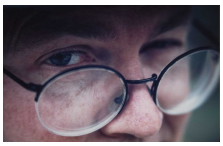
FRACK EU:
UNCONVENTIONAL INTRIGUE IN POLAND

A Preliminary Investigation of the Fracking Assault on Poland



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January 23, 2012

(For the complete report chapters index, refer to the B.C. Tap Water Alliance website, under *Stop Fracking British Columbia*)

CHAPTER 14: (Wellbore) Integrity On Trial - The Liability Nightmare

14. INTEGRITY ON TRIAL: THE LIABILITY NIGHTMARE

> *With age, the integrity of all wellbores deteriorate. Cracks and fissures develop in the annular cement due to a number of factors related to cement composition, thermal stress, hydraulic stress, compaction, wellbore tubulars, and the downhole environment. The most significant cause of sustained casing pressure in the outer casing strings is a poor cement bond that results in the development of cracks and annular channels. The cracks and microannulus channels through the cement provide a path for high-pressure fluids to migrate from deeper strata to low-pressure strata or to the surface.* [1]

From the most ancient to 'modern' times, the greatest philosophers and thinkers have consistently stated and agreed that human beings are unlike any other warm and cold blooded creatures. Simply, what sets us apart is our seemingly endless extraordinary capacity to think and communicate with each other in complex ways, our spiritual desires and abilities to apply our intelligence in reshaping and altering the physical world in which we inhabit, for good and for evil. Of all the thousands of years that humanity has managed to live and survive on Mother Earth, the Third Orb from our Sun, none have ever done before what recent generations are increasingly doing: chemically drilling into and chemically fracking her skin and mantle, technological actions not without long term consequences, consequences very difficult to predict or repair.

Somewhere in-between the timeline when the petroleum drilling era began in the 1800s and now, people, with their abilities of creative intelligence and capacity for vision, must have realized the inherent consequences and problems of penetrating and pricking the earth with holes. When these hole and cavity makers eventually realized that their artificial casings, fillings and plugs were only temporary substitutes - much like dentists filling teeth cavities - whereby every single hole drilled and sealed would have to bow before the almighty and inflexible law of material geochemical disintegration and corruption, did the professional hole makers then duly inform and advise us and our governments about the impending problems humanity must inevitably face as a result? If the hole makers had collectively, honestly and accurately advised us of the cumulative consequences long ago, would they have steered us away from doing so in the future?

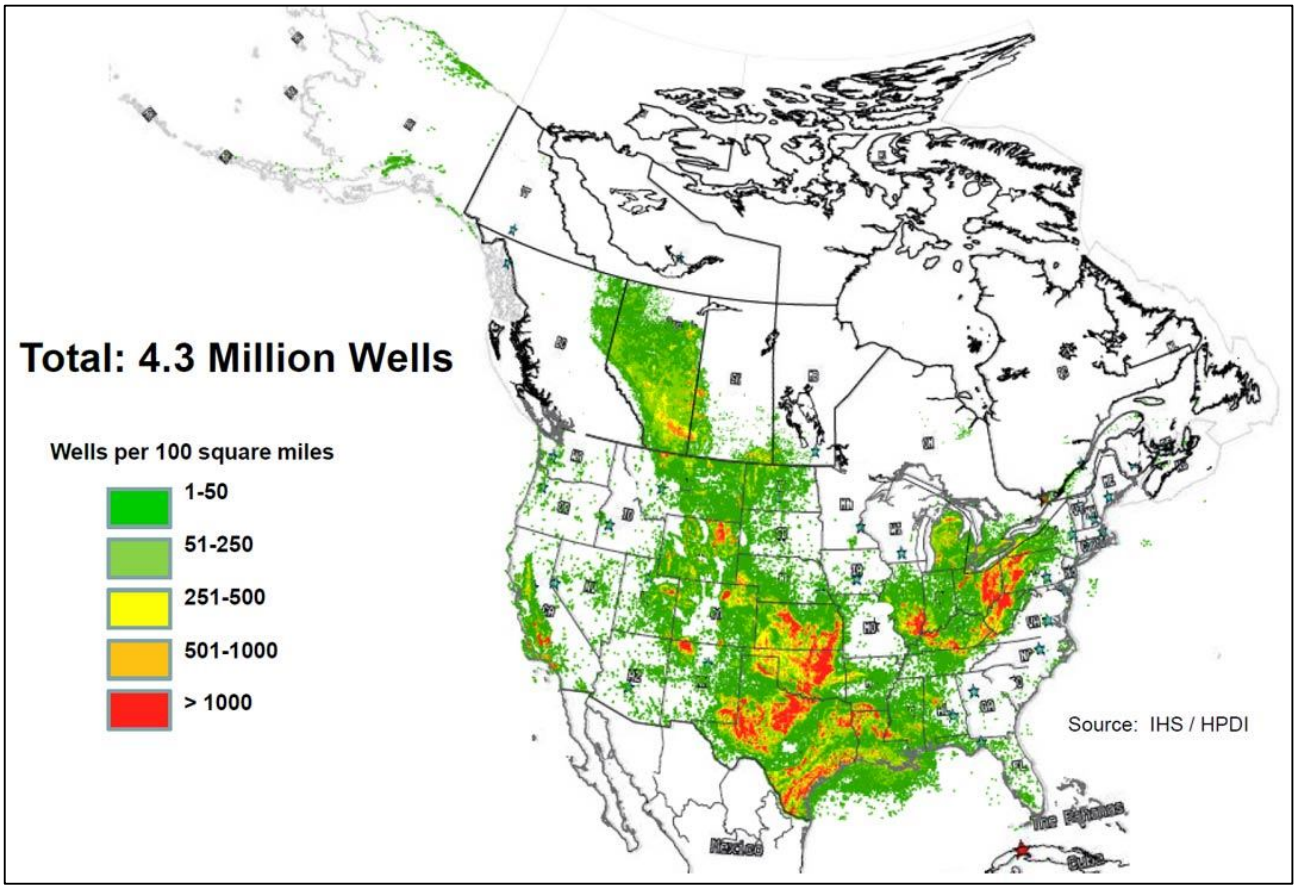
Unlike human beings, mother earth's pierced and pin-holed skin lacks the miraculous and mysterious quick self-healing powers found in the skin and bodies of humans and earth's creatures and life forms. The professional petroleum doctors assigned to monitor mother earth under their hippocratic care and ward may be facing an unprecedented malpractice lawsuit for fudging the medical charts.

In the hundreds of thousands and millions of wells drilled and fracked in just over a century on planet earth, has humanity's hubris paid the ultimate price, or, has mammon-infected hubris become an unbridled monster? Have we been fooled, or are we simply fooling ourselves? As musical artist Bob Dylan sings it, the answers are eerily "blowing in the wind."

[1] *Microannulus Leaks Repaired with Pressure-Activated Sealant*, Society of Petroleum Engineers, #91399, 2004.

14-(1). Reality Check: Responsible or Irresponsible? Prudent or Imprudent? Prudent or Perverted? Definitely not Sustainable and Very Unconventional

Examine the image below. Take a careful look. Now, sit back and give yourself ample pause to ponder and think.



What do you see here? What are you imagining and thinking about when you look at it? Does this image in any way disturb you? It ought to. If it doesn't, it's time for a reality check, particularly with regard to what the petroleum industry is proposing to our governments about what will occur over the following decades in addition to the damage already done by their insatiable needling.

This frightening and disgusting image of the total/cumulative number of oil and gas wells developed in the United States and Canada was introduced by Chesapeake Energy Corporation's chair of operations and environmental task force, Paul D. Hegemeier, on September 15, 2011, during the National Petroleum Council's (NPC's) 121st meeting held in Washington, D.C., on September 15, 2011. [2] At the meeting, the NPC unveiled a draft report and a related series of 49 topic reports and 9 white papers, *Prudent Development of North America's Oil & Gas Resources.*

[2] The proceedings were video and audio webcast, and a video version is available on the NPC's website. The map showing the 4.3 million wells is not included in any of the NPC's related reports, but was included in a pdf presentation document for the conference, a document used in the *Prudent Development* U.S. promotional tour from September to December. There are some clues to suggest that the data used for this map is six years old and may therefore be inaccurate. Are there more wells? For instance, it was stated in a 2002 report by the Canadian Council of Ministers that there were at least 600,000 abandoned wells in Canada with unknown integrity on their casing.

During the question and answer period at NPC's conference event, James Hackett responded to a question from a Platt's reporter. Hackett spoke about *"community impact challenges and community communication challenges that we have as an industry.... One of the things that we've got to make sure, and this is one of the things that the report addresses, is that we reassure the public that things are being done in the proper fashion.... Getting information to ... other stakeholders is a very important part of our job."* 46 days later, on October 31, 2011, on Halloween day, Hackett's Manager of External Affairs with Anadarko Petroleum, **Matt Carmichael**, said some startling things about how Anadarko was 'communicating' with the public in its "media plan." Carmichael said that "**we are dealing with an insurgency**," and that he was using the "U.S. Army/Marine Corps Counterinsurgency Manual" to deal with the public regarding shale gas controversies, and recommended public relations representatives "in this industry" to do the same. Carmichael also said that his "bible" was "Rumsfeld Rules." [3]

James Hackett, the chairman and ceo of **Anadarko Petroleum**, gave the overview introduction of the *Prudent Development* report at NPC's meeting event. Hackett was the Committee Chair of the NPC's *Prudent Development* study report initiative which transpired over a period of two years following a September 16, 2009 directive by U.S. Secretary of Energy Steven Chu to the NPC to, in part, reassess the development of unconventional oil and gas potential:

*Even as **we transition** to a lower carbon energy future, **fossil fuels will continue to play a major role** in the Nation's energy mix for many decades. An important part of this transition will be to recognize and **responsibly develop the natural gas resources supply chain and infrastructure in North America**. In recent years, there have been significant new developments in the North American natural gas and oil resource base. In particular, **large new unconventional source of natural gas and oil have been identified**.... I request the National Petroleum Council to **reassess** the North American resources production supply chain and infrastructure potential, and the contribution that natural gas can make to a lower carbon fuel mix... Of particular interest is the Council's advice on policy options that would allow **prudent development of North American natural gas an oil resources consistent with government objectives of environmental protection, economic growth, and national security**.... I am designating Deputy Secretary Dan Poneman to represent me and to provide the necessary coordination between the Department of Energy and the National Petroleum Council. He will also provide coordination between the Department of the Interior, Department of Transportation, Environmental Protection Agency, and other Federal Agencies as required.*

[3] See chapter 13-(10-a) of this report for the details.

Chu's September 16, 2009 directive occurred:

- when U.S. State Secretary Clinton appointed David Goldwyn as the new U.S. international energy envoy, who then implemented the Global Shale Gas Initiative, and signed initial U.S. industry cooperative shale gas and oil agreements with China and India;
- after the U.S. FRAC (Fracturing Responsibility and Awareness of Chemicals) Act was introduced in June, 2009;
- and just prior to the Environmental Protection Agency's public review of life-cycle fracking.

Was Chu steering his Nation in the proper direction when he issued the petroleum initiative to the NPC? Not according to the information that has since transpired about how methane, and the lifecycle operations of its exploration, production and delivery, is, and will continue to severely add to the looming problems of global warming. Not if one understands the long term transmission liabilities and threats from wellbores on the toxication and radiation of subsurface environments.

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Chairman and Chief Executive Officer
Anadarko Petroleum Company

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J.P. Morgan Securities LLC

NATIONAL PETROLEUM COUNCIL

The National Petroleum Council (NPC) is an organization whose sole purpose is to provide advice to the federal government. At President Harry Truman's request, this federally chartered and privately funded advisory group was established by the Secretary of the Interior in 1946 to represent the oil and natural gas industry's views to the federal government: advising, informing, and recommending policy options. During World War II, under President Franklin Roosevelt, the federal government and the Petroleum Industry War Council worked closely together to mobilize the oil supplies that fueled the Allied victory. President Truman's goal was to continue that successful cooperation in the uncertain postwar years. Today, the NPC is chartered by the Secretary of Energy under the Federal Advisory Committee Act of 1972, and the views represented are considerably broader than those of the oil and natural gas industry.

About 200 in number, Council members are appointed by the Energy Secretary to assure well-balanced representation from all segments of the oil and natural gas industry, from all sections of the country, and from large and small companies. Members are also appointed from outside the oil and natural gas industry, representing related interests such as states, Native Americans, and academic, financial, research, and public-interest organizations and institutions. The Council provides a forum for informed dialogue on issues involving energy, security, the economy, and the environment of an ever-changing world.

One of the NPC's study reports, *Sustainable Drilling of Onshore Oil and Gas Wells* (Paper #2-23), doesn't include comments about why the report is called "sustainable" drilling. In other words, the title merely 'suggests' that it is, and nowhere in this 22-page document is there a discussion about the long-term consequences of drilling, when the casings and cement in and along hundreds of thousands of well bores begin to deteriorate over time. And, there is no reference to, or discussion of, the findings and committee workshops of the Well Bore Integrity Committee (formed in 2005).

In the NPC's companion-theme document, *Plugging and Abandonment of Oil and Gas Wells* (Paper #2-25), there is also no reference to the findings and meetings of the Well Bore Integrity Committee. There is, nevertheless, a few interesting related tid-bits:

Recent shale-gas developments have rediscovered some P&A (Plugging and Abandonment) *issues in the forms of* ***older oil or gas wells which never were adequately plugged but which now pose possible cross-contamination or leakage risks****. Furthermore, eventual* ***retirement of uneconomical shale-gas wells*** *must address P&A practices that are specific to issues affecting gas wells and especially horizontal gas wells.*

The lack of progress in P&A practices is attributable ***to absence of a long-term vision****, and inattention to corresponding research, that recognizes the benefits of P&A to oil and gas development projects. Specific findings are that:*

- *Benefits from reduced operational costs and/or increased production, especially in redeveloped, older fields, generally has been underappreciated.*
- *By plugging wells correctly, future environmental issues, related to fluid or gas leakage, can be avoided and thereby preserve savings otherwise eroded by remediation or litigation costs.*
- *Research has lagged on materials and methods for plugging wells although advances in technologies for drilling and completion should be applicable to practices in plugging and abandonment.*

On October 12, 2011, the U.S. Center for Strategic and International Studies (CSIS) videotaped a two-hour forum with key leaders involved in the National Petroleum Council's (NPC's) September 15, 2011 report, *Prudent Development*. It was the big opener on the Prudent Development tour in the U.S., later debuted in December 2011 at Rice University's Baker Institute. The event was chaired by CSIS's senior vice president and director of its Energy and National Security Program, Frank Verrastro, who served in both the private and public sectors. In the private domain, he was the director of refinery policy and crude oil planning for U.S. refining giant **TOSCO**, and **Pennzoil**'s senior vice president. On the public side, Verrastro was in the White House with the Energy Policy and Planning Staff, in the Oil and Gas Office with the Department of Interior, and in the Department of Energy's Domestic Policy and International Affairs Office. He is also a member of the Council on Foreign Relations. He also chaired the Geopolitics and Policy Task Groups for NPC's 2007 report, *Hard Truths: Facing the Hard Truths about Energy*, [4] one of five studies he helped conduct for the NPC. [5]

14-(2). International Well Bore Integrity Committee Makes Shocking Statements

The first of many gatherings of the **Well Bore Integrity Committee** was held on April 2-5, 2005 at Houston, Texas Marriott Woodlands Waterway Hotel and Convention Center, where "over 50 experts from both industrial operators and from research organizations" convened. [6] The meeting occurred one month before the Bush/Cheney administration passed the Halliburton Loop-Hole exemption. The delegates at this meeting included the following representatives (with affiliations highlighted):

[4] CSIS online biography.
[5] The NPC's 2010-2011 membership term included 195 members, most of which were corporate captains of the petroleum industry. In the membership mix: Fred Krupp, the president of the Environmental Defense Fund; Kenneth Medlock from the James A. Baker Institute at Rice University in Houston; Adam Sieminski from the Deutsche Bank AG; Michael Smith from the Interstate Oil and Gas Compact Commission.
[6] *Report on Well Bore Integrity Workshop*, April 4th - 5th, 2005, Houston. Released: September 23, 2005. Written by Jonathan Pearce, British Geological Survey, on behalf of IEA Greenhouse Gas R&D Programme.

- **Advanced Resources International** - Phil DiPietro, Scott Stevens
- **Alberta Energy and Utilities Board** (ERCB) - Stefan Bachu
- **Anadarko Petroleum** - James Raney, Ricky Williams, Ken Hendricks, Tyson Schwartz
- **Argonne National Laboratory** - John Veil
- **Austin, Texas University** - Jean-Philippe (JP) Nicot
- **Battelle** - Neeraj Gupta
- **Bergen University** - Jan Martin Nordbotten
- **British Geological Survey** - Jonathan Pearce
- **British Petroleum** - Charles Christopher, Tony Espie, Larry Nugent
- **Chevron/Texaco** - Craig Gardner, Ron Lackey
- **Chevron/Texaco Energy Technology Co.** - Scott Imbus
- **Ecole Normale Superieure de Paris** - Gaetan Rimmele, Bruno Goffe
- **ENI Exploration & Production Division** - Giovanna Gabetta
- **EPRI** - Richard Rhudy
- **ExxonMobil** - Glen Benge, David Stiles,
- **Ground Water Protection Council** - Ben Grunewald
- **Halliburton** - Lance Brothers, Anthony Badalamenti,
- **Illinois State Geological Survey** - John Grube
- **Lawrence Berkeley National Lab** - Larry Myer
- **Lawrence Livermore National Laboratory** - Brian E. Viani
- **Los Alamos National Laboratory** - Bill Carey, Rajesh Pawar, George Guthrie
- **Natural Resoures Defence Council** - Jeff Fiedler
- **NETL / U.S. Department of Energy** - Barbara Kutchko, Grant Bromhal
- **New Mexico Petroleum Recovery** - Reid B. Grigg
- **Ohio Department of Natural Resources** - Scott Kell
- **Princeton University** - George W. Scherer, Andrew Duguid, Mohammad Piri, Jean H. Prevost, Michael Celia, Mileva Radonjic, Dmitri Kavetski
- **RMI** - David Tyte
- **Schlumberger** - Veronique Barlet-Gouedard, Kamel Bennaceur
- **SINTEF Petroleum Research** - Inge Manfred Carlsen, Idar Akervoll
- **Statoil** - Tor Harald Hanssen
- **Total** - Pierre Brossollet, Bernard Fraboulet
- **UT Bureau of Economic Geology** - Rebecca C. Smyth
- **U.S. Department of Energy** - Jay Braitsch
- **U.S. Environmental Protection Agency** - Anhar Karimjee, Thor Cutler.

The Well Bore Integrity group identified the following at its inaugural meeting, published some five months afterwards, a statement that is almost unbelievable as a discovery-moment:

> *Ensuring well integrity over long timescales **has not been attempted before** and represents a **new challenge** to the oil and gas industries.*

The statement is not only ominous, but it also sounds a bit fishy and suspect. It seems unbelievable that sheer numbers of petroleum scientists and engineers in North America's famed petroleum institution and laboratory halls had never attempted to collectively quantify the repercussions of serious cumulative problems related to well bores, and, in this respect, it seems shocking that they

didn't do so long ago. It perhaps suggests something else, that big petroleum didn't much care about publicly identifying these significant looming problems and dealing with them operationally and globally long ago - it didn't want to disturb a veritable host of hornet nests, and, like some mammoth ostrich, kept its head buried deep in the sand.

