping to put together this event.

**We look forward to next year and the opportunities it presents.**

# Tyndall Stone: Discovering Ordovician Fossils in Downtown and Inner-City Calgary

**Tako Koning** tako.koning@gmail.com, 587-284-3411

The Tyndall limestone is iconic building stone from the Late Ordovician (450 million years old) Red River Formation, at Garson Quarry, near the town of Tyndall, about 30 km northeast of Winnipeg, Manitoba. The Tyndall limestone, also known as Tyndall Stone, occurs within the Red River's Selkirk Member, which is 43 m thick (Coniglio, 1999). The Tyndall Stone is extracted from a 6 – 8 m thick interval within the lower part of the Selkirk Member (Pratt et al., 2016).


Tyndall Stone is used throughout Canada as an ornamental building stone. It is one of the most beautiful building stones in the world. In Ottawa the interior of the Parliament Building, Centre Block, the Confederation Hall and the Hall of Honour are clad in Tyndall. The exterior of the Museum of Civilization in Gatineau, Quebec is clad in Tyndall. The exteriors of the Provincial Legislature buildings in Winnipeg and Regina are Tyndall. It clads the University of Alberta's Tory Building, the Rimrock Hotel in Banff, the Chateau Lake Louise and the Empress Hotel in Victoria, among many others.

The Tyndall limestone was deposited in a tropical, shallow marine environment. It is fine grained and cream coloured with pervasive mottling of darker dolomitic limestone. The highly distinctive mottled appearance is due to trace fossils known as Thalassinoides, which are fossilized burrows left behind by organisms, possibly worms and crustaceans such as mole shrimp, that burrowed through the soft lime mud during or just after its deposition. These organisms were soft-bodied, leaving no fossilized remains for paleontologists to study. This adds to the enigma of the


**FIGURE 1.** The entrance to the Bank of Montreal Building (currently Goodlife Fitness) on the northeast corner of 1 Street and 8 Avenue SW, (Stephen Avenue Mall), the columns and façade are entirely Tyndall Stone.

**FIGURE 2.** "Receptaculites," the misnamed "sunflower coral." The darker mottled features in the limy matrix, so characteristic of Tyndall Stone, are burrow traces known as Thalassinoides.





**FIGURE 3.** South-facing front of the former Eaton's building (currently Hy's Steakhouse), on 8 Avenue between 3 Street and 4 Street SW, entirely clad in Tyndall Stone.

**FIGURE 4.** Entrance to the John J. Bowlen Building, former Calgary Court House Building, 620 7 Ave. SW. Built in 1969, inaugurated by Premier Harry J. Strom. White blocks are Tyndall Stone.

**FIGURE 5.** John J. Bowlen Building. The west side is entirely clad in Tyndall Stone.

**FIGURE 6.** Shoppers Drug Mart, 7 Avenue and 3 Street SW. The façade surrounding the entrance is Tyndall Stone.



**FIGURE 7.** Safeway; Maclurina gastropod. Dollar coin for scale.

**FIGURE 8.** Safeway; "Receptaculites." Dollar coin for scale.

Tyndall Stone that to this day no one knows which organisms caused the extensive burrows and mottles in the Tyndall.

The Tyndall is highly fossiliferous at the locations described in this article. The fossils represent life that flourished on an ancient sea floor. A variety of fossils can be observed including nautiloids, gastropods, stromatoporoids, brachiopods, sponges, corals, and large—up to 25 cm diameter—circular "Receptaculites" (Figure 2; now referred to the genus Fisherites; Dr. Brian Pratt, pers. comm.) which is informally called "sunflower coral" even though it is not a coral. This fossil is an enigma for paleontologists, having been assigned to various unrelated groups since its discovery. Relatively recently it was hypothesized to belong to a group of calcareous algae, but its true relationships remain a topic of speculation (Nitecki et al., 1999). Its skeleton is generally globular, though commonly squashed due to sediment compaction. Basically, it comprises a hollow, double-walled spheroid, with inner and outer walls separated by a layer of closely spaced pillars (Figures 29 and 30). Diamond-shaped plates cap each end of a pillar and fit together in a mosaic, forming the inner and outer walls. The plates and pillars are arranged in a double spiral pattern, like the arrangement of seeds in a sunflower head—hence the common name "sunflower coral." The appearance of the fossil on surfaces of Tyndall Stone is quite variable (Figures 27, 28), depending on how it was cut.

Nautiloids are cephalopods related to modern day squids or the shelled Nautilus. Nautiloids with straight shells are called orthocones, whereas those with curved shells are cyrticones (Teichert, 1964).

## DOWNTOWN

On the north side of the classic art-deco style AGT (Alberta Government Telephones) Building at 119 6 Avenue SW, built in 1929, one can observe specimens of "Receptaculites." Thalassinoides are well displayed there. The dolomitized traces are more resistant to weathering than the limestone matrix, so they are prominently etched on the surface of the blocks by almost a century of weakly acidic rain.