The Well Bore group also identified at the first meeting:

> ***It will not be possible to promise a leak-free well****, but rather we should emphasise that we can build wells employing state-of-the-art technologies which will reduce risks.*

And, stated in the *Key Conclusions* section of the second group meeting on September 6, 2006, *2nd Well Bore Integrity Network Meeting*:

> *There is clearly a problem with well bore integrity in existing oil and gas production wells,* ***worldwide****.*

These are critical and amazing revelations. At this point, the reader should take some pause to ponder what is being said here in the context of the history of drilling and fracking, and return to the map above to review the 4.3 million or so onshore and offshore wells in the United States and Canada alone, never mind the additional legions of well bores throughout the world. The important question to ask is, how long has it been known within the ranks of the petroleum industry that oil and gas wells are not "leak-free", as thousands and thousands of wells continue to be drilled each year?

Within the group of petroleum professionals that met in the early Spring of 2005, were two members from British Petroleum. (BP's **Charles Christopher** became chairman of the Well Bore Integrity committee.) Even though measures were seemingly being taken, verbally at least, to address the serious concerns about well bore integrity, what did British Petroleum do before its rig exploded with millions of gallons of oil escaping into the Gulf of Mexico? The intense and thorough public inquiries and investigations about this incident found that BP had cut corners. This is the murky reality. How many companies are cutting corners? Why are petroleum company alliances pressuring and getting our governments to de-regulate? How many secrets are there? What is happening underground where the pipes are buried where we can't observe what is really going on?

A U.S. civil engineer and former pipeline inspector recently went public - because of conscientious promptings from his own dear children - and told his story to the public and media about what he witnessed during his inspection days with a large petroleum pipeline operation. Mike Klink said that the international firm Bechtel, under contract with TransCanada Pipeline company, "chose to save money" rather than "safety" during the construction of the first Keystone pipeline. Klink was fired after he raised his concerns to Bechtel. "What did I see? Cheap foreign steel that cracked when workers tried to weld it." [7] Where is this steel being produced, and what sort of inferior quality does it have? How long has inferior and cheaper steel been used by the petroleum sector? What sort of steel is being used for thousands and thousands of short-length well casings used every year?

A critical component in the domain of well bore integrity relates to cementing issues. Various types of specialized cements are used to seal well bore casings, and it is these cements that formed the

[7] *Mike Klink: Keystone XL pipeline not safe*, December 31, 2011.

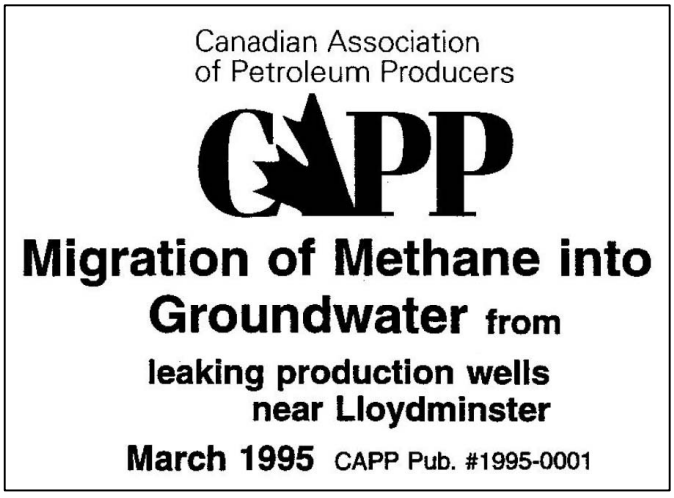
primary concern by the Well Bore Integrity Committee in 2005, and years following. In addition to "cement degradation" issues identified by the Committee in 2005 following, how many companies are cutting corners in cementing and doing it properly? How are the repeated applications in a given well bore by way of intensive brute-force fracking destabilizing the integrity of cement, and of the casing? Etc., etc.

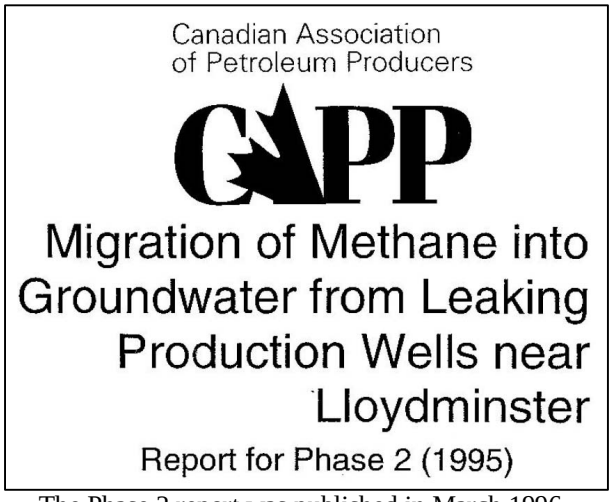
As the world eagerly watches the fracking debates unfolding in the United States and Canada while the petroleum sector is poised to seriously frack mother earth everywhere over and over again, Canada's largest and politically influential methane gas company, Encana Corporation, is fighting tooth and nail in the media to deny and repudiate the U.S. Environmental Protection Agency's December 2011 findings about Encana's fracking operations in the State of Wyoming. [8] As reported by Andrew Nikiforuk in British Columbia's Vancouver City-based Tyee:

> *an extensive study by the EPA has concluded that highly toxic and cancer-causing fluids from shale gas drilling most likely contaminated shallow groundwater in Pavillion, Wyoming. ... Across the United States landowners have reported nearly 1,000 cases of water contamination in the wake of shale gas fracking operations according to the independent press group, Pro Publica. Scores of contamination problems have also been reported in Alberta.* [9]

14-(3). Big Canada Petroleum and Canadian Government Gas Migration Studies - 1990s

How long has the petroleum industry known that its wells have been leaking, and how far into the future will well bores continue to leak at increasing rates? In the early 1990s, Canada's largest and most influential petroleum group, the **Canadian Association of Petroleum Producers** (CAPP), contributed funding for the **Saskatchewan Research Council**'s project investigating underground gas migration contamination of groundwater. The other funders included the **Lloydminster Area Operators Gas Migration Team**, the **Panel for Energy Research and Development**, and the Saskatchewan Research Council.





The Phase 2 report was published in March 1996.

[8] *Investigation of Ground Water Contamination near Pavillion, Wyoming*, December 2011, EPA 600/R-00/000. Landowners did something unusual. They broke confidentiality agreements made with companies on the contamination of their well water and gave the data to the EPA. Like fracking, these confidentiality agreements should be banned.
[9] *US Study Casts Pall over BC's Shale Gas Biz*, Andrew Nikiforuk, December 9, 2011.

- What did the petroleum industry and government gas migration task force discover from their studies in the 1990s about "gas migration" from its operations and "groundwater?"

- Because Alberta and Saskatchewan government regulators were involved in these studies, how was this information disseminated to the public?

- When did CAPP members decide to blame mother nature for their gas migration problems, after it discovered in the early and mid-1990s that the industry is to blame?

- Because CAPP member companies operate around the world, they have known that gas migration is a serious problem, globally.

1.0 INTRODUCTION

In 1995 the Saskatchewan Research Council continued an investigation of gas migration in groundwater in the Lloydminster area. This report documents the 1995 research program, which followed the initial (1994) program (Van Stempvoort and Jaworski, 1995; Schmitz, 1995).

The research project has the following objectives:

- to investigate the occurrence of methane in groundwater near leaking production wells in the Lloydminster study area,

- to determine whether the methane is derived from the leaking well or occurs naturally in the aquifer,

- to determine the concentration gradients and approximate flux rates of methane from leaking wells to shallow aquifers, and

- to predict the migration rate of methane in aquifers under various scenarios of time and physicochemical conditions (e.g., aquifer properties).

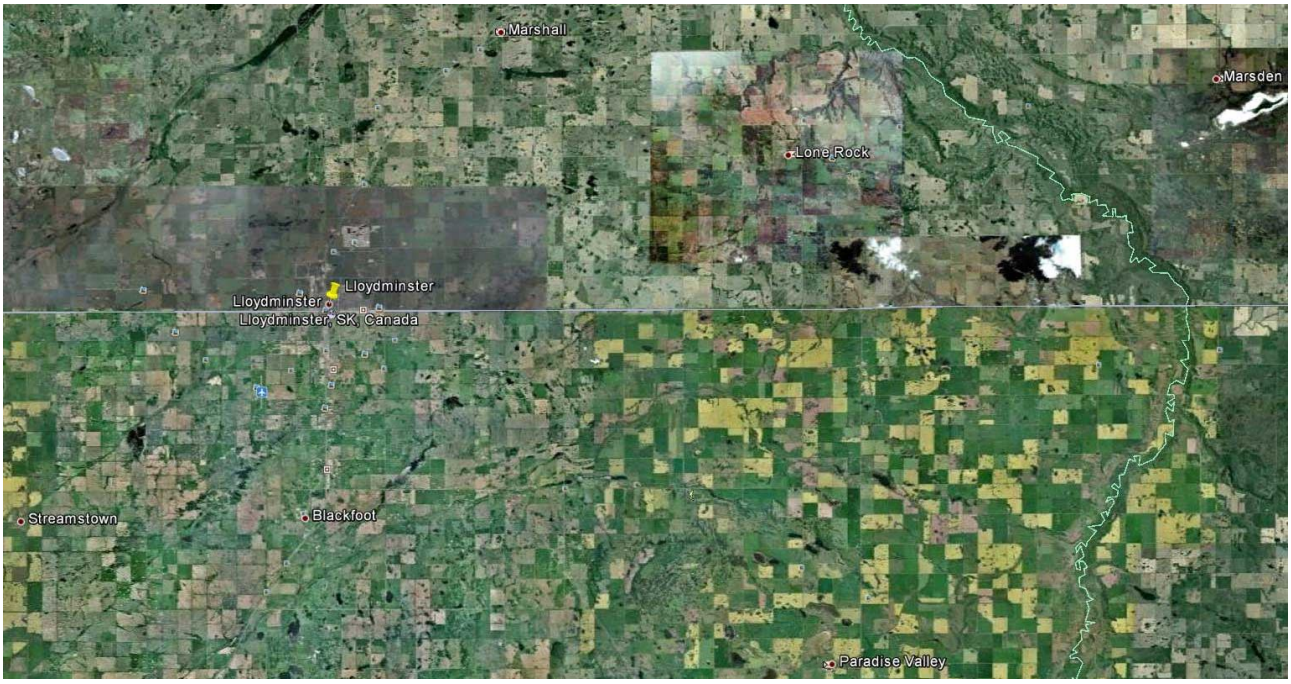
This project is funded by the Canadian Association of Petroleum Producers (CAPP), the Lloydminster Area Operators Gas Migration Team (LAOGMT), the Panel for Energy Research and Development (PERD) and the Saskatchewan Research Council (SRC). In 1995, the steering committee for this program included Ron Schmitz (Husky Oil, CAPP), Garry Lorenz (LAOGMT), Les Bernier (Saskatchewan Energy and Mines), David Blume (Provost Area Surface Rights), Tom Cook (Alberta Energy Utilities Board), Garry Ericson (Saskatchewan Energy and Mines), Margaret Klebek (Alberta Environmental Protection), Kennedy Kohlman (Koch Exploration), Brian Moneta (Elan Energy), Don Roberts (Alberta Energy Utilities Board), Scott Robinson (Saskatchewan Environment and Resources Management), Harold Seitz (Wascana Energy), Kurt Uhrich (Amoco) and Gary Webster (CAPP).

The 1995 program included five components as indicated in the following sections:

- expansion of monitoring at the Lindbergh site,
- selection of five new sites; installation of monitoring wells at two of these sites,
- investigation of dissolved methane and other hydrochemical species,
- development of modelling for simulation of methane migration in groundwater,
- survey of methane in 23 water supply wells in the Lloydminster area.

In CAPP's 1995 report *Introduction*, it describes how the investigation included a "survey of methane in 25 water supply wells in the Lloydminster area," and also included an "investigation of dissolved methane and other hydrochemical species." [10]

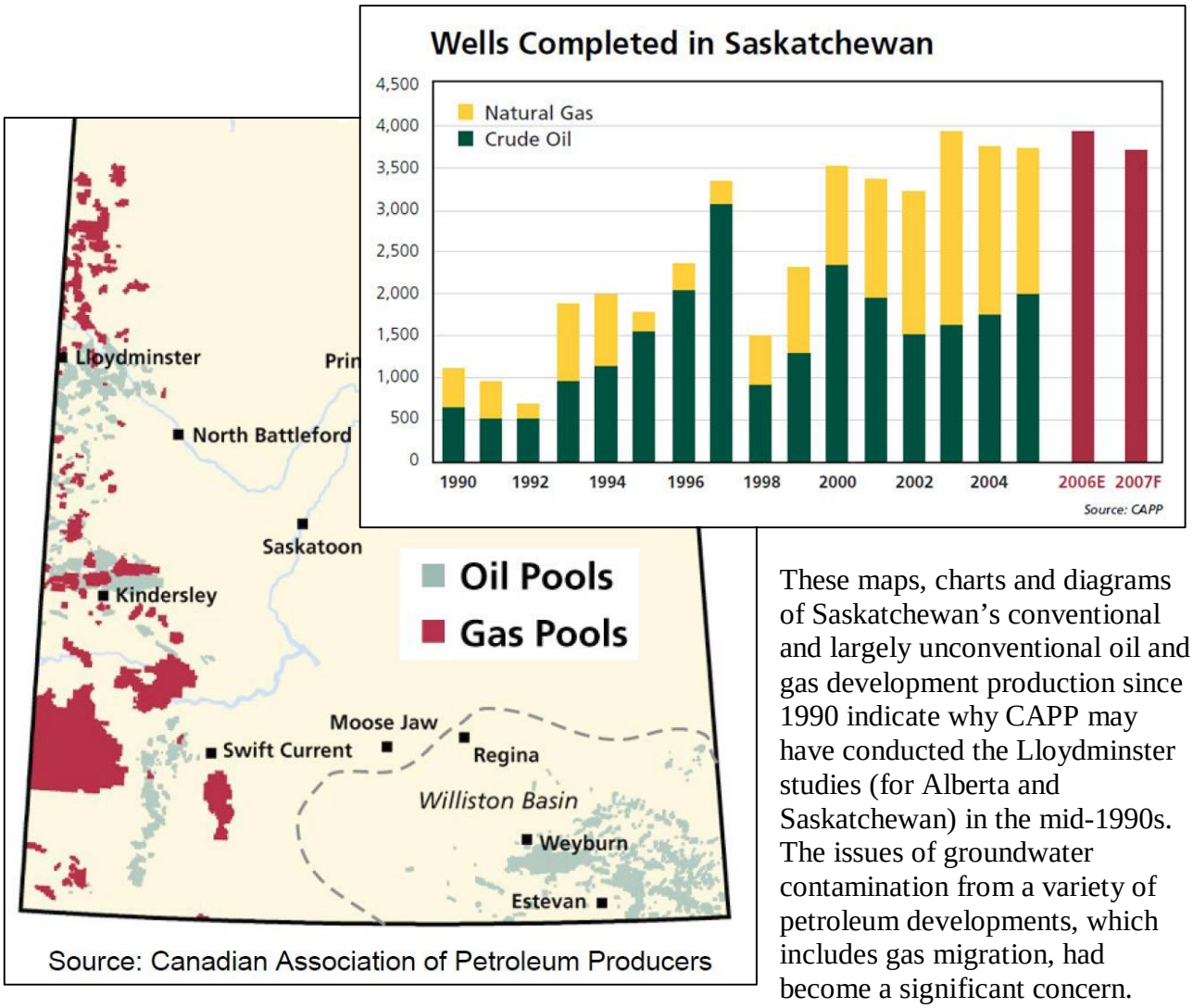
The CAPP gas migration study included a review of approximately 24,000 historic water well records in Alberta. In one of Jessica Ernst's recent public presentations, she states that only 17 of the 24,000 water wells reviewed in the CAPP study "reported "gas" present before oil and gas development." [11] Because the Alberta government's historic data records on water wells show essentially no gas present, and because that data became so significant following the significant numbers of drilling and fracking operations in Alberta since the CAPP study reports in the mid-1990s, Ernst described in her public presentations how the Alberta government later altered the public's historic water well records that were posted on the internet by removing the YES/NO box under the "is there gas present" category.



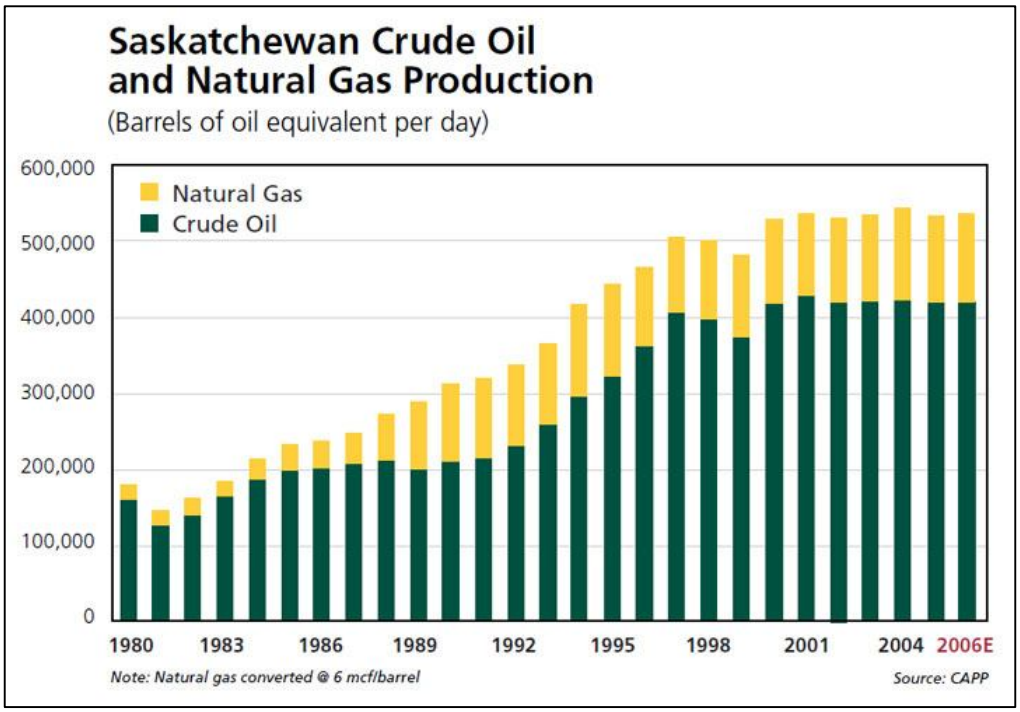
Lloydminster is located on the border between Alberta and Saskatchewan (the horizontal white line in the Google Earth image), directly east of Edmonton, Alberta. The top of this photo points eastward, and Lloydminster is in the middle left of the image. Eventually came the formation of the **Lloydminster Economic Development Corporation**, which, according to its website, "encompasses municipalities in two provinces, Alberta and Saskatchewan," representing "heavy oil and gas reserves." The website also summarizes the history of Husky Oil's refinery, which in 1992 was upgraded at a cost of $1.6 billion, and refines "heavy oil." The website also describes how "the drilling of long, horizontal wells at shallow depth was perfected in the 1980's and the early 1990's in the greater Lloydminster Region."

[10] 'Dissolved methane' means methane gas that is mixed in water. In Alberta, petroleum companies oddly no longer test for dissolved methane as Alberta's regulator, the ERCB, formerly required them to do. For copies of CAPP's 1995 studies, contact CAPP!

[11] *There's a hole in their story*, October 27, 2011, Edmonton.



These maps, charts and diagrams of Saskatchewan's conventional and largely unconventional oil and gas development production since 1990 indicate why CAPP may have conducted the Lloydminster studies (for Alberta and Saskatchewan) in the mid-1990s. The issues of groundwater contamination from a variety of petroleum developments, which includes gas migration, had become a significant concern.



Land Disturbance

Table 9 shows the increase in the number of wells drilled each year from 1995 to 2002; in 1995 a total of 2,092 oil and gas wells were drilled, compared to 3,401 wells in 2002. Adding these annual figures to the total number of wells in existence in the province prior to 1995 provides an estimate of the total number of wells in the province. Prior to 1995, there were an estimated 50,557 oil and gas wells in Saskatchewan.[10] This means that with the 2,092 wells drilled in Saskatchewan in 1995, there were a total of 52,649 wells or wellpads in the province at the end of that year. Assuming one hectare of disturbance for each wellpad, 52,649 hectares of land is

[10] Saskatchewan Department of Industry and Resources. *Mineral Statistics Handbook*, 2001.

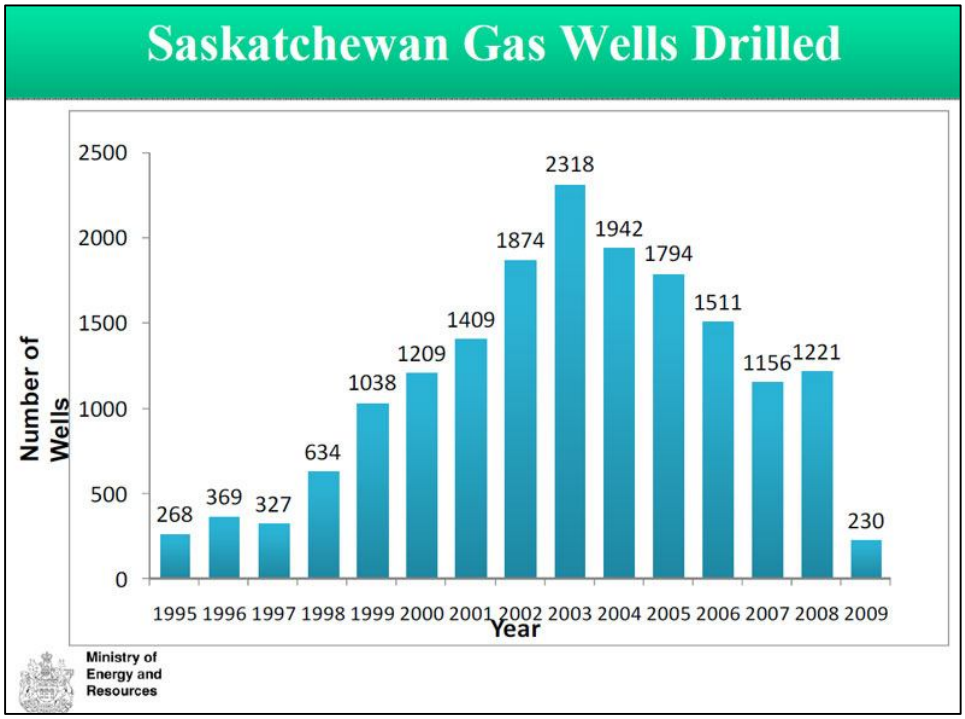
disturbed in Saskatchewan by oil and gas wellpads. Between 1995 and 2002, the footprint associated with wellpads in the province increased from 52,649 to 74,105 hectares. That 41 percent increase in the amount of land disturbed by oil and gas wellpads in the province occurred in just seven years.

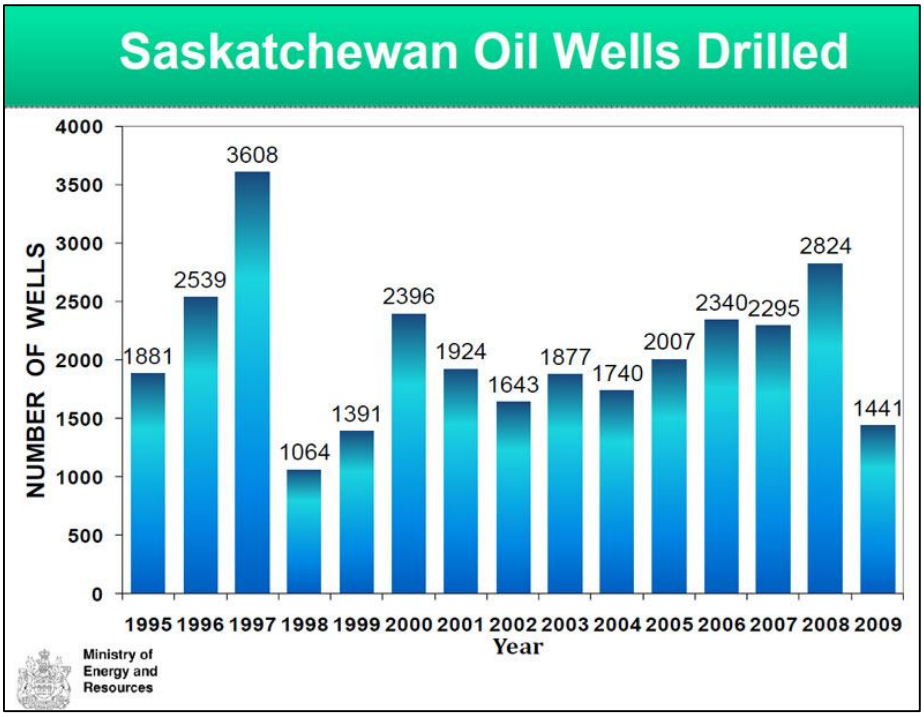
Table 9 Number of wells drilled in Saskatchewan, 1995 to 2002

WELLS DRILLED	1995	1996	1997	1998	1999	2000	2001	2002
Oil	1,550	2,039	3,059	908	1,298	2,330	1,954	1,489
Gas	210	307	248	567	990	1,160	1,372	1,713
Abandoned and Suspended	332	518	525	202	185	210	183	199
Total Annual Growth	**2,092**	**2,864**	**3,832**	**1,677**	**2,473**	**3,700**	**3,509**	**3,401**
CUMULATIVE FOOTPRINT (hectares)	**52,649**	**55,513**	**59,345**	**61,022**	**63,495**	**67,195**	**70,704**	**74,105**

Source: Saskatchewan Industry and Resources, Mineral Statistics Yearbook

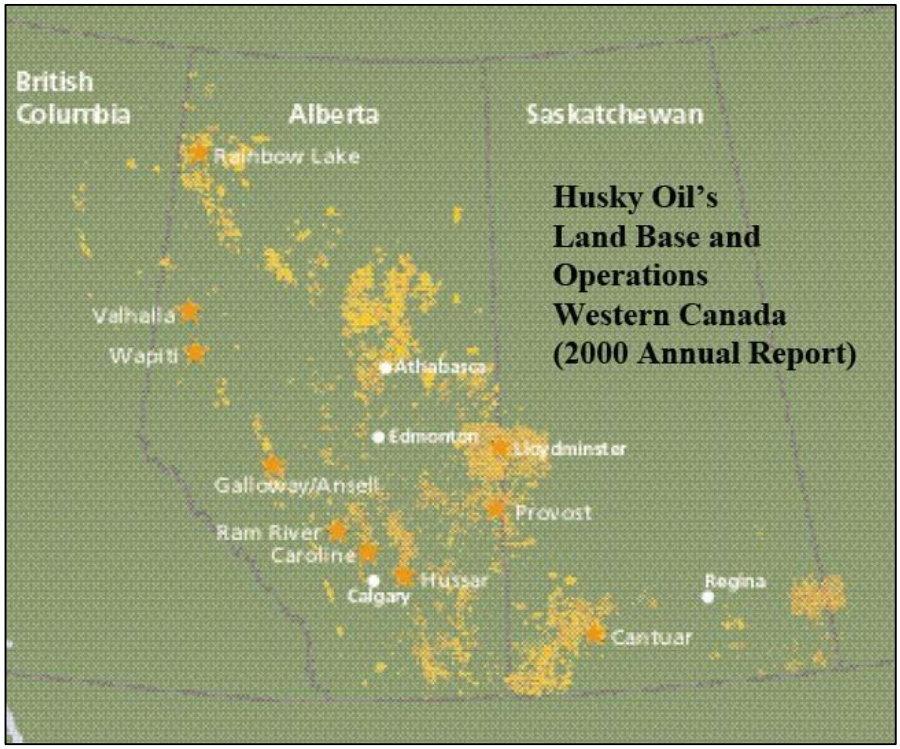
The trend in the table above is expected to continue. Saskatchewan anticipated record drilling activity in 2003, with a total of 3,900 wells drilled,[11] compared to 3,401 wells drilled in 2002. Table 10 shows the total length of all pipelines built in Saskatchewan each year from 1995 to 2002. Prior to 1995, there were 17,837 kilometres of pipelines in the province. Adding this figure to the 1995 figure reveals the total kilometres of oil and gas pipelines in Saskatchewan at the end of 1995: 18,133 kilometres. The cumulative figures in Table 10 demonstrate the expansion of oil and gas pipelines in the province between 1995 and 2002, from a total of 18,133 kilometres in 1995 to a total of 21,125 kilometres in 2002. That is a 17 percent increase in the total kilometres of pipelines in the province over seven years.





14-(3.a). Ron P. Schmitz, P. Carlson, M.D. Watson, B.P. Erno - 1993 Husky Oil Study

About two years before CAPP's Lloydminister studies, one of Canada's former largest petroleum companies, **Husky Oil**, a member of CAPP, conducted an internal, non-peer reviewed research study on methane gas migration. The initial results were published in 1993 for Husky by Schmitz et. al, *Husky Oil's Gas Migration Research Effort - an Update*. Husky's researchers reported that the problems of methane gas migration caused by Husky's wells were substantial, whereby 46 percent of the wells that they tested ***already*** had gas migration. They reported to Husky that it would be too difficult to completely prevent the gas from escaping, and too expensive, too costly to repair. They also found that Husky's deep well bores were leaking biogenic methane ("swamp" gas) to surface. [12]



[12] Jessica Ernst, *There's a Hole in Their Story*, Lethbridge powerpoint presentation, November 24, 2011.

14-(3.b). R.W. Krooyman, M.B. Muir, R.P. Marcinew, K. Bennaceur in Manitoba

About five years before CAPP's Lloydminster studies, a number of researchers, Krooyman et. al., published peer reviewed data in a September-October 1989 issue of the Journal of Canadian Petroleum Technology, *Effective Hydraulic Fracturing of the Lower Amaranth Formation in Southern Manitoba*, concerning the contamination of underground water zones by several petroleum wells in the province of Manitoba. It concerned areas fracked (hydraulic fractured) for oil in southwest Manitoba, in the **South Pierson field**. The authors related that fracking in several oil wells propagated into the underlying water zone. [13]

14-(3.c). Dyck & Dunn in Saskatchewan

About ten years previous to CAPP's Lloydminster studies, a 1986 peer reviewed document authored by Willy Dyck & Colin E. Dunn (with the Geological Survey of Canada), published in the Journal of Geophysical Research, *Helium and Methane Anomalies in Domestic Well Waters in Southwestern Saskatchewn, Canada, and their Relationship to other Dissolved Constituents, Oil and Gas Fields, and Tectonic Patterns*, made a disturbing conclusion about water well contamination by the petroleum industry in the province of Saskatchewan, whereby "methane concentrations were the highest where petroleum industry drill hole density increased." [14] The finding was based on data the authors collected **ten years before their report was published**. In the summer of 1976, the authors conducted a regional groundwater survey of 939 (nine hundred and thirty-nine) water wells and springs over an area of about 18,000 square kilometres in the southwest part of Manitoba. In areas closest to oil and gas wells is where the authors found the highest concentrations of methane.

14-(4). The 1994 Chafin (in the closet) Report

The CAPP Llyodminster 1995-1996 reports apparently relied upon an American federal government report as a general template for its studies (see page 14-15 for excerpts from Phase 2). That document (preceded by a January 1993 Chafin et.al. interim report [15]) was published by the U.S. Geological Survey in 1994 and was authored by Daniel T. Chafin, *Source and Migration Pathways of Natural Gas in Near-Surface Ground Water Beneath the Animas River Valley, Colorado and New Mexico USGS Water Resources Investigations*. [16] The Chafin report is, without question, one of the most important earlier precedent documents researched and published by the U.S. government on underground methane migration caused by and linked to the petroleum industry, and is important as a precursor of Canadian studies by private and public sectors.

In fact, the 'well' researched report - tri-funded in the neighbourhood of $250,000 by the USGS, the oil and gas industry, and La Plata County - became such a source of irritation to both the petroleum industry - even though the petroleum industry had funded it - and to federal and state government agencies because of its stimulating and profound findings, that it was essentially cast into the proverbial closet. For instance, was it sheer coincidence that the EPA's industry-stacked committee in its voluminous final 2004 report, *Evaluation of Impacts to Underground Sources of Drinking*

[13] Ibid.
[14] Ibid.
[15] D.T. Chafin, D.M. Swanson, and D.W. Grey, 1993. *Methane-concentration and methane-isotope data for ground water and soil in the Animas River Valley, Colorado and New Mexico, 1990-91: Interim Report*. USGS, Water Resources Investigation Report 93-4007.
[16] CAPP's reports used part of Chafin's title in their reports, signifying the importance of Chafin's work.

7.3 Methane in Groundwater in Other Oil and Gas Producing Areas

Dyck and Dunn (1986) found methane (and helium) anomalies associated with oil and gas fields in southwestern Saskatchewan. In their 1976 survey of 939 domestic wells and springs, they found that methane concentrations tended to be highest in areas where exploration drill hole density increased, and also had a weak positive correlation with depth of sampling.

Chafin et al. (1993) and Chafin (1994) documented a 1990-91 survey of 203 water supply wells and 2 springs in the Animas River Valley of Colorado and New Mexico. Gas has been produced from various formations in this area for decades. Recent expansion of the development of a coal-bed gas field in this area has led to public concern about "the possibility of increasing concentrations of natural gas in domestic water supplies".

A concurrent survey of soil gas concentrations was conducted, at the groundwater collection sites and adjacent to 352 gas wells in the area. The carbon isotopic composition of methane in a few of the groundwater samples was analysed and compared to data for gas from production wells, cathodic-protection wells and soil adjacent to gas wells in the area. Chafin (1994) concluded that most "shallow" gas in the area is probably derived from deep, thermogenic sources. Chafin did not find evidence for substantial vertical migration of methane by natural processes, including diffusion and fracture transport. He stated that the soil gas data "indicate that gas-well annuli are more important than natural fractures for the upward migration of gas". Chafin concluded that "manmade migration pathways probably introduced most near-surface gas to the study area".

8.0 SUMMARY AND RECOMMENDATIONS

Samples were collected from all available monitoring wells and analysed for methane concentrations and other selected hydrochemical parameters. Elevated concentrations of methane were detected in the aquifers at each site. The levels were typically highest within several m of the production wells.

Excerpts from the March 1996 CAPP Report for Phase 2 (1995)

and a list of all the members in the study

Carbon Isotope Consortium (1994-2000):

Husky Oil Operations Ltd.
Canadian Occidental Pet. Ltd.
Amoco Canada Petroleum Company
PanCanadian Petroleum Limited
Murphy Oil Company Ltd.
Anderson Exploration Ltd.
Ranger Oil Ltd.
Petro-Canada Ltd.
Koch Exploration Canada Ltd.
PetroVera Resources Limited
Imperial Oil Ltd.

Pat Foo (EUB)
Bryan Szatkowski (Gchem)
George Vilcsak (Maxxam)

Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, failed and ignored citing the critical 1994 Chafin report in a separate appendix dedicated to the San Juan fracking basin?

Four years after Chafin's final report was published, the U.S. inter-state Ground Water Protection Council and the Interstate Oil and Gas Compact Commission - while jointly counteracting the LEAF versus EPA litigation [17] working its way through the federal courts - had the cheek and audacity to state to U.S. politicians and the public that fracking was not responsible for contaminating America's groundwater systems.

Other counter-spins ensued shortly afterward in the Colorado/New Mexico professional petroleum contracting network, whereby geologist Steven Finch Jr. wrote a short report in September 1996 saying that it was "impossible" to determine if the petroleum industry was "responsible" for the "methane contamination" cases as reported by Chafin in 1994. [18]

Due to a combination of factors coming to bear by the mid-1990s exposing the highly controversial problems and liabilities of drilling and fracking, the petroleum counter forces began to declare Marshall Law on science and 'evidence' that challenged its unbridled forays into mining North America's unconventional resources as North America's conventional oil and gas reserves were in decline through rapid depletion. By controlling American State and Canadian Provincial regulators, the petroleum complex was hoping to get away with and stall some of the more formidable environmental and health scandals that

Sources and Migration Pathways of Natural Gas in Near-Surface Ground Water Beneath the Animas River Valley, Colorado and New Mexico

by Daniel T. Chafin U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 94-4006

Shallow ground water contains natural gas in parts of the San Juan Basin that are underlain by gas-bearing rocks of Cretaceous age. Domestic water supplies are obtained from aquifers in rocks and alluvium of Tertiary age overlying Cretaceous rocks. Recent development of methane from coal beds of the Fruitland Formation in the San Juan Basin has caused public concern about the possibility of increasing concentrations of natural gas in domestic water supplies. The Animas River valley, one of the most populated areas in the San Juan Basin, is underlain by productive gas fields of the Fruitland Formation and other rocks. In July 1990, the U.S. Geological Survey began a study of the occurrence of natural gas in ground water in the Animas River valley between Durango, Colorado, and Aztec, New Mexico (fig. 1). This study was done in cooperation with the Colorado Oil and Gas Conservation Commission (COGCC), La Plata County, Colorado, and the Southern Ute Tribal Council. Existing data were provided by the New Mexico Oil Conservation Division (NMOCD), the Gas Research Institute, and Amoco Production Company.

The purpose of the study was to identify the sources and migration pathways of natural gas in near-surface ground water in the Animas River valley. The specific objectives of the study were to:

(1) Map the occurrence of methane in near-surface ground water;

(2) Assess the current chemical quality of near-surface ground water and evaluate the potential for upward movement of water containing large concentrations of dissolved-solids; and

(3) Determine possible sources and pathways of migration for natural gas in near-surface ground water.

Sources could include bacterial processes at shallow depths, indigenous thermogenic gas in near-surface aquifers, or thermogenic gas from deep gas-yielding reservoirs. Pathways to the near-surface environment could include upward diffusion through rock pore spaces, migration along natural fractures, leaking gas wells, gas-well annuli, and other manmade conduits.