Ten-metre-tall Corinthian-style columns of Tyndall Stone grace the entrance of the heritage Bank of Montreal Building on the northeast corner of 1 Street and 8 Avenue SW, built in 1932 (Figure 1).

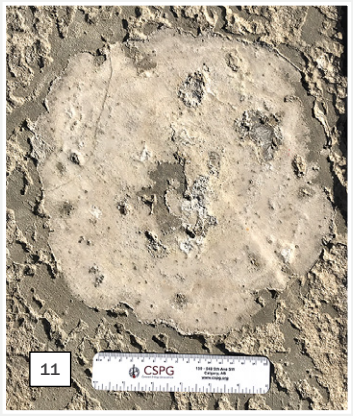
Similar style columns of Tyndall Stone can be seen at the entrance to the Centre for the Performing Arts, southeast corner of 1 Street and 8 Avenue SE. Built in 1930, it was originally called the Calgary Public Building. Both buildings are on the Stephen Avenue Mall.

Further west on 8 Avenue, between 3 and 4 Streets SW, the south-facing façade of the former Eaton's building is clad in Tyndall Stone (Figure 3). A block north of this, the Shoppers Drug Mart on the southeast corner of 7 Avenue and 3 Street SW has a more modern Tyndall Stone façade (Figure 6).

The front and west sides of the John J. Bowlen Building, formerly the Calgary Court House, at 620 7 Avenue SW, are Tyndall Stone (Figures 4 and 5).

The oldest Tyndall-clad building in Calgary is not downtown. Rather, it is the 109-year-old Canadian Imperial Bank of Commerce (CIBC) building in Inglewood, at 1230 9 Avenue SE which was built in 1911 and continues to function as a CIBC bank. There are many other Tyndall-clad buildings in downtown Calgary: keep your eyes peeled!





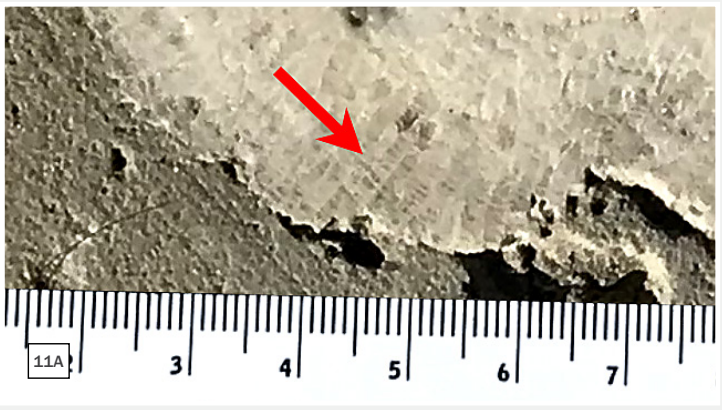




**FIGURE 9.** Kensington Safeway. Blocks of Tyndall Stone are randomly placed on the plaza for use as benches.

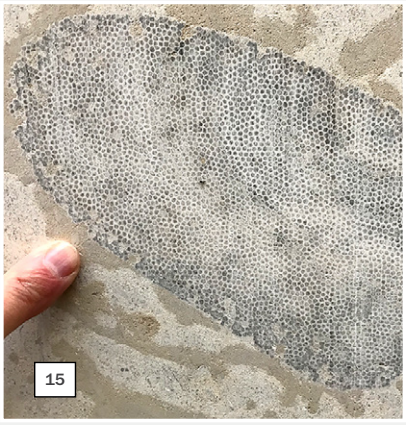
**FIGURE 10.** Safeway; a large sponge, Aulacopella, and a straight-shelled (orthocone) nautiloid in the lower right corner. Dollar coin for scale.

**FIGURE 11.** Safeway; cross-section of a Favosites-like "honeycomb" tabulate coral head. Ruler is 15.7 cm long. See detail, Figure 11a (next page) and compare to Figure 15 at SAIT campus.

**FIGURE 11A.** Safeway; enlarged detail of Figure 11, showing coral tabulae and corallite walls (arrow). Scale in cm and mm.

**FIGURE 12.** Safeway; side of a block showing a laminated organic buildup, perhaps stromatoporoid and/or coral. Note how resistant burrows stand out in relief. Block is 0.5 m tall.