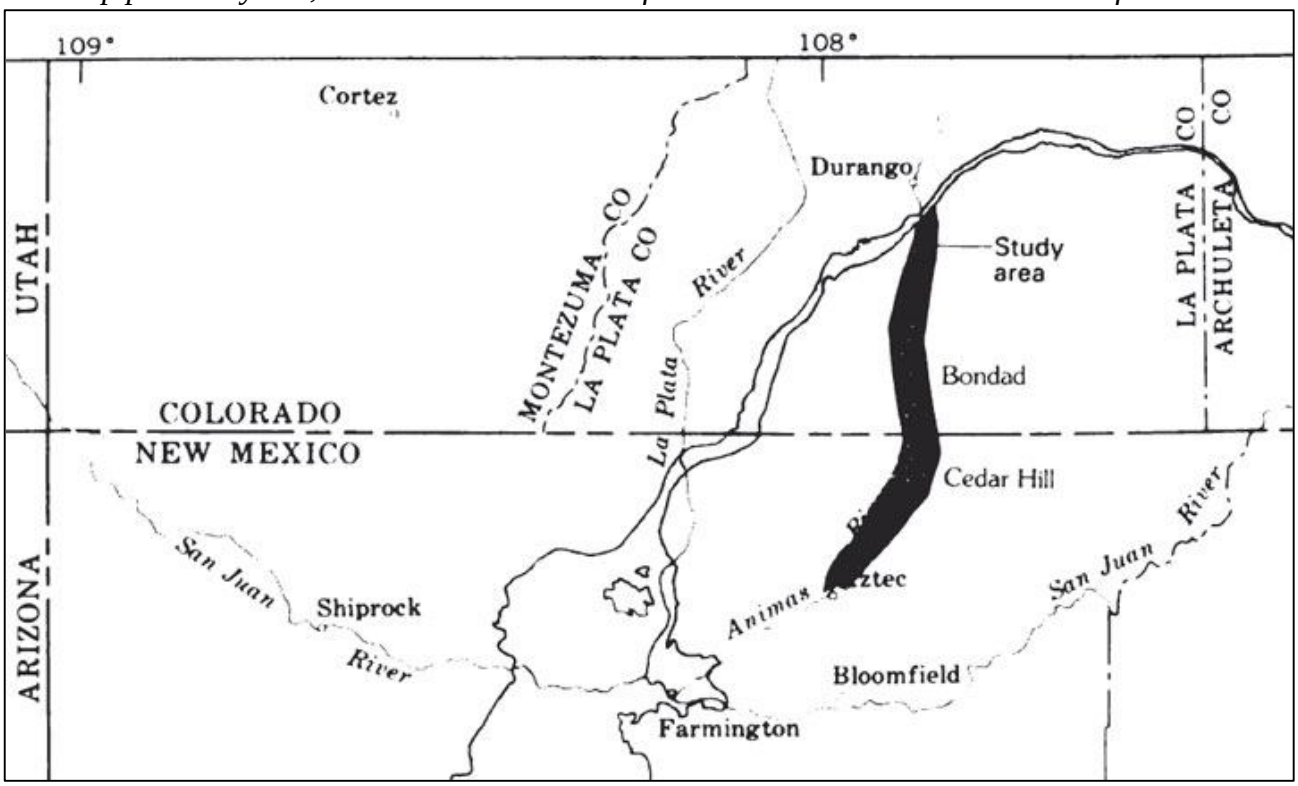
[17] See Chapter 9 of this report for the details.

[18] *Groundwater Issues Related to Coal-bed Methane Production Northern San Juan Basin, New Mexico and Colorado*.

have come to bear in North Petro America. The almighty dollar became the definitive motivation for state and federal tax revenues, for landowner agreements, and for petroleum contractors, in the facilitation of the pro-fracking campaign machine.

The following is a copy of an entire article published in the *High Country News* on April 19, 1993, ***Fouled Water Leads to Court***. [19] It concerns the landowners who had complained to the Colorado and New Mexico State governments and to federal government officials since the 1980s about the unconventional coalbed methane developments in the lower Colorado and upper New Mexico sections of the San Juan coalbed basin:

> *DURANGO, Colo. - After years of futile public hearings, letter-writing and media campaigns, residents of La Plata County in southwestern Colorado have turned to lawsuits and civil disobedience to protect themselves from the impacts of an oil and gas boom. Since 1980, the year Congress approved lucrative tax credits for coalbed methane gas production, U.S. energy firms have drilled over 1,000 wells into coal seams south of Durango looking for pockets of trapped methane gas.*
>
> *The wells are scattered throughout the Animas and San Juan river basins across a checkerboard of public and private land. While the wells have generated profits for oil companies, they have also brought pumpjacks, pipelines, compressor stations, and gravel transport roads to the residents of mostly rural La Plata County - sometimes right to their backyards (High Country news, 12/4/89).*
>
> *But what continues to unite residents there and in neighboring New Mexico counties are accounts of foul-tasting well water, flaming pitchers of lemonade and exploding kitchen pipes. For years, residents on both sides of the border have asked the Bureau of Land*



[19] Other accounts following the litigation were covered in the Durango Herald.

Struggle of 2 towns against pollution detailed in journal

By BOB QUICK
The New Mexican Staff

Monday, July 23, 1990 THE NEW MEXICAN A-3

Air and water pollution from mining and gas drilling were so bad at two rural towns in northern New Mexico that citizens banded to force state and federal government officials help solve the problems.

That's the story in Questa and Cedar Hill as told in the summer issue of *The Workbook*, a quarterly publication of the Southwest Research and Information Center, a non-profit, Albuquerque-based institute concerned with the environment and social change.

Writer Chris Shuey focused on residents of Cedar Hill who have organized to demand a government investigation into the source of coalbed methane gas. They say the gas is ruining drinking water and harming crops in their small town a few miles south of the Colorado border in San Juan County.

Organization also is the key for the citizens of Cedar Hill, a small town along the Animas River four miles south of the Colorado state line.

Private wells are common there and so is alfalfa, a hay crop grown by many of the farmers in the area.

Unfortunately, according to author Shuey, both the water wells and the alfalfa aren't what they used to be because a recent surge in boring for methane gas has caused natural gas to bubble up into water supplies and fields.

The natural gas comes from what is known as the Fruitland Formation, coal beds 2,800 feet under the town. Its concentration is so strong it kills alfalfa and makes well water smelly and oily, Shuey said.

The author said the gas even caused a water well to catch fire. The level of natural gas is so high in some wells that they could explode, Shuey said.

The gas buildup wouldn't have happened if thousands of new wells hadn't been drilled to tap methane in the coal beds, Shuey said. The natural gas migrates to the surface along the uncemented portions of the methane wells, Shuey said.

Residents of the area became so concerned about the problem they formed the Cedar Hill Clean Water Coalition and asked the state Oil Conservation Division and the Environmental Improvement Division to conduct a "water fair" to test water supplies.

Management, the Forest Service and the Colorado Oil and Gas Commission for tougher regulations, arguing that gas production is polluting their wells and drinking water. So far the agencies have refused to slow the boom.

Recently, the growing coalition of residents and environmentalists ***found an ally in a U.S. Geological Survey draft report released earlier this year****.*[20] *In a two-year study, USGS scientists found methane gas in one-third of water wells inspected and concluded that oil and gas drilling is the main source of contamination of the shallow aquifers in the Animas River Valley.*

*Western Colorado Congress president Jerry Swingle says the report shows that "****the industry isn't anywhere near as competent in preventing that kind of contamination as they have led everyone -including regulators - to believe****."*

Based in part on the USGS report, lawyers representing hundreds of area residents filed a class-action lawsuit Feb. 11 charging four oil companies - Amoco Production Company, Meridian Oil Inc., Southland Royalty Company, and Phillips Petroleum - with recklessness and deliberate disregard for the safety of local residents. The suit says the four oil companies ignored their tests, which showed that methane from their deep wells was polluting shallow aquifers, and asks for both actual and punitive damages. A victory could result in strict new controls on oil and gas drilling, well maintenance and groundwater monitoring.

"You're not looking at a bunch of hippies who live out in the wilderness or Earth First'ers who have come in to file this lawsuit," says Chris Shuey, a water resources specialist who acted as a technical consultant for the residents. "These are people who have lived there for generations and some of them work or have worked in industries associated with the oil and gas industry. I think they felt litigation was the last avenue available to them."

However, both the oil companies and the BLM, which regulates oil and gas drilling on public lands, say they think the methane migrates into upper aquifers naturally through cracks and fissures underground.

20

Selected Previous Studies

The presence, origins, and effects of natural gas in ground-water systems has been described and evaluated by several investigators. Water levels of water wells near Houston, Texas, increased during 1942-44 because of a leaking gas well (Rose and Alexander, 1945). Water-level rises of 4 to 61 ft were measured at distances of 1.5 to 11.7 mi from the gas well. Some water wells produced gas with water and, in extreme cases, the ground around casings was eroded by the forceful venting of gas (cratering). The authors concluded that serious damage could be caused to water wells in Houston if gas wells near the city became defective and gas entered water-bearing sands.

They say the USGS report is a product of bad science and bias. *"We are somewhat disturbed," the BLM responded in written comments, "that several apparent contradictions are present and many conclusions are drawn based on what could arguably be characterized as inconclusive data."*

"We are also concerned that, to a certain degree, the tone of the document seems to lack objectivity," said the agency's district manager, Sally Wisely, in a letter.

The USGS, which was hired in a 1989 compromise among the various parties to the dispute as a neutral investigator, stands by its research. *"I find (the BLM's comments) really peculiar," says USGS district director David Lystrom. "**We're both Department of Interior agencies. What axe are they grinding?**" Lystrom says his agency stands by its report, and will issue a final document within a year.*

Local residents and environmental groups say the BLM's reaction reflects a long-standing refusal to trust evidence linking rising numbers of methane-contaminated private wells with the gas boom.

Seepage of large quantities of natural gas over an unpopulated area of about 0.9 mi^2 in a gas-well field in northwestern Oklahoma was described by Preston (1980). Analyses of seepage and produced gases caused the author to suspect that a faulty gas well caused the seepage.

*Residents have also battled with the U.S. Forest Service, most recently over the agency's decision to allow **Amoco** to drill 15 wells on environmentally sensitive lands in the HD Mountains on the eastern edge of La Plata County.*

Last September, the Forest Service closed the drilling area to the public after Western Colorado Congress and the San Juan Citizens Alliance blockaded and shut down Amoco's drill rigs. After a second protest, which drew 80 people, the Forest Service charged eight people with criminal trespass.

A biogenic source for methane in near-surface (308 to 400 ft deep) ground water in bedrock in Weld County, Colorado, was concluded on the basis of carbon-isotope data (Rice and Threlkeld, 1982). Rice and others (1984) determined that thermogenic gas was seeping to the surface at LaSalle, Colorado, and believed that deep, abandoned water wells were the conduits for upward, near-surface migration but were not able to conclude whether the gas migrated from the producing formation at about the 7,000 ft depth because of natural phenomena or drilling activities.

In a January trial, two women, including a San Juan Alliance organizer, were found guilty and fined $250. However, Judge Edward Schlatter said he was troubled by the verdict. Protesters had intended the rally to be peaceful and legal at all times and, he believed, did not know they were across the closure line.

*"**The Forest Service acted as a publicly financed security force for Amoco**," says Western Colorado Congress' Swingle. "The decision to prosecute was motivated not by justice, but was intended as punishment, intimidation and a clear message to all citizens that dissidents will not be tolerated."*

The comment by Western Colorado Congress [21] representative Jerry Swingle about the U.S. Forest Service backing the petroleum industry is a critical insight into the corruption history of the Service. Ever since the President Eisenhower years in the early 1950s, the post-war years, the U.S. Forest Service took on a new face and became ever-more less the spokesman of conservation and the protector of drinking water sources and more and more the agent of big business out to clear cut federal public lands, a scandal-ridden history. One of the least understood and least academically researched topics in the U.S. on public forest land resource issues concerns how the Forest Service became instrumental in the demise of a few thousand of the Nation's protected drinking watershed sources. [22] In this sense, the concurrent thematic intrigue with the Forest Service and the demise of drinking well water with the petroleum sector, particularly following the President Reagan Republican years in the 1980s and the erosion of federal environmental policies and regulations.

The effects of a leaking gas well in Ohio on ground-water chemistry were studied by Kelly and others (1985). They reported that elevated methane concentrations were accompanied by elevated concentrations of iron, manganese, calcium, sulfide, alkalinity, and pH and by decreased concentrations of dissolved oxygen, sulfate, and nitrate. These investigators report that homeowners complained about an intense sulfide odor, increased iron concentrations, and staining of commodes with a black precipitate.

Gas-composition data from a variety of sources in the Animas River valley between Bondad, Colorado, and a few miles south of Aztec, New Mexico, were reviewed by Shuey (1990). He concluded that about half of the samples from domestic water wells and seeps in fields and the river contained gas from the Fruitland Formation that had migrated up uncemented intervals of *conventional gas wells* after initial dewatering of *coal-bed gas wells* completed in the Fruitland Formation.

The litigation which ensued, based initially on the preliminary or draft report that was published by Chafin et al. in January 1993, evolved through four jurisdictional courts over a period of almost five years, until matters were eventually settled out of court for most of the lawsuit landowners: La Plata County District Court; the United States District Court for the District of Colorado; the United States District Court in Albuquerque (New Mexico); the court for the sovereign Southern Ute Indian Tribe.

There were at least two fronts of citizen group concerns by as early as 1989 in the U.S. concerning tainted waters in the early development stages of fracking coalbed methane: in Alabama and in New Mexico/Colorado. And, as described in an article published in the New Mexican newspaper on July 23, 1990, rural residents were already the forerunners and precursors of what Josh Fox made famous in his 2010 documentary, *Gasland*, the frightening ability to ignite coalbed methane fracked tap water on fire!

Gases in ground water, from a surface seep, from *cathodic-protection wells*, and from gas-well *surface casings* in the Cedar Hill, New Mexico, area were studied by Beckstrom and Boyer (1991). They could not determine the specific sources of gases in ground water and determined that the surface-seep gas was thermogenic gas from an unspecified source. Beckstrom and Boyer (1991) determined that the gas in three surface casings migrated from the Fruitland Formation and moved up *annuli* of conventional gas wells that were not cemented across coals of the Fruitland Formation.

[21] The Western Colorado Congress is an association of six community groups, which is affiliated with the Western Organization of Resource Councils (www.worc.org).

[22] For a summary discussion, see Chapter 10, *The Bull Run Watershed Reserve and the United States Supreme Court*, in *From Wisdom to Tyranny: A History of British Columbia's Drinking Watershed Reserves*, by Will Koop, May 21, 2006.

Of the four petroleum companies named in the February 1993 lawsuit launched in La Plata County, **Amoco** was also operating in Canada, in the provinces of Saskatchewan and Alberta. Wikipedia reports that "by 1970, Amoco had become one of the largest integrated oil corporations in the world through acquisitions and internal growth," that "its oil and gas activity was concentrated in the US southwest and in western Canada," and that its Canadian operations were headquartered in Calgary, Alberta. [23] Was Amoco in some way involved in CAPP's Lloydminster report studies in the mid-1990s? What were the political petroleum connections and concerns between the petroleum operations in New Mexico/Colorado and Alberta/Saskatchewan?

The La Plata area citizenry lawsuit case was becoming well-known within the petroleum sector, particularly by its legal firms. Shortly after the release of Chafin's draft in early 1993, James A. Beckstrom with Amoco Production Company co-authored an article with David G. Boyer, *Aquifer-Protection Considerations of Coalbed Methane Development in the San Juan Basin*, which was published in the Society of Petroleum Engineers Journal. The 'word' about gas migration and groundwater contamination was quickly being broadcast to the petroleum world, particularly as the LEAF versus EPA litigation was about to take off in 1994.

There was a period of boom in the San Juan Basin from 1950 to 1953 (Matheny and Ulrich, 1983). In 1950, additional gas-bearing zones were discovered in the Fruitland Formation, Mesaverde Group, and the Dakota Sandstone in Colorado. The completion of a natural-gas transmission line from the San Juan Basin to the west coast of the United States in 1951 greatly enhanced development, and substantial accumulations of gas were discovered in 1952, especially in the Mesaverde Group. Development and exploration continued at a more moderate pace during 1954-75 when most conventional gas wells were completed in the study area. The rate of development escalated during 1976-81 after the New Mexico Oil and Gas Commission authorized the drilling of a second well in the Mesaverde Group in each 320-acre producing unit in 1975 and the completion of additional wells in the Dakota Sandstone in 1980. The Colorado Oil and Gas Commission authorized the completion of additional wells in the Mesaverde Group and Pictured Cliffs Sandstone in 1979. These authorizations quickened the development rate, which was greatly enhanced by the 1976 issuance of a sharp price increase for interstate gas sales by the Federal Power Commission. Conventional completions decreased after 1981 because of the nationwide surplus of natural gas.

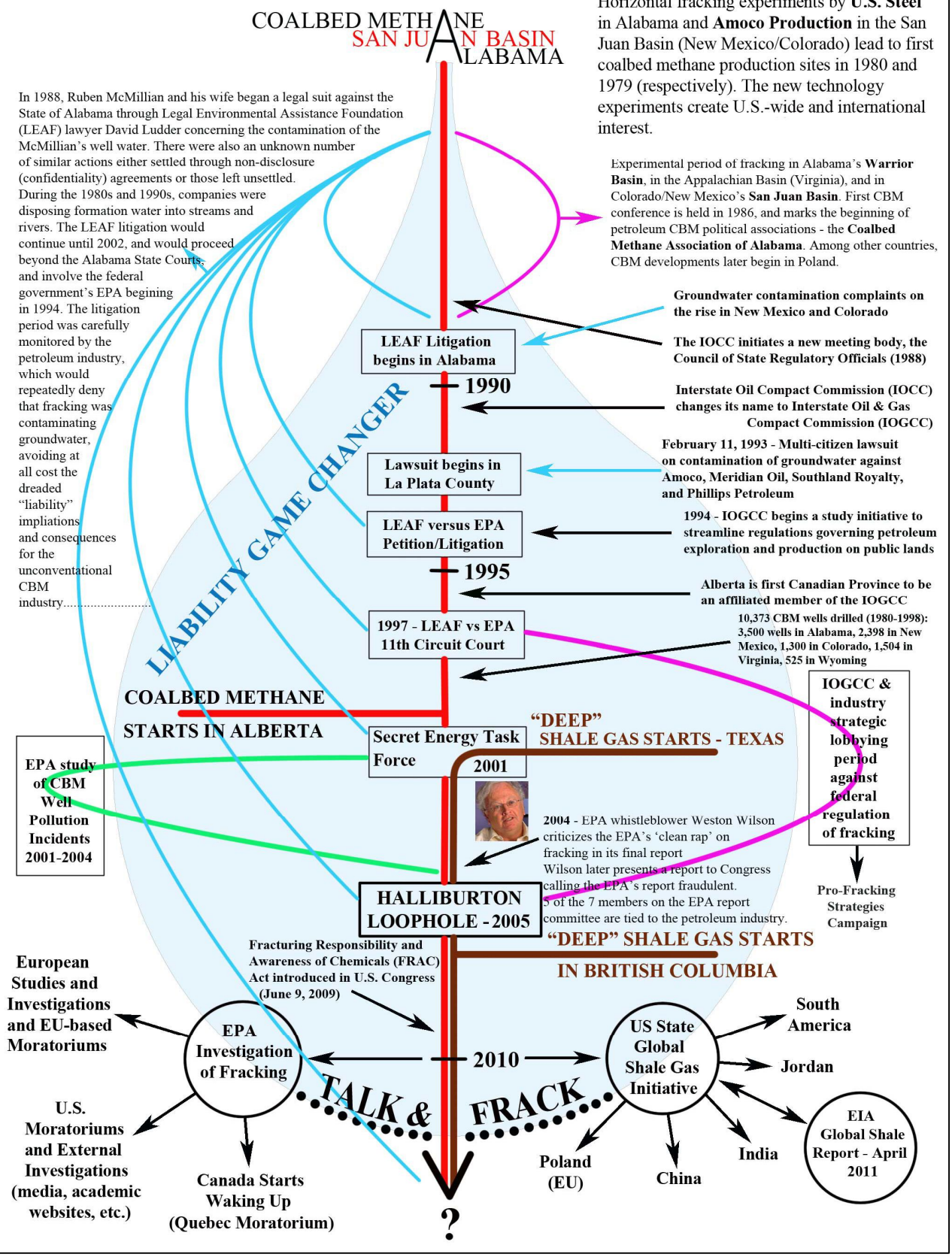
Intensive development of methane from coal beds of the Fruitland Formation began in the mid-1980's in response to tax credits authorized by the Crude Oil Windfall Profits Tax Act of 1980. Originally scheduled to last through 1990, those credits were extended through 1992. Coals in the Fruitland Formation in the Cedar Hill area were the first to be studied and developed. The Gas Research Institute (1991, p. 6) estimated that, at the end of 1990, about 1,000 coalbed-methane wells in the Fruitland Formation had a cumulative production of about 100 billion ft^3 of gas, primarily in the north-central part of the basin.