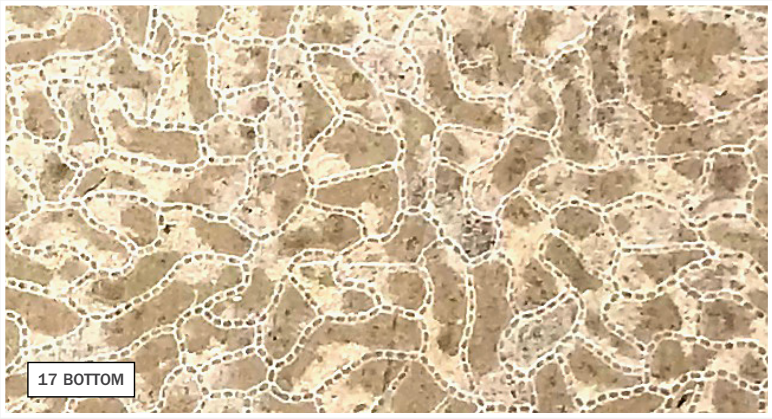
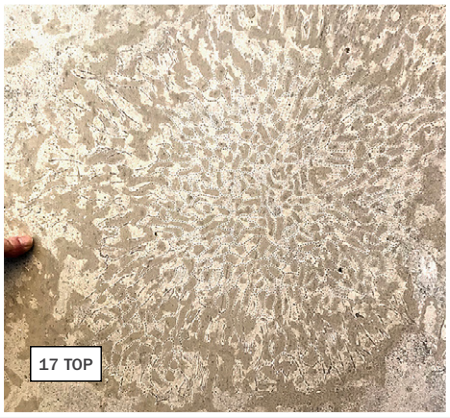



**FIGURE 13.** SAIT; north entrance to the Senator Patrick Burns Building which was built in 1967. The white columns are Tyndall Stone. The slabs have been subject to 53 years of weathering but show very little signs of deterioration, allowing the numerous fossils to be clearly viewed.

**FIGURE 14.** SAIT; This is the south side of the Senator Patrick Burns Building, entirely clad with white, fossiliferous Tyndall Stone.

**FIGURE 15.** SAIT; A "honeycomb" tabulate coral colony, probably Trabeculites or Saffordophyllum. Note the closely-set polygonal corallites.



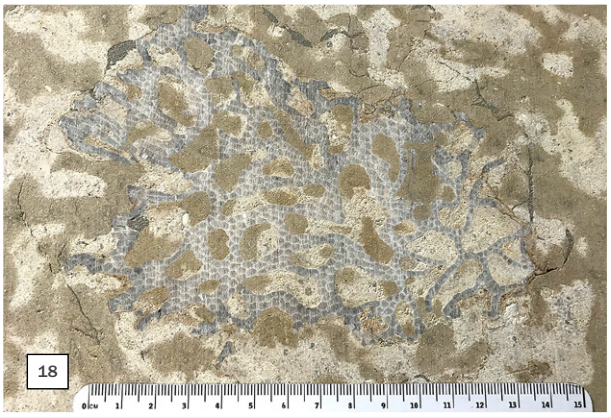
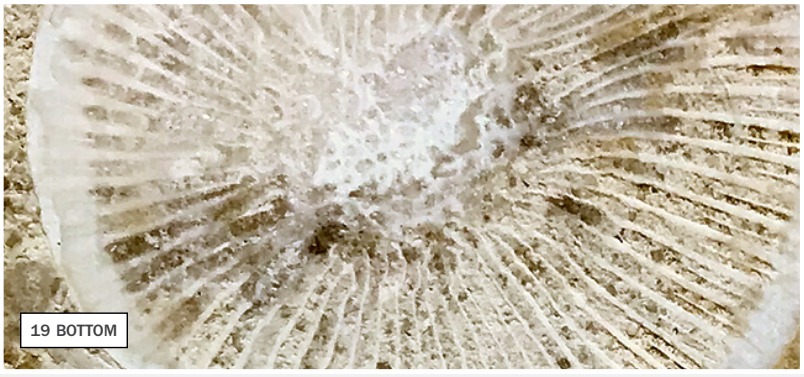




**FIGURE 16.** SAIT; a gastropod (snail), cf. Hormotoma sp., height approximately 4 cm.

**FIGURE 17.** SAIT; top image shows a large tabulate coral colony, probably Catenipora, a "chain coral." Diameter approximately 40 cm. Lower image is an enlarged detail, showing the chain-like arrangement of the corallites in cross-section.

**FIGURE 18.** SAIT; Another tabulate "chain coral," this one probably Manipora, distinguished from Catenipora(?) (Figure 17) by the commonly double or triple-width "chains" of corallites.

**FIGURE 19.** SAIT; two small, solitary rugose corals ("horn corals") in cross section. The smaller individual may be a different species, a younger specimen of the same species, or a mature specimen that was simply cut closer to the tip of the "horn." Lower image is an enlarged detail of the bigger specimen.

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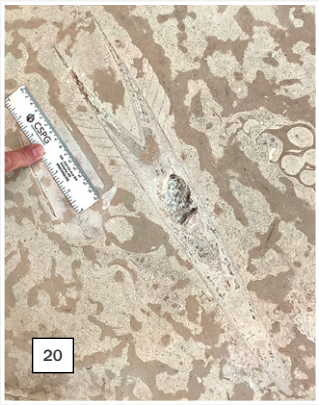