Fractures were mapped between Bondad and a few miles south of Cedar Hill and fractures were correlated with water wells containing methane (Steven T. Finch, John W. Shomaker, Inc., written commun., 1992). The results indicated a weak, negative correlation between fracture density and the number of water wells containing methane and relatively strong, positive correlations between (1) the numbers of gas wells and water wells containing methane; and (2) the numbers of structural folds and water wells containing methane.

Amoco was also the stage manager with a host of other parties in an ugly, complex and lengthy litigation battle that began in early 1992 against the Ute Indian Tribe which has Reservation lands within the San Juan coalbed methane basin, litigation which ended in 1999. The petroleum industry, along with the help of government, seemed to be a giant steamroller, out to flatten any obstacle in its path to obtain the grand methane prize.

[23] Wikipedia, *History of the Petroleum Industry in Canada (Natural Gas Liquids).*

UNCONVENTIONAL FRACKING TIMELINE - U.S. HISTORY



Reported in the Washington Post on April 12, 1990, *Long Feared, Methane Now Valued; Technology, Tax Credits make use of Coal-Bed Gas as Fuel Feasible*, Amoco invested "$90 million in a network of wells, pipes and compressors that covers thousands of rugged, deep pine areas in Jefferson County," Alabama. According to biography information posted on the internet by a team of experienced geologists called *The Unconventionals*, two trained geologists, Ed Robbs and Jeff Roberts, were responsible for evaluating the "exploration potential for numerous U.S. basins for Amoco Production Company," where Roberts credits himself as being "the first geologist to evaluate the unconventional potential of coalbed methane of the Black Warrior Basin for Amoco," and being "an expert in the evaluation of fractured reservoirs, horizontal exploration prospects, basin tectonic analysis, and exploration economic analysis."

An account in the March 2000 edition of AAPG's Explorer magazine, *Coalbed Methane Comes of Age*, by way of an interview with Denver, Colorado consultant Keith Murray, states that while U.S. Steel pioneered exploration of coalbed methane on its private lands in Alabama in the late 1970s, Amoco Production also conducted concurrent pioneering experimental development of CBM in the San Juan Basin "in 1977-1978 at the Cedar Hill Field," and that "that first field came on line in 1979." In other words, Amoco was there at the very beginning with U.S. Steel experimenting with coalbed methane fracking. Amoco also entered into a contractual relationship with U.S. Steel on U.S. Steel's Alabama lands. It was reported that the Amoco Production Co. had leased 40,000 acres of land from USX Corp. (U.S. Steel). [24]

Relation to Age of Gas Wells

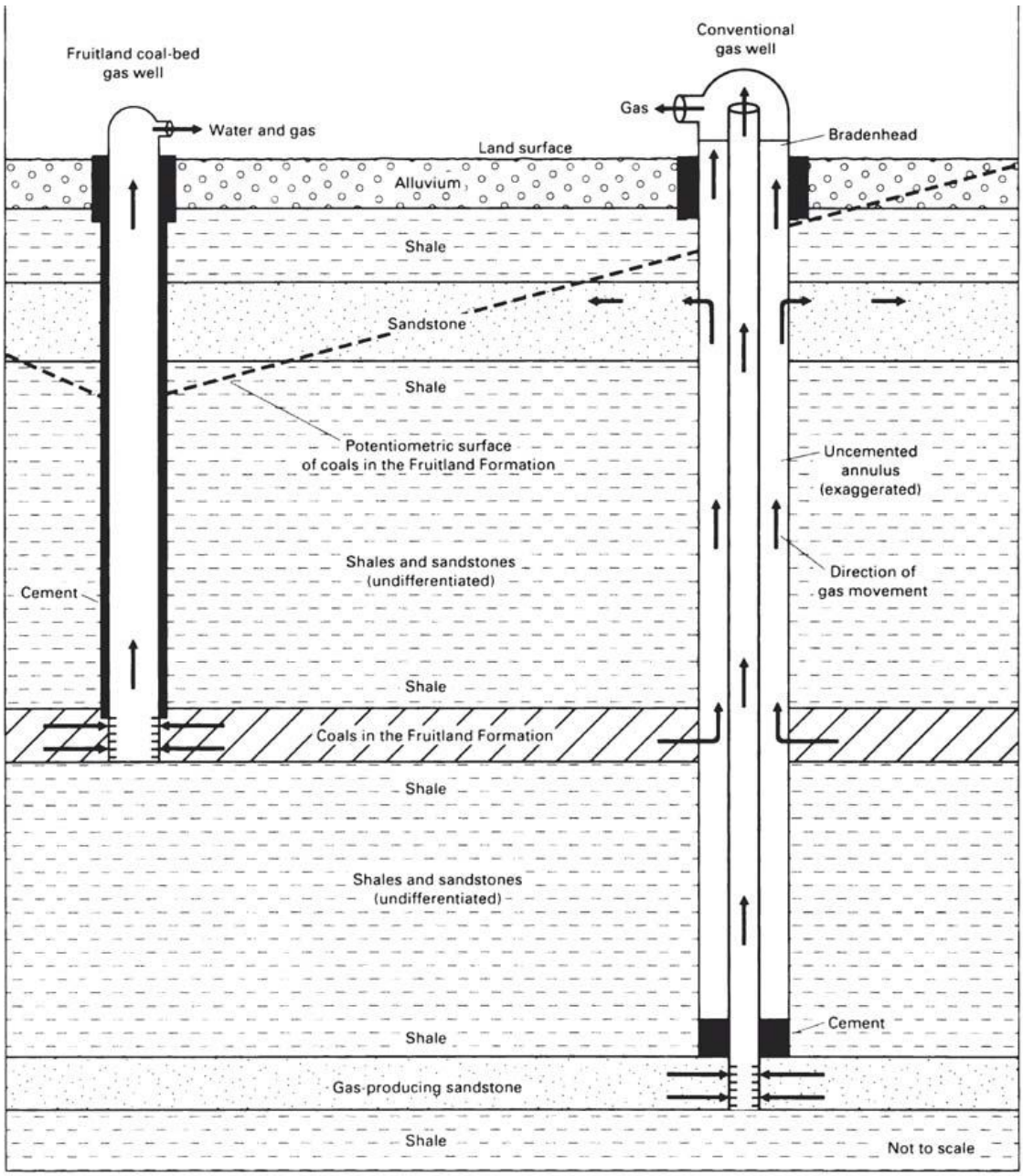
To determine whether soil-gas-methane concentrations have some relation to the age of gas wells, soil-gas measurements were divided into two groups on the basis of the completion year of the wells. Those gas wells completed during 1937-76 were compared to those completed during 1977-90 to divide the data into two nearly equal parts. Summary statistics for these two groups are listed in table 2, and side-by-side box-plots are shown in figure 10.

Gas wells completed during 1937-76 have a greater mean soil-gas-methane concentration (32 mg/L_g) than do gas wells completed during 1977-90 (25 mg/L_g). However, by not including the 1,200-mg/L_g concentration for the gas well at 33N-09W-31CCD from the 1937-76 group, the mean would be 26 mg/L_g. The 1977-90 group had a greater 75th-percentile value of 0.3 mg/L_g compared to 0.03 mg/L_g and had slightly greater percentages of concentrations equaling or exceeding 0.005 and 10 mg/L_g

Amoco also made a number of other joint venture agreements in Alabama that included Energen Corp. and Taurus Exploration.

In Peggy Hocutt's famous fracking letter to New Mexico Senator Jeff Bingamen, she identifies Amoco as the company that allegedly contaminated her, and her neighbour's, Jefferson County well water, which resulted in her being hospitalized and her ill health ever since: *Our problems started when **The State Oil & Gas Board**, Tuscaloosa, Alabama, issued Permit #5946-C., to **USX-Amoco Oil Production**, in September, 1988.* [25]

[24] *County to be hotbed for methane drilling*, Tuscaloosa News, January 5, 1989.
[25] See chapter 9-(1), *Alabama's Unconventional Legacy*, for Hocutt's letter.



Chemical and geological evidence suggests that substantial quantities of natural gas are not migrating from deep gas-bearing formations along natural fractures into the shallow subsurface environment beneath the study area. Comparisons between soil-gas-methane concentrations measured adjacent to 352 gas-well casings and 192 ground-water sites used as background measurements indicate that gas-well annuli are more important than natural fractures for upward migration of gas.

Manmade migration pathways probably introduce most near-surface gas to the study area. Primary migration pathways consist of 1) leaking, conventional gas wells and 2) uncemented annuli of conventional gas wells along coals in the Fruitland Formation. Uncemented annuli along sandstones in the upper Fruitland Formation and Kirtland Shale introduce less gas than coals in the Fruitland Formation because these sandstones are not substantially charged with gas, except locally. Secondary migration pathways consist of gas-well annuli, cathodic-protection wells, seismic-test holes, and bedrock water wells. Of these, gas-well annuli are the predominant secondary migration pathway because leaks from gas-well casings and from uncemented, gas-yielding coals and sandstones occur within them and because of their great number and depth.

Fascinating diagram from Chafin's 1994 report. It illustrates the complex interrelationships of methane migration between nearby older conventional and new unconventional well bores.

Chafin found that subsurface gas migration was **not caused by mother nature**, but by human nature. It was not natural, **it was unnatural**, and, through recent coalbed methane drilling and fracking, unconventional.

Primary migration pathways consist of leaking, conventional gas wells, and uncemented annuli of conventional gas wells through coals in the Fruitland Formation. Numerous examples of leaking, conventional gas wells in the study area are documented by COGCC and NMOCD records. Most such leaks are caused by either corroded or mechanically ruptured production casings or defective wellhead seals, which permit gas to leak from production casings into surface casings. Both types of leaks release gas into the uncemented annuli of gas wells, which are exposed to bedrock sandstones (fig. 23).

The second primary migration pathway for thermogenic gas in the study area is uncemented annuli of conventional gas wells through coals in the Fruitland Formation. Uncemented sandstones in the upper Fruitland Formation and Kirtland Shale can cause similar gas leakage into gas-well annuli, but these uncemented sandstones are less important pathways because they are not substantially charged with gas except locally. Coals in the Fruitland Formation are dewatered by pumping to promote desorption of gas from the coal matrix (Fassett, 1989, p. 133-134). Pumping induces a drawdown of the potentiometric surface in the coal around the well in the Fruitland Formation. Eventually, this lowered surface reaches offset conventional gas wells, and those wells without cemented annuli through the coals in the Fruitland Formation provide conduits for upward flow of desorbed gas (fig. 24). Beckstrom and Boyer (1991, p. 376) concluded that this process caused the accumulation of gas in the bradenheads of three conventional gas wells in the Cedar Hill area in 1989.

Manmade Conduits

Discussions in the section "Analysis of Isotopic and Molecular Composition of Gases from Water, Soil, Gas-Well Casings and Cathodic-Protection Wells" suggest that most occurrences of near-surface natural gas are related to conditions associated with gas wells. Given the previously described factors that are unfavorable for diffusion and natural-fracture migration pathways from deep gas reservoirs to the near-surface environment, it is reasonable to conclude that man-made migration conduits introduce most near-surface gas to the study area. For purposes of discussion, man-made migration pathways can be divided into 1) primary pathways, which transport gas from source formations to the subsurface environment, and 2) secondary pathways, which transport gas from primary pathways to the near-surface ground water and soil.

Chemical and geological evidence suggests that substantial quantities of natural gas are not migrating from deep gas-bearing formations along natural fractures (joints and faults) into the shallow subsurface environment beneath the study area. Comparisons between soil-gas-methane concentrations measured adjacent to 352 gas-well casings and 192 ground-water sites (used as background measurements) indicate that gas-well annuli are more important than fractures for upward migration of gas. If natural fractures were the important conduits for upward migration, greater soil-gas-methane concentrations probably would be measured at some of the ground-water sites located on or near major fracture zones. The relatively systematic vertical and north-south variation in produced-gas maturities for formations beneath the study area argues against substantial vertical migration of gas and for effective trapping near source rocks.

2005 photo of the remains of a house after it exploded from underground methane. The photo was used in an undated powerpoint presentation by the San Juan Citizens Alliance, *Methane Migration from Seeps and Abandoned Wells.* The presentation cites a 1995 report, *Pine River Investigative Team Report,* summarizing: "explosive levels of methane have been found both inside and outside homes along the Fruitland Formation outcrop." The presentation cites concerns about: improper casing or cementing; damaged casing or cementing; orphan wells (many old wells lack proper casing or cementing); deterioration of casing or cementing over time.

14-(5). Post Chafin: The New Bradenhead Policies

Because of public complaints to government emanating from landowners and ranchers in New Mexico and Colorado in the 1980s, and shortly after Chafin et. al. began studying methane migration in the San Juan Basin around 1990, the U.S. Bureau of Land Management (BLM) "aggressively pursued bradenhead testing" beginning in 1991. [26]

> *The Colorado Oil and Gas Conservation Commission issued "Rule 10 of Order 112-85" also requiring annual bradenhead testing of all gas wells under State of Colorado Jurisdiction in the Ignacio-Blanco Field of Colorado. Since 1991, bradenhead testing has been an integral part of BLM and COGCC efforts to remediate gas wells which have exhibited excessive pressures indicating potential for ground water contamination and/or natural gas resource loss.* [27]

The BLM is America's big agency in charge of federal land planning and land use permitting. As stated in its 2007 report, "bradenhead testing has been instrumental in identification of defective gas well-bores." [28] The legacy and rapid drilling into Mother Earth was creating administrative nightmares for government agencies responsible for watching over the petroleum industry, particularly as citizens in the San Juan fracking Basin area began investigating and calling for accountability. Beginning in 1994, BLM began publishing information reports on its San Juan bradenhead monitoring program.

> *Gas wells within designated "**critical**" groundwater areas (Areas constituting an approximate 1 mile buffer zone surrounding domestic wells where methane has been detected in higher concentrations than 1.0 mg/L in 1994 and 1995) are targeted by BLM for remediation when bradenhead pressures exceed five psig. In all other non-designated areas the bradenhead pressure action threshold is 25 psig. Wells with less than these threshold bradenhead pressures, but which exhibit sustained measurable flow throughout the 30-minute test period, and wells with bradenhead valves issuing a fluid flow are also subject to remediation.*
>
> *The bradenhead testing program is loosely associated with groundwater quality monitoring of La Plata County domestic water wells. As a result of BLM and COGCC testing of domestic water wells in the San Juan Basin of Colorado, 17 areas of critical concern have been identified. The Critical Areas show anomalously **high concentrations of methane** entrained in groundwater or are of critical concern because of proximity to the **HD Mountain Area** or the **Tiffany Enhanced Coal Bed Methane Recovery** area. The gas signature (relative amounts of gas constituents and carbon isotope ratios) of the methane gas can indicate whether the gas is of shallow biologic generation, alteration of existing soil gas, or a possible gas well leak. The HD Mountain and Bondad/Sunnyside areas were specifically targeted in 1996 for domestic water well testing to determine the effectiveness of gas well remediation. Locations of continuing concern were identified where measurable bradenhead pressures and entrained methane in groundwater persisted. In 1998 the BLM and the COGCC combined efforts to retest areas not addressed in 1996. Water wells tested*

[26] *2005 Bradenhead Testing and Comparison with Prior Data*, Bureau of Land Management, San Juan Resource Area, May 2007.
[27] Ibid.
[28] Ibid.

in 1998 were selected particularly in the proximity of remediated gas wells. Water wells with elevated baseline concentrations of methane and having methane stable carbon isotope ratios greater than -55 per mil (thereby indicating possible thermogenic signatures and association with natural gas producing horizons) were targeted. Water wells with lower baseline methane concentrations, but in proximity to remediated gas wells, were also tested. The results of monitoring in calendar year 2000 indicated that methane contamination of water wells was decreasing, presumably in response to remedial actions of potentially defective well-bores. The findings continue to direct remediation efforts toward identifying potentially defective gas well-bores. Ongoing monitoring of groundwater is also being conducted. [29]

Earlier BLM reports have presented the following results:

Bradenhead Testing and Groundwater Protection Program Overview and 1992 Results
This report discussed groundwater protection and the results of 1992 testing. In summary, 37 percent of jurisdictional gas wells tested showed bradenhead pressures exceeding 0 psig, and 10 percent had pressures greater than 25 psig.

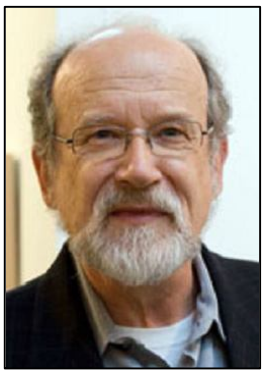
Dissolved Methane Concentrations in Groundwater, La Plata and Archuleta Counties, Colorado
More than 200 domestic water wells within the Ignacio-Blanco Field were tested by the BLM during 1993. Relatively high concentrations of methane gas were discovered in 13 geographic areas of La Plata County. Within these 13 areas, gas wells with measurable bradenhead pressure received high priority as remediation candidates.

1993 Bradenhead Testing Program Overview and Test Results
Bradenhead test results for calendar year 1993 were presented. Gas production related potentials for shallow aquifer contamination were discussed. In summary, 29 percent of jurisdictional gas wells had pressures exceeding 0 psig, and 9 percent exhibited pressures greater than 25 psig.

Final Report - 1994 Groundwater Monitoring, San Juan Basin, La Plata County, Colorado Comprehensive Infill Testing
This cooperative report released by the BLM and the COGCC, produced water quality measurements from 383 domestic water well sites in La Plata County, supplementing the 1993 BLM water study of 200 wells. A groundwater quality baseline was established. Redefining and expanding the 13 areas depicted in the 1993 study, a total of 17 areas with relatively high concentrations of entrained methane-in-water were delineated by diminishing methane concentrations and apparent isotopic transitional zones. Data regarding wells coincident with those tested in the 1994 BLM/COGCC testing was incorporated from the 1990 USGS study of water wells in the Animas River Valley, and from data listed in the Ignacio-Blanco Groundwater Task Force study of 1991. The 17 areas were further defined by carbon isotopic analyses that suggested biogenic or thermogenic origins of the entrained methane. [30]

[29] Ibid.
[30] Ibid.

14-(6). Maestro Muehlenbachs Measures the Mix of Man-Made Migrant Molecules Making Much Mischief



Asked if Alberta's oil patch regulator or B.C.'s Oil and Gas Commission had approached one of the world's leading experts on how to fingerprint leaking gases from gas formations, Muehlenbachs replied quickly. "No," said Muehlenbachs. "No one pays any attention to me. The Alberta regulators are only interested in optimizing production."

On the University of Alberta's website, under the Department of Earth & Atmospheric Science, it states that professor "Dr. Karlis Muehlenbachs specializes in using stable isotope variation in many aspects of geochemistry, e.g. history of seawater, isotopic paleoclimate proxies, oxygen diffusion in minerals, contamination of groundwater by natural gas, and in-situ steam-assisted heavy oil extraction." There is also a long list of 373 publications he has authored, co-authored, and participated in, publication dates ranging over a span of forty years, from 1971 to 2011.

On November 14, 2011, Muehlenbachs appeared as a speaker at a Resources for the Future's (RFF's) conference event in Washington, D.C., *Managing the Risks of Shale Gas: Identifying a Pathway Toward Responsible Development*. The U.S. conservative think tank event was part of RFF's *Center for Energy Economics and Policy*'s recently formed 2011 initiative on the "responsible development" of shale gas. The event, which was audio and video broadcast, was perhaps the first time that one of Muehlenbachs' usual in-house presentations was broadcast, and his summary professional findings and views on the petroleum industry's operations made digitally public. That resulted in great public interest in what the professor said and the visuals he presented, particularly in Quebec.

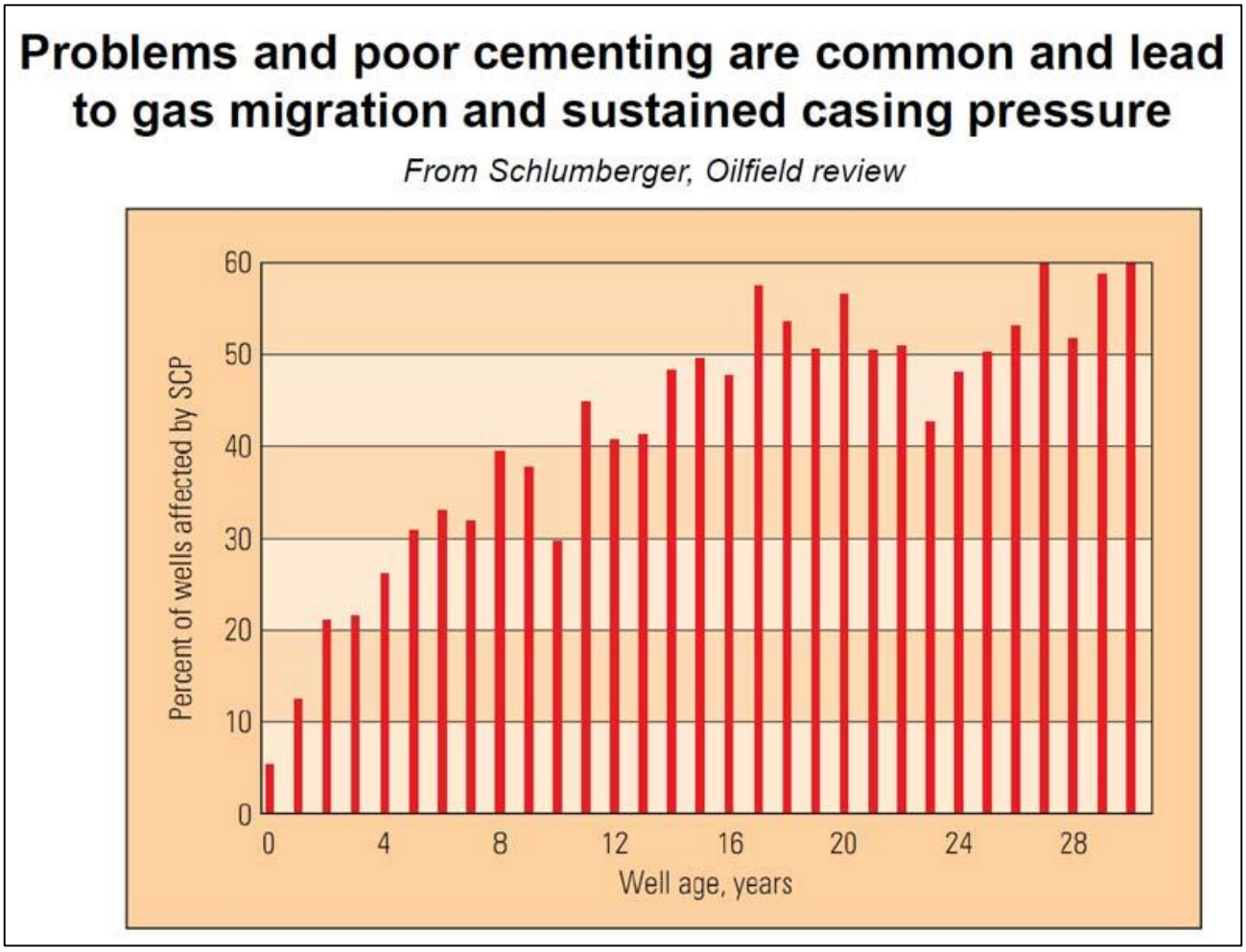
In Muehlenbachs' presentation, *Identifying the Sources of Fugitive Methane Associated with Shale Gas Development*, he said that he had conducted research on Jessica Ernst's property area in Rosebud Alberta. (See Appendix F, for an account of Muehlenbach's research in 2006.) "Is the source that you see burning in the water tap, was it industry induced or was it natural background? What I want to do in this particular presentation is to show you from stable isotope and scientific analyses that you can actually differentiate these gases and identify what their source is."

Near the beginning of his presentation, he introduced a comment by **Mike Dawson**, the **president of the Canadian Society of Unconventional Resources**, published in the Calgary Herald newspaper: "If a well bore is properly cased with steel and cemented, the risk of any interaction between drinking water and fracturing fluid is 'significantly diminished." The challenging question Muehlenbachs raised in response to Dawson's comment, in lieu of a recent and revealing industry report on this very subject, was "how often is the job done right, how often are these wells completed correctly? And, what happens when they are not completed correctly, if the cementation is not done right, if the finishing is not done right?"

> *Remember, if you are doing fracking, especially this multiple fracking, is that once you cement it, once you set everything in place, you are putting these big pressure pulses through the pipes. And, the question is, does that actually help or hinder the retention of the gas?*

The leaks that you see around a petroleum well or gas well don't necessarily come from the target area where you are trying to produce, the leaks could come from anywhere along the production stream.

My experience in thousands of wells in Alberta, which is true for probably everywhere else in the world, is at least 70 percent of the gases that you catch at surface came not from the production zone, but somewhere along the well bore because of poor cementing that we talked about.



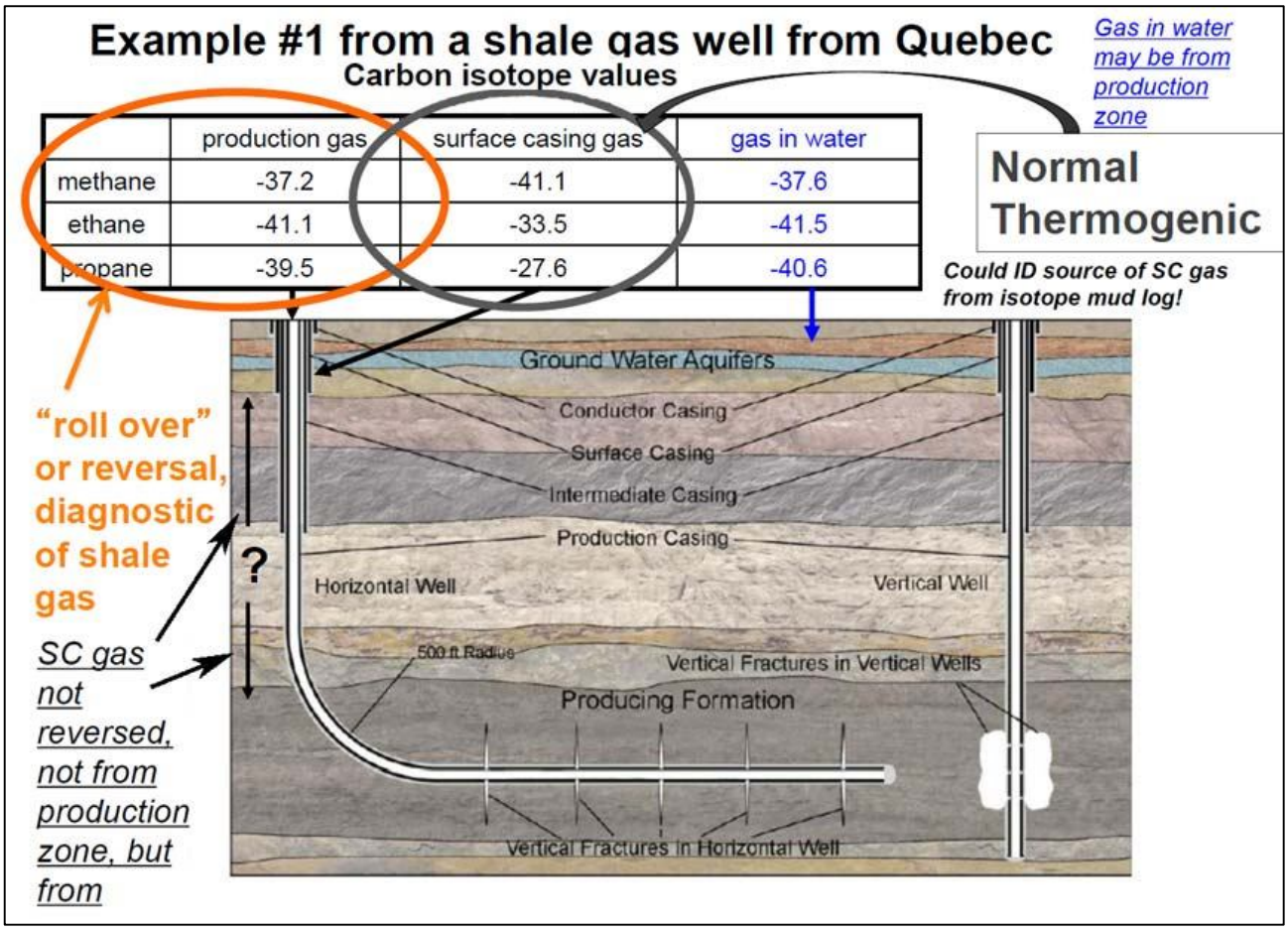
How often do you have this problem? This is Schlumberger's federal treatment of U.S. information, which asks the question, what fraction, or what percent of the wells on the offshore Gulf Coast have these cementing problems? We see that it is a function of age. So, by the time that a well is 16 or 20 years old, about 60 percent of all the wells have developed problems with their cementing or their sealing. In Alberta, which is on land, all the oil wells, gas wells, in Alberta are on land, and all the statistics are more or less similar.

Dr. Muehlenbachs introduced findings from recent data analyzed at his lab sent to him from two shale gas wells sampled from the Utica shales in the southwest region of the province of Quebec. About a year previous in early January 2011, it was reported in the Quebec and national media that "Quebec's Ministry of Natural Resources has found leaks in more than half the shale gas wells it

inspected, according to a report compiled for the province's environmental protection agency." [31] The disturbing information from the December 7, 2010 report, that 19 of 31 newly drilled shale gas wells were leaking, came three months before a final Quebec government report on fracking in late February, 2011, and caused a public uproar.

> *The wells that were found to have leaks belong to Talisman Energy, Gasem, Canbriam, Questerre and Canadian Forest Oil and date back to 2006. Alberta-based Talisman Energy owns 11 of the wells cited in ministry's report, but spokesperson Hope Deveau-Henderson said leaks are a common occurrence.... (said Andre Belisle, president of the Quebec Association Against Atmospheric Pollution) the only solution is a moratorium.* [32]

Later in January 2011, due to the issues of the shale gas leakages from the government report, Quebec's Environment Minister Pierre Arcand raised a few of his comrades' eyebrows when he openly questioned the government's pro-fracking shale gas development plans at a January 21st Liberal caucus meeting held at Lac-Beauport, north of Quebec City.



Following the internet release of Dr. Muehlenbachs' presentation in Washington on November 14, 2011 where he presented his findings on two Quebec shale gas wells, Quebec's La Press newspaper interviewed Muehlenbachs and reported his comments on December 24, 2011, that "the gas in water is very similar to production gas. You have Utica shale gas in water. I don't know how it got

[31] *CBC news, Leaks found in shale gas wells: Que. report*, January 5, 2011.
[32] Ibid.

there, but it is." [33] The reporter asked if the professor would reveal the name of the petroleum company that sent him the samples, but he refused to divulge the information. La Presse reported in early January 2012, that Talisman Energy gave him the samples. As he stated in his November 14th presentation, Muehlenbachs rephrased the documented frequency of well bore leakages found in the recent Schlumberger report study of 15,000 wells in the Gulf of Mexico where half of the wells, over 7,000 in number, were already leaking after only 15 years of age in the offshore underground.

> *"There is an obvious correlation with age, he says. "The leaks increase as the wells get older." And, he thinks that shale gas wells will be worse, because of the extreme pressures that have to go through during the hydraulic fracturing stages. "If you add fracking at high pressures, it is disastrous," he says. "Steel tubing is flexible. Cement around it is hard. So it cracks."*

Meuhlenbachs' isotopic analyses were reviewed by Quebec's Environment Ministry. In the La Presse article, the Ministry's hydrogeologist, Charles Lamontagne, said that his Ministry was nevertheless confident in its own findings, whereby it never found any data linking gas migration to groundwater contamination.

In keeping with Lamontagne's stubborn position, Environment Minister Arcand was quoted five days later in another article published by La Presse on December 29, 2011, criticizing Dr. Muehlenbachs by inferring that his scientific techniques and analysis were essentially experimental and therefore unreliable: "Minister Arcand thinks that the analysis technique used by Mr. Meuhlenbachs, while it is promising, is still only at the scientific development stage and still has to be validated by the scientific community." [34]

In the same article (rough English translation):

> *Mr Muehlenbachs says the isotopic tests he made let us know the exact origin of gas by measuring the concentration of carbon-13 in the molecules. He says either the gas found a pathway in a natural fault after the fracking of the well, or the gas came up the tubing because of a defective cementing, or it was naturally there already.*
>
> *This last hypothesis cannot be put aside because of the lack of baseline information on the chemical signatures of the gas in Quebec groundwater.*
>
> *But Mr Muehlenbachs favors the human factor rather than the natural one. "From a geological point of view, the shale was sealed 300 million years ago." he says. "And then man intervened."*

[33] *De l'eau souterraine contaminee par le gaz de schiste*, 24 decembre 2011.
[34] *Eau contaminée: le ministre Arcand prend la situation "très au sérieux*", La Presse, 29 decembre 2011. The following is the actual quote in French: *Mais le ministre Arcand considère que la technique d'analyse employée par M. Muehlenbachs, bien que "prometteuse," en est "seulement à l'étape du développement scientifique" et doit encore être "validée par la communauté scientifique."*

At the end of Muehlenbachs' presentation on November 14th, during the question and answer period, someone commented on concerns raised by Muehlenbachs on having government regulators require industry to conduct "pre isotopic fingerprints." The commenter said, the "Water Control Board in Pennsylvania or West Virginia wouldn't require that at the moment, and you're making the recommendation for regulatory changes." "Yes," Muehlenbachs replied. "I definitely recommend that. They should require that. In the Province of Alberta it is a requirement around coalbed methane wells, shallow wells. There is no reason why you shouldn't have it on deeper wells.... Well sometimes ... I mean, if you want to be a cynic, you say they don't want to do it because they don't want to see the answer."

Over a month after the RFF conference event, Alberta author and journalist Andrew Nikiforuk published an article on Dr. Muehlenbachs in The Tyee on December 19, 2011, *Fracking Contamination 'Will Get Worse': Alberta Expert*. Nikiforuk's article was quickly absorbed and discussed by the world's internet readers, hungry for new information on the world's biggest topic, fracking. Especially relevant in the United States, where, as he writes in the article, the EPA is conducting a highly publicized review on Encana Corporation's contamination of groundwater in Pavillion, Wyoming, the federal agency which is soon scheduled to release a report on its two year public review of fracking. Here are some excerpts from Nikiforuk's piece:

> *"The shale gas boom combined with hydraulic fracking will cause wellbores to leak more often than run-of-the-mill conventional wells," says Karlis Muehlenbachs, a geochemist at the University of Alberta. "The problem is going to get worse, not better."*
>
> *Muehlenbachs, a leading authority on identifying the unique carbon fingerprint or isotopes of shale and conventional gases, says regulators must do better baseline groundwater testing and rigorously check wells for leakage. (Industry calls these leaks surface casing vent flow or sustained casing pressure.)*
>
> *"The biggest problem is that half or more the wells drilled leak due to improper cement jobs or industry is not following best practices," adds Muehlenbachs.*
>
> *Earlier this month the U.S. Environmental Protection Agency found that EnCana, the continent's second largest shale gas producer, had contaminated groundwater in Pavillion, Wyoming.*
>
> *Those findings, which contradict industry assurances, didn't surprise Muehlenbachs, who has studied leaking wells in Alberta's heavy oil fields for decades.*
>
> *Although petroleum engineers now admit that companies routinely blast fluids and gas into other industry wells hundreds of metres away (B.C., Texas and North Dakota have all documented such cases), they still claim that "fracture communication incidents" can't happen with groundwater.*
>
> *Muehlenbachs, who has documented numerous cases of groundwater contamination, calls such denials dishonest. "Such claims do more harm than good to industry. Don't they realize that social license matters to industry?"*
>
> *Whenever methane leaks from one well into a neighboring wellsite, "industry says let's fix the leaks," says Muehlenbachs. "But as soon as the leaks enter groundwater, everyone*

abandons the same logic and technology and says it can't happen and the denials come out. ***In Alberta, it's almost a religious belief that gas leaks can't contaminate groundwater.****"*

Yet it happens routinely. At a conference in Washington D.C. last month sponsored by Resources for the Future, Muehlenbachs showed evidence that shale gas drilling activity in Quebec and Pennsylvania had in several cases resulted in surface contamination.

In two cases (companies sent him gas samples to analyze), he found that deep shale methane from the Utica Shale definitely leaked up the wellbore and contaminated groundwater. In another case, gas originating along the wellbore had moved into water.

A similar example in Pennsylvania's Marcellus shale formation again found that deep shale methane rich in propane and ethane had leaked to the surface casing, contrary to all industry predictions. The Marcellus lies 2,300 to 6,000 feet deep, which is a little shallower than B.C.'s Montney play at 6,000 to 8,200 feet.

As a highly respected and well-published scientist, Muehlenbach's timely forthright take on the petroleum industry's contradictory and illogical statements that groundwater contamination is not linked to unnatural petroleum developments, delivers refreshing credence to the consistent and rising tide of public testimonies and criticisms levelled against the petroleum industry over the last 35 or more years.

In William Marsden's 2008 book, *Stupid to the Last Drop: How Alberta is Bringing Environmental Armageddon to Canada (And Doesn't Seem to Care),* it describes how Muehlenbachs was a research scientist in the Canadian Association of Petroleum Producers' 1994-1995 Lloydminster studies:

If you fly over eastern Alberta in the area of Lloydminster, you'll see hundreds of pear-shaped bare spots about five metres in diameter scattered throughout the wheat and canola fields. Scientists refer to them as "plumes." They are barren earth. Nothing grows there. This is because the gas wells in the area leak methane.

By the time Alberta began drilling for CBM, there was plenty of evidence in the government's own archives that methane gas from producing and dormant wells could migrate into aquifers and to the surface. In 1995, the Saskatchewan Research Council and the Alberta government studied methane gas leakage and migration from plugged oil and gas wells around Lloydminster. One of the researchers was Dr. Karlis Muehlenbachs, a geochemist in earth and atmospheric sciences at the University of Alberta. He found that a "large number" of well sites were leaking methane into groundwater aquifers and also up through the soil, killing vegetation around the wellhead (methane deprives roots of oxygen). Tests revealed that methane levels were up to fourteen milligrams per litre. Muehlenbachs is categorical: "There is no question that methane migrates into aquifers."

When companies abandon a non-producing well, they are required by law to plug it with mud and cement. This is supposed to stop harmful gases from migrating upwards and contaminating shallow aquifers and surface vegetation. But geologists admit that the cement plugs are seldom perfect. Gaps form between the casings and the borehole walls and sometimes channel into the cement itself. This is particularly critical in older wells where surface casings were designed to anchor drilling equipment in the event of a blowout rather

than to protect groundwater. Over time, as the ground moves and borehole casings age and corrode, the gaps can become more pronounced. Studies done in Alberta and Saskatchewan show that about 57 percent of old wells leak methane and other gases into aquifers and the atmosphere. Nobody knows how much methane leaks each year from these oil and gas wells.... estimates indicate that the amounts are substantial. The U.S. Environmental Protection Agency claims that methane leakage from oil and gas wells and pipelines makes up more than one quarter of the total methane emissions to the atmosphere.... Methane is twenty-three times more powerful than carbon dioxide as a greenhouse gas. With more than 60,000 CBM wells planned in Alberta, the problem could be enormous."