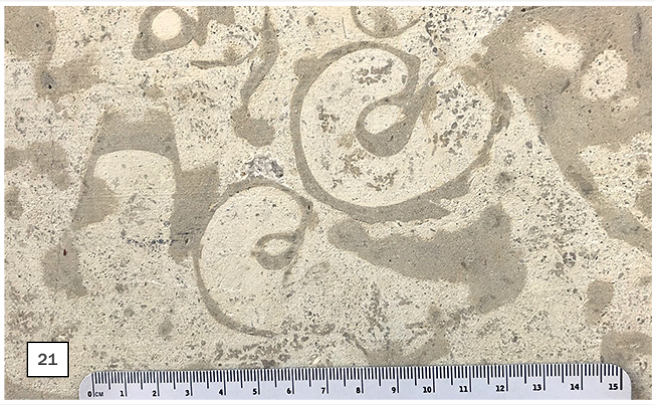



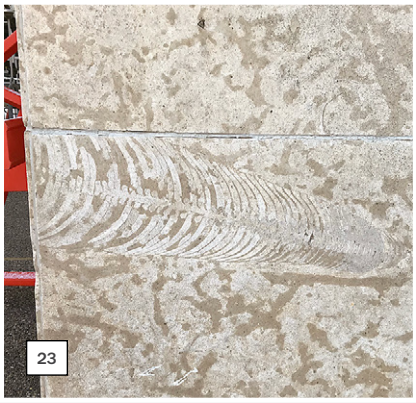


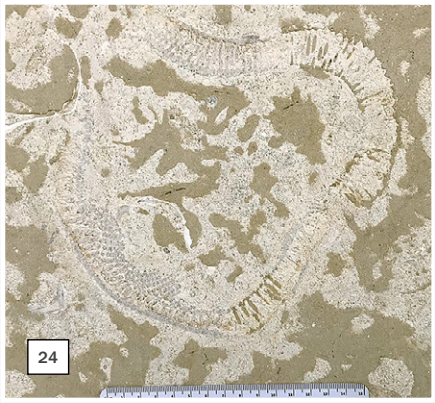



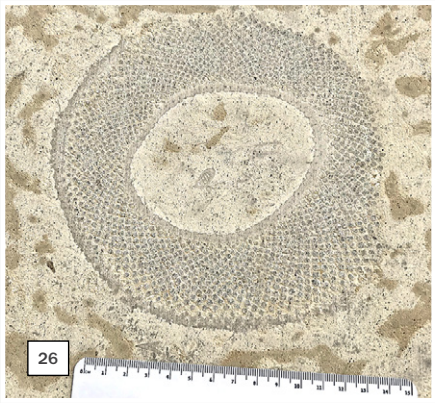



**FIGURE 20.** SAIT; a large orthocone nautiloid showing internal structures, length 48 cm. Hormotoma gastropod on right.

Fi**GURE 21.** SAIT; a pair of gastropods, cf. Hormotoma sp.

**FIGURE 22.** SAIT; large orthocone nautiloid, width 20 cm.

**FIGURE 23.** SAIT; large orthocone nautiloid, length 50 cm.

**FIGURE 24.** SAIT; "Receptaculites," width 20 cm.

**FIGURE 25.** SAIT; large, semi-circular (cyrtocone) nautiloid, similar to Winnipegoceras, length about 30 cm.

**FIGURE 26.** SAIT; "Receptaculites," width 15 cm.

**FIGURE 27.** SAIT; detail of Figure 24, "Receptaculites" cut at right-angles to the surface of the spheroidal skeleton, showing the pillars that separate the inner and outer walls. This is same fossil as Figure 28 but cut at a different angle.

## KENSINGTON SAFEWAY STORE, SUNNYSIDE

In front of the Safeway store in Sunnyside-Kensington (northeast corner of 10 Street and 3 Avenue NW), ten blocks of Tyndall Stone are present (Figure 9). The top dimensions of each block are about 1.0 m by 1.0 m and the depth is 0.5 m. These blocks allow the observer to study the fossils in 5 dimensions (top, front, two sides and back).

For a paleontologist or anyone interested in fossils, the blocks provide a unique opportunity since, by standing beside these blocks and looking down, you can imagine yourself snorkeling above and looking down through clear, warm water on the organisms which lived on or above the Late Ordovician sea floor, 450 million years ago.

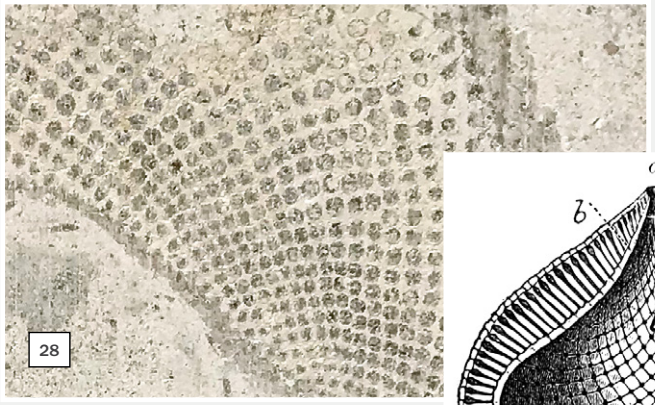

FIGURE 28. SAIT; detail of Figure 2, "Receptaculites" cut nearly parallel to the surface of the spheroidal skeleton. Here the pillars separating the inner and outer wall are visible in cross-section, forming the characteristic "sunflower" pattern.