*"I see all kinds of very poor bond logs [acoustic readings than can show gaps in cement casings]," one veteran Alberta geologist, who didn't want his name used for fear he would lose business, says. "**I have never seen a bond log that shows me absolute cement top to bottom**."*

Some companies don't even bother to plug non-producing wells, he says. Fixing leaks and plugging wells can cost hundreds of thousands of dollars per well. If a company doesn't officially abandon the well, they are not required to plug it. "Lots of wells are put on standby because its easier and cheaper than if they try to abandon it," Muehlenbachs says. "And that is a really serious issue. They are usually leaking. And the only reason that they don't legally abandon them is because there is obviously something wrong with them. So the ones there's nothing wrong with they will legally abandon. So selectively you are left with the ones that have the problems. And the big problem is that a lot of them have this gas migration. Gas leaks to the surface and into the aquifers and soils and stuff."[35]

A short review of the 1995 Lloydminster studies was recently published in the April 2010 issue of the New Technology Magazine, an article written by Maurice Smith, *Final Chapter - Application of modern technologies tames stubborn icon of Alberta's oilpatch*. Smith describes how by the early 1990s the provinces of Alberta and Saskatchewan had "serious environmental problems" from "almost half of the several thousands of heavy oil wells drilled in the Lloydminster area," which were "releasing between 0.01 and 200 cubic metres of gas per day," and were "presenting a contamination risk to shallow drinking water aquifers, in addition to the threat of destruction of arable soils around wellheads and an increased contribution to atmospheric methane contributions."

Of considerable intrigue, Smith writes that the **Amoco Canada Petroleum Company** "got the ball rolling in the 1990s" regarding the initiation of the Lloydminster studies. Intriguing, because, as described in chapter 14-(4) of this report above, Amoco was deeply embroiled in groundwater contamination allegations in New Mexico, Colorado and Alabama from its unconventional fracking operations. Here is the clear connection to Amoco's operations in Canada, whereby the multinational company's looming concerns about liabilities in the United States were being legally extended at the same time into its Canadian domains, creating, thereby, international intrigue.

Smith interviewed Muehlenbachs about the Lloydminster history, where he said it was Amoco's geologist Earl Jensen (who recently died) who initially contacted Muehlenbachs about conducting the project: "Jensen approached me to get involved with the science of it. ... We worked mostly with Husky and Amoco, collecting samples of production gases and samples of surface casing vent flows

[35] Chapter 13: *The Last Cowboys and Cowgirls (Alien Invasion).*

Tuesday, November 16, 1993 THE NEW MEXICAN B-5

Report says drilling problems ignored

Methane in water is result, paper says

The Associated Press

DENVER — State and federal regulators failed to halt natural gas drilling in the Four Corners area even though they knew the drilling could lead to methane gas seeping into drinking water, the *Rocky Mountain News* reported.

The *News* said in a copyright story that regulators from the Colorado Oil and Gas Conservation Commission and the Bureau of Land Management knew since 1989 that rapid expansion of drilling activity could cause problems, but approved hundreds of permits for new wells anyway.

The *News* said an Amoco Production Co. scientist published a study two years ago describing how methane could migrate from gas wells into water wells. He was later transferred to Siberia.

The drilling continued despite scores of complaints by citizens that they could sometimes light their tap water on fire, and it was not until last week that Colorado regulators publicly acknowledged the possible link and called for a drilling moratorium if the problem proves widespread.

"Did anyone ever look at the big picture? No," said Tom Pike, a section chief in the drinking water division of the regional Environmental Protection Agency office. "No big environmental impact study was ever done."

Amoco officials say there is no proven link between drilling and methane contamination. They say residents have noticed naturally occurring methane bubbling to the surface for over a century.

At stake is an estimated $25 billion worth of natural gas that lies beneath rural Four Corners communities near Durango and Farmington, N.M. Pipelines carry most of the gas to Los Angeles.

Industry experts estimate that 50 trillion cubic feet of methane lies beneath the 9,000-square-mile San Juan Basin, which stretches from southern Colorado into New Mexico and across the Ute Mountain Ute reservation to Arizona and Utah.

Oil companies rushed into the area after Amoco discovered a cost-effective way to release methane from the water-laden Fruitland coal layer 3,000 feet underground. As drilling increased, residents began to videotape themselves setting fire to water from faucets, hoses and showers and complained the water tasted bad.

"We went year after to Denver, but they just thought we were complaining," said Pati Temple, an area resident who wrote a letter to former state gas commission director William Smith in 1989. He told her not to worry, the *News* said.

But the *News* said behind the scenes, Smith and others were acknowledging problems.

Note: With the reference to Siberia in the article above, Amoco Production Company did have operations in Siberia in 1993, through its subsidiary **Amoco Eurasia Petroleum Co**.

Activists, Amoco Poised to do Battle over Drilling - Oil Firm wants to put in 15 additional wells in mountains near Bayfield

Both sides are poised to go forward in their dispute over gas-well drilling on forest lands in the mountains east of Bayfield.

Amoco Production Co. is preparing field workers at its Durango Operations Center for drilling approval fro company headquarters in Denver, Houston and Chicago, said spokesman Jack Rigg. (Rocky Mountain News, September 12, 1992)

Gas-Well Protest

About 30 protesters on Tuesday commandeered a bulldozer and halted Amoco Production Co's gas-well construction project in the San Juan National Forest. Amoco workers had begun building five coalbed methane wells at the site Monday after an appeal by conservationists stalled. The protesters - members of the San Juan Citizens Alliance and Earth First! - said they wanted to halt the construction until their appeal of the Forest Service's approval of the project is .... (Rocky Mountain News, September 16, 1992)

Amoco Starts Drilling

Amoco Production Company has begun a $2 million drilling program near Durango after fending off repeated attempts by environmentalists to block the project.

But the company still faces hearings in U.S. District Court and the Department of Interior, where environmental groups are seeking to shut down the project on the grounds it may endanger area water supplies. (Rocky Mountain News, September 29, 1992)

Methane Levels 17 Times Higher in Water Wells Near Hydrofracking Sites

May 09, 2011

DURHAM, N.C. – A study by Duke University researchers has found high levels of leaked methane in well water collected near shale-gas drilling and hydrofracking sites. The scientists collected and analyzed water samples from 68 private groundwater wells across five counties in northeastern Pennsylvania and New York.

They found no evidence of contamination from chemical-laden fracking fluids, which are injected into gas wells to help break up shale deposits, or from "produced water," wastewater that is extracted back out of the wells after the shale has been fractured.

The study appears this week in the online Early Edition of the *Proceedings of the National Academy of Sciences*. It is the first peer-reviewed study to measure well-water contamination from shale-gas drilling and hydrofracking.

"At least some of the homeowners who claim that their wells were contaminated by shale-gas extraction appear to be right," says Robert B. Jackson, Nicholas Professor of Global Environmental Change and director of Duke's Center on Global Change.

"We found measurable amounts of methane in 85 percent of the samples, but levels were 17 times higher on average in wells located within a kilometer of active hydrofracking sites," says Stephen Osborn, postdoctoral research associate at Duke's Nicholas School of the Environment. The contamination was observed primarily in Bradford and Susquehanna counties in Pennsylvania.

Water wells farther from the gas wells contained lower levels of methane and had a different isotopic fingerprint.

"Methane is CH4. By using carbon and hydrogen isotope tracers we can distinguish between thermogenic methane, which is formed at high temperatures deep underground and is captured in gas wells during hydrofracking, and biogenic methane, which is produced at shallower depths and lower temperatures," says Avner Vengosh, professor of geochemistry and water quality. Biogenic methane is not associated with hydrofracking.

"Methane in water wells within a kilometer had an isotopic composition similar to thermogenic methane," Vengosh says. "Outside this active zone, it was mostly a mixture of the two."

The researchers also compared the dissolved gas chemistry of water samples to the gas chemistry profiles of shale-gas wells in the region, using data released publicly by the Pennsylvania Department of Environmental Protection.

"Deep gas has a distinctive chemical signature in its isotopes," Jackson says. "When we compared the dissolved gas chemistry in well water to methane from local gas wells, the signatures matched."

Methane is flammable and poses a risk of explosion. In very high concentrations, it can cause asphyxiation. Little research has been conducted on the health effects of drinking methane-contaminated water. Methane isn't regulated as a contaminant in public water systems under the EPA's National Primary Drinking Water Regulations.

Hydraulic fracturing, also called hydrofracking or fracking, involves pumping water, sand and chemicals deep underground into horizontal gas wells at high pressure to crack open hydrocarbon-rich shale and extract natural gas. Shale gas comprises about 15 percent of natural gas produced in the United States today. The Energy Information Administration estimates it will make up almost half of the nation's production by 2035.

The Duke team collected samples from counties overlying the Marcellus shale formation. Accelerated gas drilling and hydrofracking in the region in recent years has fueled concerns about well-water contamination by methane, produced water and fracking fluids, which contain a proprietary mix of chemicals that companies often don't disclose.

"Based on analysis of the 68 wells, we found no evidence of contamination from chemicals contained in fracking fluids and produced water," Osborn says. Additional tests would expand the size of the sample, he says, and help further allay any unfounded concerns.

All funding for the study came from the Nicholas School and Center on Global Change. Nathaniel R. Warner, a PhD student of Vengosh's, co-authored the study.

Independent of the PNAS study, Jackson and colleagues at the Center on Global Change, Nicholas School and Nicholas Institute for Environmental Policy Solutions have issued a white paper on hydrofracking at www.nicholas.duke.edu/cgc. It includes recommendations for monitoring and addressing potential environmental and human health risks

mostly, and we noticed that there is a consistent difference between the surface casing vent and the production stream:"

> *"I think the biggest breakthrough we had was that we demonstrated that most of the leaks come from some shallower horizon," says Muehlenbachs. "We could show there is a very clear profile with depth in the isotope ratios of the methane, ethane [and] propane, and we could match very well the surface casing vent flow with the template from the mud logs and identify where most of the leaks in the Lloyd area are actually coming from.*
>
> *"Before we did this, the working knowledge was, 'We will just dump more cement down there and sooner or later it will stop leaking,' but if they were trying to cement off the production side, well, no matter how much they put in, it would still have a surface casing vent flow problem. Now we know we can't just assume that the gas is leaking from the target zone."*
>
> *Isotopic analysis, performed using the mass spectrometer at the UofA's stable isotope laboratory, found that while the bacterial methane originating in the various Mannville Group sands did not display unique isotopic signatures, the gases from each of the overlying Upper Cretaceous Colorado Group shale units were isotopically distinct. Researchers were surprised to find that the deeper Mannville Group gases were extensively biodegraded, while the immature incipient thermal gases of the Colorado Group shales remained unaltered.*
>
> *The isotopic signatures represent the different genetic histories of the Colorado and Mannville Group deposits, says Muehlenbachs. "The origin of the gas doesn't have to match the age of the rock; it has to match the history of the rock."*
>
> *The large number of leaks is to some degree a function of the local geology. Some of the shales don't hold cement well, and in some cases the geological formations might be more prone to cause corrosion.*
>
> *"In Lloydminster there are tens of thousands of wells and about half of the wells have gas migration problems," Muehlenbachs says. "Most of the leaks would be from 300 or 400 metres, whereas the oil production is from about 600 metres…. Legally, sooner or later, every single well has to be abandoned to a very high standard."*

In Muehlenbachs' myriad investigations and findings of applied scientific isotopic fingerprinting he was involved in from the early 1970s to 1994 at the University of Alberta, the Lloydminster studies marked the first occasion that he, with the aid of research students, used the procedure in investigating the gaseous properties of hydrocarbons. [36]

Because of the forensic nature of Muehlenbachs' expertise in isotopic fingerprinting of hydrocarbons, it is hardly surprising that his evolving mastery of this subject was called upon by a recently formed international committee organizing the International Network of Environmental Forensics (INEF) Conferences. The INEF, formed in 2008, "is a non-profit interest group with the

[36] Personal Communication.

Royal Society of Chemistry (RSC)." [37] The INEF convened its first conference in 2009 in Calgary, Alberta. The second conference, held in Cambridge University's St. John's College in July 2011, included the following topical subjects:

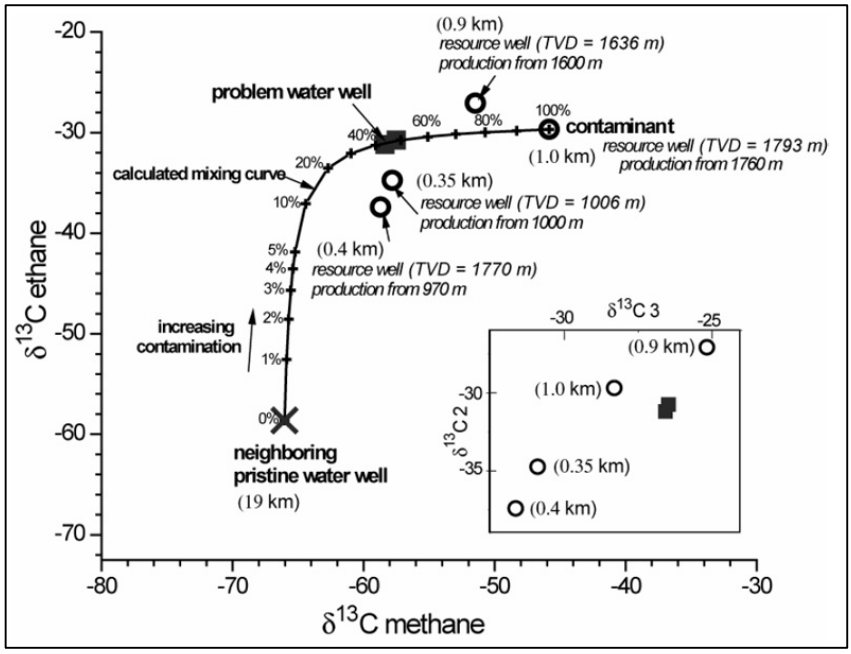
- Fingerprinting techniques to identify the source and age of a contaminant release
- Environmental litigation and law impacting forensic investigations
- Presenting complex environmental data in court – strategies to get the information across
- Forensic field investigations and surveys in terrestrial and marine environments
- Uses of remote sensing and aerial photography in forensic investigations
- Advanced forensic analytical techniques
- Quality assurance and quality control of analytical data
- International environmental forensic reference materials, standards, and new directives
- Application of microbiological techniques to identify the origin of a contaminant release
- Petroleum hydrocarbon fingerprinting and source identification in a marine environment
- Lessons from the Gulf of Mexico Deepwater Horizon release
- Age dating techniques for oil, chlorinated solvents, dioxin/furans, radioactive materials and metals
- Contaminant transport modelling
- Visualization of forensic evidence
- Forensic statistics (PCA, PVA, etc.)
- Groundwater contamination, characterization and modelling
- Implementation of forensic investigative techniques
- Methodology for the rigorous analysis of forensic evidence
- Application of stable isotopes in forensic investigations

As described by R.D. Morrison and J.R. Hone's paper, *Introduction to Environmental Forensics*:

> *Environmental forensics is the systematic and scientific evaluation of physical, chemical, and historical information for the purpose of developing defensible scientific and legal conclusions regarding the source or age of a contaminant released into the environment. As such, there is a multitude of forensic techniques available for contaminant age dating and source identification including, but not limited to aerial photo interpretation/ photogrammetry, chemicals associated with discrete chemical processes, identification of the manufacturer of a particular product, chemical additives and/or impurities, chemical profiling, degradation modeling, corrosion models, contaminant transport modeling, surrogate chemical analysis, chronological changes in chemical processes resulting in diagnostic markers, compound specific isotopic analysis, polychlorinated biphenyl (PCB) congener analysis and degradation product ratio analysis.*

On the morning of July 26th, Meuhlenbachs' 30-minute presentation was called, *Fingerprinting of Gas Contaminated Groundwater and Soil in Petroloferous Regions, Alberta, Canada*. One of the other two panel members in the *Petroleum Hydrocarbons* workshop session, was Pennsylvania State University Frank Dorman's presentation, *Environmental Forensic Investigation of Composition of Hydraulic Fracturing Fluids Used in Gas-Well Drilling in the US*.

[37] *Announcement and Call for Abstracts, INEF Cambridge Conference 2011, A conference for the Environmental Forensic Community, St. John's College, Cambridge, United Kingdom, July 25-27, 2011*.



In Barbara Tilley and Muehlenbachs 2008 report, *Recognizing Natural Gas Contamination of Water Wells in a Petroliferous Region*, they state the following:

Sixty years of petroleum development has resulted in over 500,000 petroleum wells drilled in the Western Canada Sedimentary Basin, many in agricultural areas that rely on groundwater. The impact on groundwater quality by petroleum development is increasingly becoming a societal concern triggered by intensive, recent CBM development. Carbon isotope values of gases vary within the basin (Tilley and Muehlenbachs, 2007) and can be used forensically to quantify natural gas contamination of groundwater.

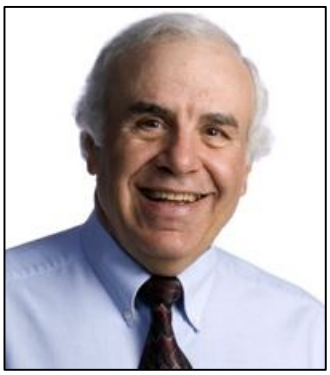
Figure 1. Gas contamination in a water well. Graph compares the carbon isotopic compositions of gas from one farm water well (black squares) sampled twice, 6 months apart, that contains in addition to methane and ethane also propane, butanes and pentanes. Data from four resource wells located a kilometer or less from the problem water well (actual distances in brackets), and a gas from a presumed pristine water well 19 km away, are also shown. The calculated mixing curve shows how the isotope ratios of gas change on mixing two gases with differing isotope ratios as well as differing proportions of methane and ethane (after Jenden et al., 1993). The methane and ethane isotope data can be explained if gas in the problem water well is an almost one to one mixture of shallow gas found in the pristine neighboring water well (99.5% methane; 0.5% ethane) and gas from 1,760 m as in the resource well 1.0 km away from the problem well (78% methane and 13% ethane). The insert plots the isotopic compositions of propane versus ethane of the problem water well and the four resource gases. The propane in the water well is too high, relative to gas from the 1.0 km well, implying a deep contaminant source not identical to the one modelled.

As of May 2006, Alberta requires baseline testing of domestic water wells prior to CBM development. Surprisingly, many presumed pristine water wells contain effervescing methane (· 13C = -85 to -50 per mil) with traces of ethane (· 13C = -70 to -30 per mil), indicating that some of the water wells have already been contaminated. One farm water well (Figure 1) contained propane, butane and pentane in addition to methane and ethane. Figure 1 compares the isotopic compositions of gases from this problem water well, a neighboring pristine water well, and four nearby, recent, resource wells. The isotope ratios of the ethane in the resource wells and the problem well are similar, in sharp contrast to the neighboring water well, indicating contamination of the water well by deep gas.

Attributing specific contaminant sources to a given resource well has proven to be even more difficult in areas where there is ongoing CBM development. Landowners have

filed complaints about gas contamination of their water wells. However, in one area, the problem gas seems to be attributable to previous conventional petroleum development rather than the current CBM drilling and production. Carbon isotope analyses of water wells in another area suggest a few per cent of CBM contamination in water wells. Unfortunately, lack of pre-drilling background water data prevents reliable quantification of the contamination.