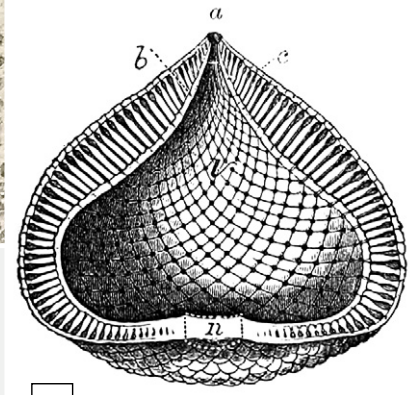


FIGURE 29. Reconstruction of "Receptaculites" from Billings, 1865 (his figure 373, p. 378). a = aperture, b = inner wall, c = outer wall, v = internal cavity. Note pillars (white) between inner and outer walls.

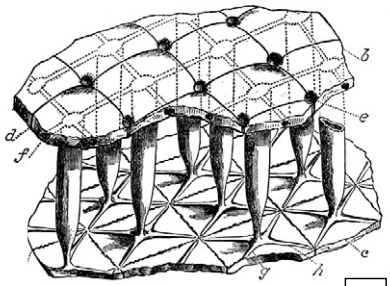

FIGURE 30. Reconstruction of the wall structure of "Receptaculites" from Billings, 1865 (his figure 357, p. 382). The important features to note are the inner (top) and outer walls, supported by pillars, characteristic of this fossil.

FIGURE 31. SAIT; A large Maclurina gastropod (snail).

## SOUTHERN ALBERTA INSTITUTE OF TECHNOLOGY (SAIT)

The best location in Calgary to view Tyndall Stone fossils is at the SAIT campus, south of 16 Avenue between 10 and 14 Streets NW. In the southeast corner four large buildings are covered by slabs of Tyndall Stone. These slabs are still relatively new so the texture is quite fresh and unweathered, allowing the fossils to be seen almost in their original state. There is nearly 1.0 km of continuous, accessible Tyndall exposure at SAIT, so you will see new specimens with repeated visits. It's best to visit with others to get the benefit of more eyes on the rocks and more opportunity for discussion.

## ACKNOWLEDGEMENTS

The first time I led this field trip was on September 12, 2020 for the Alberta Palaeontological Society. My interest in the Tyndall began four years ago when I read an article by Dr. Clint Tippett, retired Shell Canada geologist and Past President of the Canadian Society of Petroleum Geologists (CSPG) in the November/December, 2018 issue of the CSPG Reservoir magazine. Clint's article was titled Geology in Your Neighborhood, wherein he described various fossil localities in Calgary including the fossiliferous Tyndall Stone on the north side of the historic AGT building, downtown Calgary.

I owe a big thank-you to Dr. Brian Pratt, Professor of Geology at the University of Saskatchewan (Saskatoon), who was more than generous with his time and knowledge in many email discussions, identifying fossils seen in the photographs.

Thanks also to Dan Quinsey, author of the book Moose Mountain, Alberta: Exploring the Natural History of Canyon Creek and Area for his help with identifying fossils and for general advice. Furthermore, Howard Allen, Editor of the Bulletin of the Alberta Paeleontological Society was very helpful in significantly contributing to the text of this article and editing photos of the fossils.

In addition, I would like to recognize Dr. Les Eliuk, retired Shell Canada geologist and carbonate specialist now living in Three Hills, Alberta for his recommendation to me to check out the Tyndall Stone fossils at SAIT. I live in the community of Rosedale and live within six streets of SAIT. I have walked many times past the buildings mentioned herein but I had never noticed the many beautiful fossils on the sides of the buildings there. I have had a lifetime interest in paleontology and have searched for fossils worldwide whenever the opportunity arose. I was flabbergasted to learn that, after having spent a half-century searching for fossils, the most interesting fossils I have discovered in the world are within one kilometre of my backyard!

## REFERENCES AND FURTHER READING:

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# 2022 UPCOMING EVENTS INFORMATION


# SEPTEMBER

## September 6th - 8th

**Tuesday – Thursday | 8:00 am – 4:30 pm**

### CSPG Short Course

**Sequence Stratigraphy: Non to Marginal Marine & IV Deposits**

Instructor: Brian A. Zaitlin
Location: Core Research Centre

## September 8th

**Thursday | 12:00 pm – 1:00 pm**

### Structural Geology Technical Division

**Discrete Fracture Network (DFN) Modelling of Induced Seismic Lineaments To Help Reveal The Natural Fracture Architecture Of The Montney Formation, British Columbia**

Speaker: Dr. Steve Rogers
Location: Schlumberger Meeting Room

## September 12th

**Monday | 12:00 pm – 1:00 pm**

### Basin Analysis Sequence Stratigraphy Technical Division

**Campanian-Maastrichtian Intercontinental Seaway: A Virtual Outcrop Tour from the Book Cliffs of Utah to the Badlands of Alberta**

Speakers: Rudy Strobl and Wes Sutherland
Location: geoLOGIC Classroom

## September 14th

*Virtual*

**Wednesday | 12:00 pm – 1:00 pm**

### International Geology Technical Division

**Examples of geological interpretation of surface EM methods in Oil & Gas Exploration**

Speaker: Patricia de Lugão

## September 15th

**Thursday | 12:00 pm – 1:00 pm**

### GeoWomen

**Being a Good Ancestor: My Journey of Truth and Reconciliation**

Speakers: Jocelyn Keith-Asante and Friends
Location: TBD

# 2022 UPCOMING EVENTS INFORMATION

## September 17th

**Saturday | 7:30 am – 5:00pm**

### Field Trip

**Structural Geology Transect in the Eastern Canadian Rocky Mountains, Calgary (AB) to Field (BC)**

Speakers: Normand Bégin
Location: TransCanada Highway 1

## September 27th

*Virtual*

**Tuesday | 12:00 pm**

### Environmental and Basin Analysis Sequence Stratigraphy Technical Divisions

**Geomorphic History and Preservation of Archeologically Significant Areas in the Hanford Reach of the Colombia River, Washington State**

Presenter: Benjamin Joel Deans

# OCTOBER

## October 3-5th

**Monday – Wednesday | 9:00 am – 5:00 pm**

### Structural Geology Technical Division

**Late Triassic-Early Jurassic extensional tectonics in the Neuqu´en Basin (Argentina). New insights from stratigraphic and structural analyses of the Chachil depocenter**

Speaker: Natalia Marina Hernandez
Location: Schlumberger Meeting Room

## October 6th

**Thursday | 12:00 pm – 1:00 pm**

### Structural Geology Technical Division

**Discrete Fracture Network (DFN) Modelling of Induced Seismic Lineaments To Help Reveal The Natural Fracture Architecture Of The Montney Formation, British Columbia**

Speaker: Dr. Steve Rogers
Location: Schlumberger Meeting Room

## October 17-18th

**Monday & Tuesday | 9:00 am – 5:00 pm**

### CSPG Short Course

**Introduction To Geosteering**

Instructor: Janelle Springer
Location: CSPG Classroom

## October 20th

**Thursday | 12:00 pm – 1:00 pm**

### GeoWomen

**Stories and Numbers Highlighting Harassment in Mining Workplace and Solutions towards Safe, Inclusive and Respectful Workplaces**

Speaker: Susan Lomas
Location: TBD

## October 21st

**Thursday | 7:30 pm – 8:30 pm**

### Paleontology Technical Division

**The Messel Pit, Central Germany – Fossilized Treasures of the Eocene**

Speaker: Tako Koning
Location: Mount Royal University

# NORTH AMERICA IN CONTEXT: OVERARCHING THEMES ACROSS THE INDUSTRY

1. GEOTHERMAL REGULATION IS RELEASED BY THE AER
2. M&A REMAINS A FOCAL POINT IN 2022
3. GAS PRODUCTION IN THE US IS EXPECTED TO GROW; WHAT IMPACT IS INFLATION HAVING?

## CANADA:

### Alberta releases geothermal development regulation

The Alberta Energy Regulator (AER) has released Directive 089 providing guidance on geothermal developments in the province. The Directive provides details on the requirements that must be met for the lifecycle of geothermal development: initiation, construction, operation and closure. Many existing requirements for oil and gas development apply to the development of geothermal resources such as risk assessments and licensing (i.e. Directive 067). There are two streams of development within the document which have differing implications:

- **Commercial resources**, or those which are sold to others, are subject to the Geothermal Resource Development Act (GRDA). This applies to wells, facilities and pipelines with applications to geothermal resource development.
- **Noncommerical resources**, such as those used by developed for their own purposes, are not subject to the GRDA.

Geothermal projects gain clarity from the AER following the release of Directive 089. With the energy transition continuing and the looming target of 2030 fast approaching, development regulation clarity will help to expedite geothermal resource development. The commercial versus noncommercial distinction, will give operators with existing facilities some respite from duplicating reporting if they choose to incorporate geothermal resources within their projects. Some examples of companies such as Razor Energy have existing geothermal resource development, but there have been previous studies and continued work on the potential of geothermal resources in sectors such as the oil sands for heat and energy generation.

### M&A continues in Canada

Deals continue to be made in Canada with Strathcona acquiring Serafina Energy, Enbridge taking a stake in Woodfibre LNG and Kiwetinohk consolidating in Placid Montney. Repsol appears to have sold off another portion of their Canadian portfolio to Kiwetinohk, while retaining operating interest in the Bigstone processing facility. This deal follows a divestment of Duvernay acreage to Paramount, bringing the total to Cdn$130 million since July 2022. Private companies are making waves, with Strathcona continuing its growth through acquisitions and Teine's acquisition of Repsol's Alberta assets.

Strathcona's deal is for a cash consideration of Cdn$2.3 billion (US$1.8 billion). The deal is expected to close on 29 August 2022, coinciding with an initial Cdn$1.9 billion payment. This deal follows a September 2021 acquisition of another private Saskatchewan focused producer, Caltex Resources, for Cdn$700 million (US$550 million). At the time, the Caltex assets produced roughly 13,000 boe/d of EOR heavy oil for a deal metric of Cdn$54,000/ flowing boe (US$42,000/flowing boe).

For Enbridge, de-risked and under development LNG projects are rare in Canada. Woodfibre was and is charging ahead and is now entering the high-cost construction phase. Construction is set to begin in 2023 and complete in 2027. The project will cost US$5.1 billion.

### Canadian gas returns to negativity:

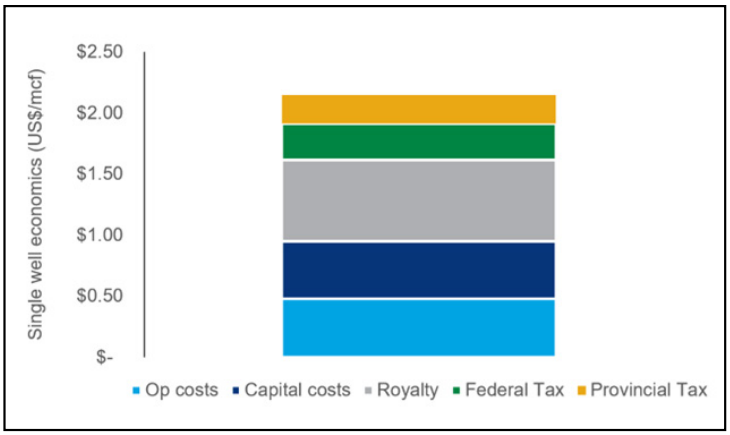
On 18 and 19 August, Westcoast Station 2 spot prices in Western Canada turned negative for the first time in three years to settle around -US$0.1/mmbtu. The other Canadian price benchmark AECO hovered below US$1/mmbtu on 19-23 August while Henry Hub briefly moved briefly into double digit territory. The main culprit behind the extremely distressed prices is various regional pipeline maintenance projects that both trap supply at the wellhead and impact export capacity leaving western Canada.

Despite a significant AECO differential to Henry Hub, the economics of Montney wells are robust. For example, looking at a single well from our upstream research's Murphy Montney BC asset economic model, we are able to break down the costs a producer may incur at the well level.

### Montney single-well economics (gas driven)

Source: Wood Mackenzie upstream research, royalties and taxation run under our current price deck (July 2022)

MONTNEY SINGLE-WELL ECONOMICS (GAS DRIVEN)

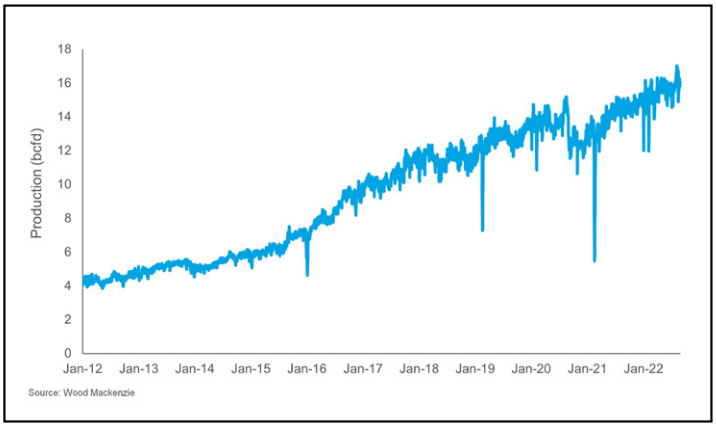



## LOWER 48:

### Permian gas production achieves record rates, expected to continue

Lower 48 gas production increased to new record highs during late July and into August. The Permian and Haynesville were the biggest drivers and continue to exhibit outsized growth relative to other plays. Recent processing plant and pipeline outages have since reduced production levels, but we expect strong growth in the Permian and Haynesville to continue. Surging Haynesville production isn't surprising considering the 43% jump in rig activity this year and absolutely stunning well results some companies have been recording. Record gas volumes in the Permian stand out since the rig count remains below pre-crash levels and US independents continue to de-prioritize growth. Despite those production headwinds, the region grew by 1.7 bcfd over the past 12 months.

But understanding where Permian volumes go from here is arguably just as important as the play hitting record production. We expect continued growth throughout the remainder of this year resulting in just over 0.7 bcfd (exit-to-exit) for 2022. Next year, growth continues as well with another 1.23 bcfd expected to come online. Another 20-30 rigs are expected to be added next year, but growth will be driven from nearly 60% of those additions heading to the Delaware Basin. This is incredibly significant for the gas outlook when considering recent Delaware Basin wells are typically making over 150% more gas than Midland Basin wells in the first 180 days.




### Inflationary impacts on upstream budgets

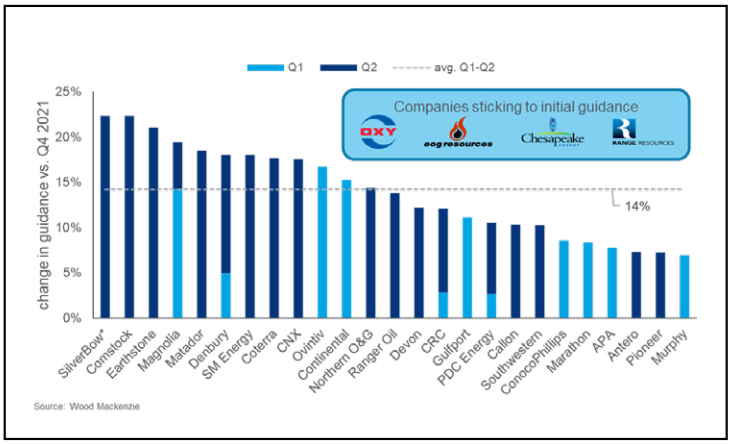
A faster-than-expected demand recovery has strained an already tight oil and gas market, driving operators to increase budgets. Upstream investment at the start of the year had previously rebounded 18% versus 2021, now at 21% (only 7% below 2019 levels). The number one culprit is inflation, affecting close to 80% of revisions. Higher prices have been seen across the board encompassing goods, services, and labor. Activity uptick was the second-most mentioned category in the latest round of earnings calls, affecting over half of announcements.

Investment revisions are concentrated within North America. APA Corporation mentioned higher increases and more volatility in the US while prices internationally have remained relatively stable. BP observed similar pricing when contrasting its US subsidiary BPX with its remaining portfolio. But BPX's spending increase also showcases the current leverage short-cycle shale has on 2022 commodity prices. BPX's annual capex budget is up 13% over earlier guidance, via a mix of the aforementioned inflation and activity.

The largest uplifts are observed among the smaller-sized E&Ps within our Focused US peer group. Diversified Independents – composed of larger-than-average US-based operators – have been more constrained in their revisions. In fact, the only four US players sticking to their initial guidance are Oxy, EOG, Chesapeake and Range.

PERMIAN NATURAL GAS PRODUCTION

## L48: Q1 and Q2 changes in capital expenditure guidance




### Hedged volumes continue to decline

For the first time since we began tracking E&P hedge activity, US operators in our hedging analysis peer group saw a net drop in crude hedge volumes quarter over quarter. During the period, EOG terminated 75,000 b/d and 0.5 bcfd worth of 2022 and 2023 oil and gas hedges, cancelling out the net 63,000 b/d in new hedge contracts added by Diamondback, Coterra and others.

During Q2, EOG reportedly paid $1.3 billion to terminate a portion of its hedge contracts. By cancelling those contracts, we estimate that the company will avoid a possible $1.8 billion in losses under our high price scenario.

Based on this price outlook, US-focused operators in our peer group are expected to see a $19 bn loss against existing hedges from August to year-end. Gas hedges especially continue to be a drag on earnings as this group has locked in 56% of total 2022 gas production at an average strike price of just $3.21/mcf. As balance sheets continue to improve and market fundamentals continue to support a positive price outlook, hedging will have a reduced role in company strategy. In Q2 calls, Appalachian producers like Southwestern and Range indicated that although hedging will continue to be a core tactic, the fraction of gas production covered will shrink.


**SCOTT NORLIN, GIT**

**Research Analyst, Upstream Canada**


Scott joined the Canadian Upstream Research team at Wood Mackenzie in June 2019. He is responsible for providing financial asset valuation and objective commercial analysis on company and play activity across Canada. His coverage ranges from North American large caps to junior private producers. He also covers CNRL and Cenovus for the corporate analysis team, providing high level company valuation and strategy analysis.

Prior to joining Wood Mackenzie, Scott gained comprehensive experience in exploration and development of upstream assets. Scott worked at Parex Resources on conventional assets, Devon Energy on the Jackfish oil sands project and also has field experience in unconventional plays.

Scott holds a Bachelor of Geology degree with honours from the University of Calgary and is a registered Geologist in training with the Association of Professional Engineers and Geoscientists of Alberta.


**BRANDON MYERS**

**Senior Analyst – Lower 48 Upstream**


Brandon is a senior analyst with our Lower 48 research team. Having joined Wood Mackenzie in 2017, he has worked on the integration of subsurface data with L48 research and conducted research into every major unconventional play in the US and Canada.

Prior to this, Brandon's career included roles in both energy efficiency and the oil and gas industry. He was a founding partner of Firefli LEDs, a carbon reduction focused LED lighting company that focused on solutions for high rise towers and industrial facilities.

After that he spent time as an energy analyst for Nemalux, a Canadian, heavy industry LED manufacturer that specializes in carbon and power reduction solutions for wellsite facilities.

He was a conventional field geoscientist for an innovative junior oilfield optimization exploration company in Calgary through 2016 and early 2017.

Brandon graduated from the University of Alberta with a BSc, Specialization in Geology. Academically his focus was on the organic geochemistry of the Duvernay shale and his thesis was focused on hydrocarbon generation and expulsion modelling across Encana's Kaybob acreage.

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