14-(7). Dr. Anthony Ingraffea's Eastern Canada Invitational



I am a university professor, but I'm certain Conoly-Schuller and her colleagues decidedly won't like my simple message for them: "Tell the whole truth." [38]

"It can't be safe, there will always be problems and you can't get around it," he told the audience, which filled the entire main floor of the theatre. [39]

With the recent public concerns and growing opposition to proposed fracking developments in Canada's eastern Atlantic provinces of New Brunswick and Nova Scotia, community organizations and NGOs sponsored consecutive speaking tour engagements and conferences held from November 30 to December 10, 2011 featuring two prominent and outspoken North American fracking critics: Alberta's Jessica Ernst and New York State Cornell University professor Anthony Ingraffea. The events, which were videotaped and posted on the internet, were also reported by print, television, and internet media. [40]

Through his wealth of academic experience and training with the technical aspects of engineering, technology and science of fracking, Ingraffea has crafted a translation and exposure of those complexities into simple, educational, meaningful and truthful ways. And, as the public has recently come to bear witness, there are literally only a handful like him inside the industry (including retired professionals) that have had the courage and tenacity to tell the truth.

On Cornell University's website, Dight C. Baum Professor of Engineering Anthony R. Ingraffea's biography states: he has taught structural mechanics, finite element methods, and fracture mechanics at Cornell since 1977. [41]

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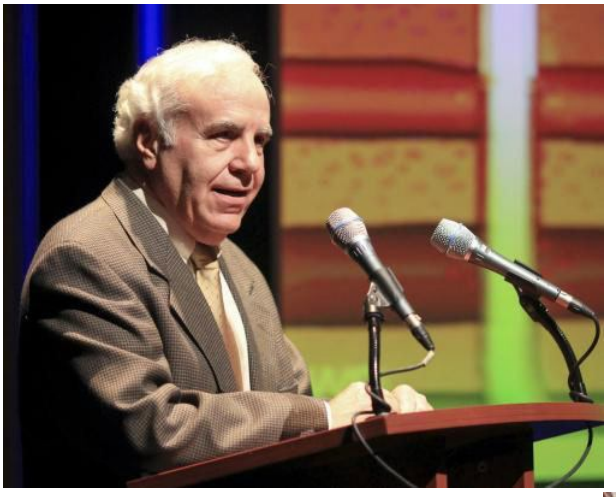
[38] *Does the natural gas industry need a new messenger?* CBC News, November 29, 2011.
[39] *Expert warns of risks of fracking*, December 1, 2011, Times & Transcript.
[40] For about the last two years, Ingraffea previously only made numerous public presentations in a variety of public forums on the subject of fracking in the United States, and held a few video conferences internationally. A number of the U.S. presentations are available for viewing on the internet, primarily on YouTube.
[41] The website biography continues with the following: "Dr. Ingraffea's research concentrates on computer simulation and physical testing of complex fracturing processes. He and his students performed pioneering research in the use of interactive computer graphics in computational mechanics. He has authored with his students over 200 papers in these areas. He has been a principal investigator on over $35M in R&D projects from the NSF, NASA Langley, Nichols Research, NASA Glenn, AFOSR, FAA, Kodak, U. S. Army Engineer Waterways Experiment Station, U.S. Dept. of Transportation, IBM, Schlumberger, Digital Equipment Corporation, the Gas Research Institute, Sandia National Laboratories, the Association of Iron and Steel Engineers, General Dynamics, Boeing, Caterpillar Tractor, and Northrop Grumman Aerospace.
Professor Ingraffea was a member of the first group of Presidential Young Investigators named by the National Science Foundation in 1984. For his research achievements he has won the International Association for Computer Methods and Advances in Geomechanics "1994 Significant Paper Award" for one of five most significant papers in the category of

Ingraffea's opener in the land of Canada was on the evening on November 30th, 2011 in Moncton, New Brunswick's Capital Theatre. He began by introducing his famous assessment of exposing the petroleum industry's 'four fracking myths,' and advised the audience: "Be careful of the(ir) words. Every word has a technical meaning, but it also has a political meaning."



- **Myth 1** - Fracking for gas developments is a 60-year old well-proven technology (No - the technology is still evolving and new brute force fracking is different);
- **Myth 2** - Fluid Migration from faulty wells is a rare phenomenon (No - it is a well-known, chronic problem);
- **Myth 3** - The use of multi-well pads and cluster drilling reduces surface impacts (No - they facilitate and prolong intense industrialization and leaves a larger, long-term footprint);
- **Myth 4** - Natural gas is a *clean fossil fuel* (No - over its life-cycle, unconventional natural gas is likely no cleaner than coal or petroleum, and conventional gas is comparable to those other fossil fuels).

Computational/Analytical Applications in the past 20 years, and he has twice won the National Research Council/U.S. National Committee for Rock Mechanics Award for Research in Rock Mechanics (1978, 1991). His group won a NASA Group Achievement Award in 1996, and a NASA Aviation Safety Turning Goals into Reality Award in 1999 for its work on the aging aircraft problem. He became a Fellow of the American Society of Civil Engineers in 1991.
Professor Ingraffea has received numerous awards his outstanding teaching at Cornell. He received the first Society of Women Engineer's Professor of the Year Award in 1997, the 2001 Daniel Luzar '29 Excellence in Teaching Award from the College of Engineering, and, in 2005, was named Weiss Presidential Teaching Fellow at Cornell University. He has been a leader in the use of workstations and information technology in engineering education, with grants from the NSF, U.S. Department of Education, Digital Equipment Corporation, Sun Microsystems, and Hewlett-Packard in these areas. He organized and was the first Director of the NSF-supported, $15M Synthesis National Engineering Education Coalition, a team of eight diverse engineering colleges. Synthesis developed, implemented, and assessed innovative programs and technologies to improve the quality of undergraduate engineering education and to attract and graduate larger numbers of women and under-represented minority engineers. He is Cornell Co-PI on a NASA/NYS/AT&T sponsored project to develop an Advanced Interactive Discovery Environment for collaborative distance design in engineering education, teaming with faculty from aerospace, mechanics, and civil engineering from Cornell and Syracuse universities.
He was named Co-Editor-in-Chief of Engineering Fracture Mechanics in 2005, received the ASTM Irwin Award for meritorious contributions to the practice of fracture mechanics in 2006, and was named a Fellow of the International Congress on Fracture in 2009.

While exposing some the of features behind Myth 2 over a period of about 25 minutes, Ingraffea included a number of images in his power point presentation to help educate the audience on the technical and structural problems concerning the cementing of well bores, the problems of iron casings that are fitted, connected together, and pushed far into the earth under stress, and the impacts that brute force fracking (intense pressures forced through the well bore from powerful diesel engines) has on these made-made intrusions and on the deep environments underground. The audience eagerly devoured his information.

Prof. Ingraffea: Nie ma łupków bez ryzyka

Rozmawiała Monika Libicka 28 maja 2011 18:45, ostatnia aktualizacja 09 sierpnia 2011 13:30

Wieża przygotowana do odwiertu gazu łupkowego. Fot. PAP

Zobacz także

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Ambasada USA: Polska ma największe zasoby gazu łupkowego w Europie. Starczą na 300 lat!

Opinie i komentarze

Ostudźmy łupkową gorączkę

Tomasz Deptuła

Przeraża mnie euforia z jaką w Polsce podchodzi się do tematu wydobycia gazu łupkowego.

Newsweek Poland - May 28, 2011

Polska na wydobyciu gazu łupkowego może skorzystać, ale ryzyko dla środowiska i zdrowia też musi być brane pod uwagę – mówi prof. Anthony Ingraffea Z Cornell University.

Temat polskiego gazu łupkowego, w którego wydobycie chcą się zaangażować liczne amerykańskie firmy, był jednym z najważniejszych w rozmowach z Barackiem Obamą,. Ekologiczni przeciwnicy gazu łupkowego rozpętali na świecie kampanię dyskredytującą amerykańskie technologie. Postanowiliśmy sprawdzić, na ile realne są zagrożenia, na które zwracają uwagę, bo ile możemy na łupkach zyskać, wiadomo – setki miliardów i niezależność energetyczną.

NEWSWEEK: Polskie złoża szacuje się na kilka bilionów metrów sześciennych gazu łupkowego wartych nawet 500 mld dolarów. Są tacy, którzy mówią, że dla naszego środowiska naturalnego to zła wiadomość.

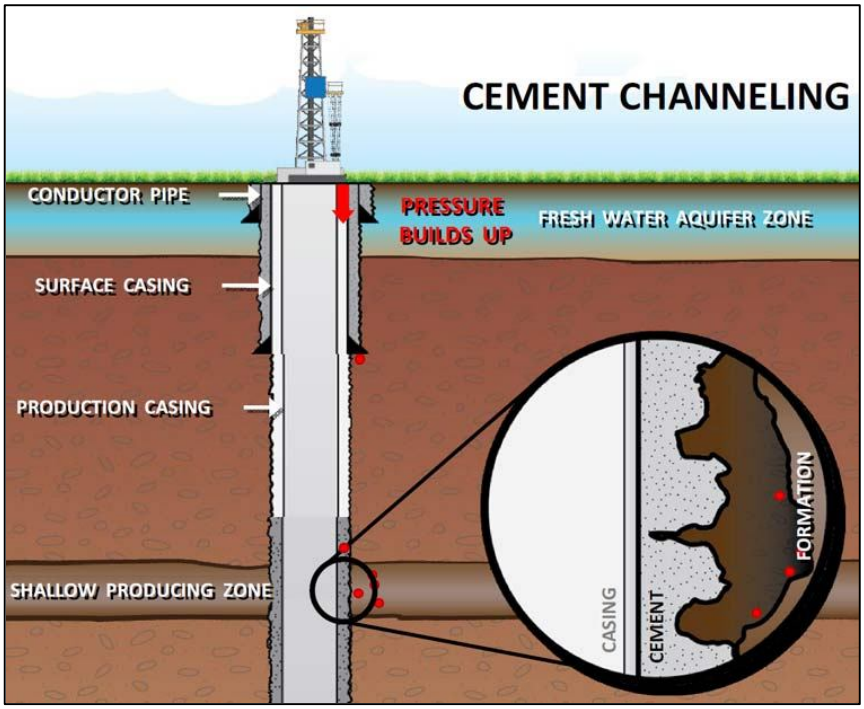
ANTHONY INGRAFFEA: Mogą mieć rację, jeśli nie przygotujecie właściwie procedur związanych z wydobyciem gazu oraz koniecznością usuwania toksycznych odpadów produkcyjnych.

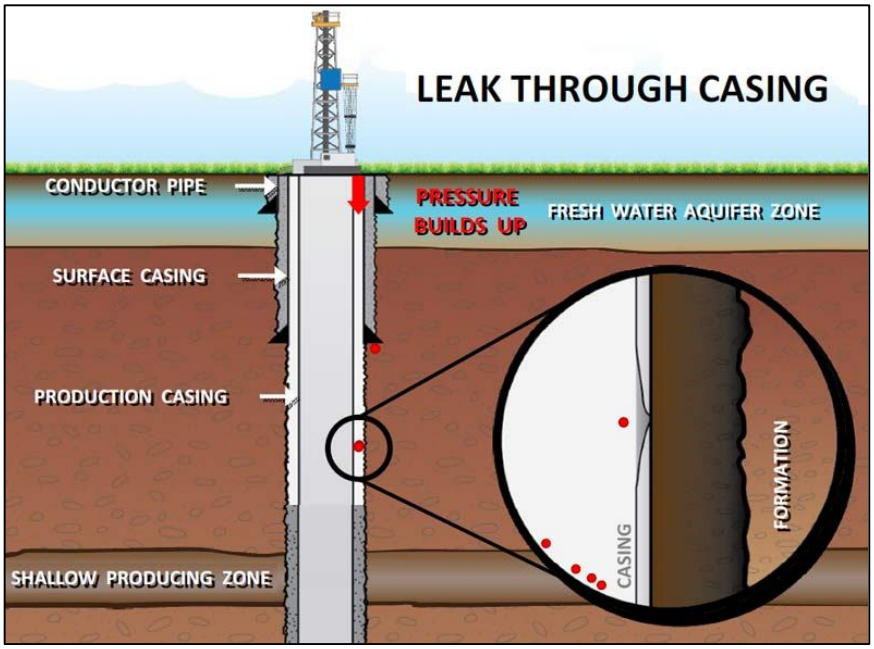
He began by showing a video of a well bore head, and the excavated or cavity area created around it, shaped much like a deep snow hollow around a tree in winter. In this cavity is where rain or ground water seep is captured, and is where one can often detect the gas bubbles that may leak from and up along the long length of the well bore cement/casing.

> *"Loss of well bore integrity occurs when the hydrocarbons come up outside the well. That's what you are looking at here. That's gas. Mostly methane in this case. It's bubbling up outside the well.... That's the potential for two problems. Because the gas has now been liberated from three or four thousand feet down, and it's coming up outside the well, what does it have to go through to get to the surface? An aquifer. And when it gets to the surface, if it's not captured, where does it go? Into the atmosphere. That's not good either."*

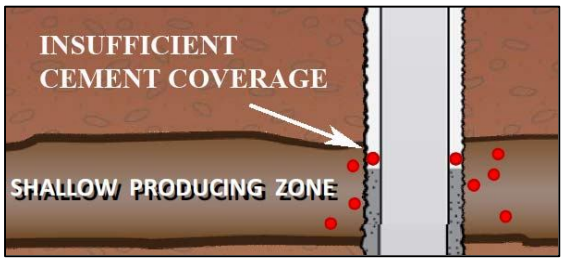
Ingraffea proceeded to explain the problems related to cementing and fracking the well bore, the essentials in well bore mechanical integrity. He said that a well bore "typically goes through other intermediate shales that also have gas pressure ... here's some gas, and it's trapped. It can't get out and go up this open anulus because the cement is sealing it. **IF** the cement seals it! I'm going to show a couple of pictures of just some of the things that can go wrong."

"During that period of time the cement is liquid (when it is pumped down the well), it has to be, otherwise it is not going to flow.... while it's a liquid, if it's in contact with gas that is sufficiently of high pressure, you are now forcing the gas of high pressure into a liquid cement, and you get what is called channelling. The gas can actually move the cement out of the way - because it is still a liquid - and channel up and into an open anulus, if there is one (depending upon how far up the cement as been set). That's one thing that can go wrong. And that's a problem."





"Another thing that can go wrong is with the casing. How long does the casing have to be there? Forever. Not until the well runs dry. It has to be there forever, otherwise your well becomes a conduit for whatever is down there. So you want the casing to last a really long time. And, the casing is steel. Steel corrodes, especially with what's coming up the well is full of salt water.... This is not one continuous steel pipe. It is jointed together. Every joint is a weakness. Joints can fail. So, if you have a failure of the casing in a region where you have an open anulus and no cement, gas can get out and can get into an underground source of drinking water."



"*Insufficient cement coverage*. There are incidents which are documented, they are in the open literature, where somebody made a mistake on the cement chemistry. And they pumped the cement down the well. It came back up. They wanted it to come up to here, but it locked up, that is, it solidified before it got back up to the level they wanted it to. Which now means that these gas molecules (the red dots) can get into this open anulus, go up to the surface, and if they are contained, that pressure builds up, and gas can go into an underground source of drinking water." That's 3 of about 10 different things that can go wrong."

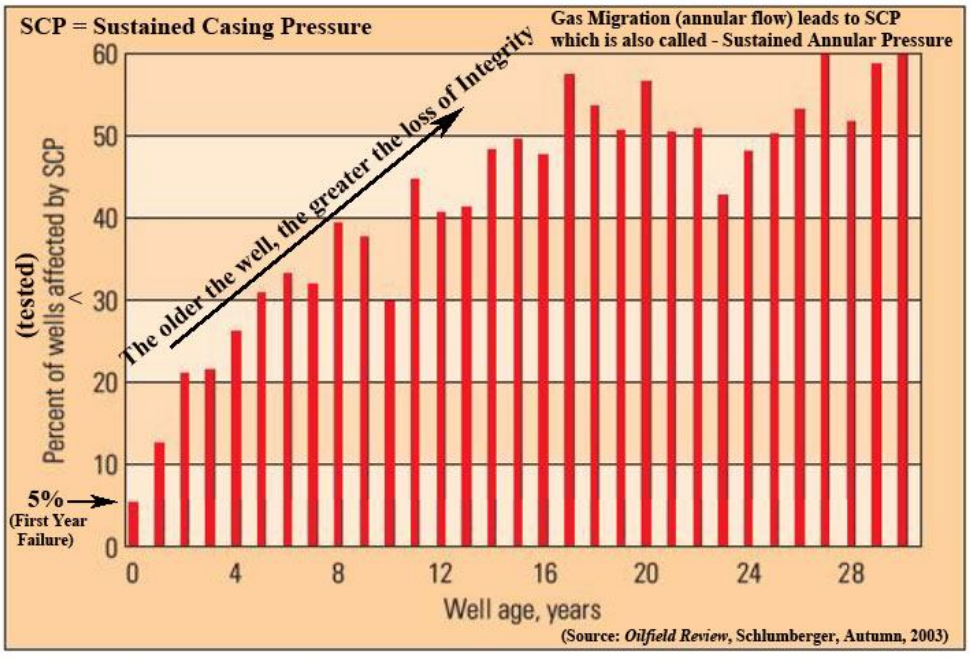
Figure 4: Incomplete displacement of drilling mud and resulting cement and drilling fluid channels. Over time, the gels in the drilling fluid well shrink, forming a gas flow path in the annulus.[3]

Petroleum Society's 5th Canadian International Petroleum Conference
From Watson, **PAPER 2004-297**

"And the industry knows them. There have been dozens of papers written on these problems over the years."

"Here's an example. An actual physical example of one of those problems: channelling. This is a cross section. Here is an inner layer of casing. Here is an outer layer of casing. Here is the cement that is between them. How good of a bond is it? This is a case where channelling occurred. So, gas coming from below can clearly make it's way up through that loss of bond. These are all industry reports, industry images, industry data. I'm not making it up."

Ingraffea then presented the same Schlumberger data that Dr. Muehlenbachs presented concerning the leaking wells in the Gulf of Mexico.



^Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

"Let's look at industry data. So how often do these things happen, of all these five, six, seven, eight, nine, ten things that can cause a well to go bad - to allow hydrocarbons and other things to come up *outside* the well and potentially impact underground sources of drinking water, or the atmosphere - how ***rare*** is that?"

"Industry data, Schlumberger. The

horizontal axis is the age of a well. Vertical axis is the "percent of wells tested affected by Sustained Casing Pressure." Sustained Casing Pressure means "annular pressure in one or more of the casing annuli." In other words, the well has failed. Gas is coming up outside the well in one or more of the annuli that were supposed to be properly cemented. So, this is data from thousands of wells."

Wells at Risk

Since the earliest gas wells, uncontrolled migration of hydrocarbons to the surface has challenged the oil and gas industry. Gas migration, also called annular flow, can lead to sustained casing pressure (SCP), sometimes called sustained annular pressure (SAP).

In the Gulf of Mexico, there are approximately 15,500 producing, shut-in and temporarily abandoned wells in the outer continental shelf (OCS) area.[4] United States Minerals Management Service (MMS) data show that 6692 of these wells, or 43%, have reported SCP on at least one casing annulus. In this group of wells with SCP, pressure is present in 10,153 of all casing annuli: 47.1% of the annuli are in production strings, 26.2% are in surface casing, 16.3% are in intermediate strings, and 10.4% are in conductor pipe.

The presence of SCP appears to be related to well age; older wells are generally more likely to experience SCP. By the time a well is 15 years old, there is a 50% probability that it will have measurable SCP in one or more of its casing annuli. However, SCP may be present in wells of any age.

4. United States Minerals Management Service statistics: http://www.gomr.mms.gov (accessed August 21, 2003).

Excerpts from Schlumberger's Autumn 2003 publication, *Oilfield Review.*

Identifying Causes of Gas Migration

Annular gas may originate from a pay zone or from noncommercial, gas-bearing formations. Some of the most hazardous gas flows have originated from unrecognized gas behind conductor, surface or intermediate casing. Typically, gas flow that occurs immediately after cementing or before the cement is set is referred to as annular gas flow, or annular gas migration.

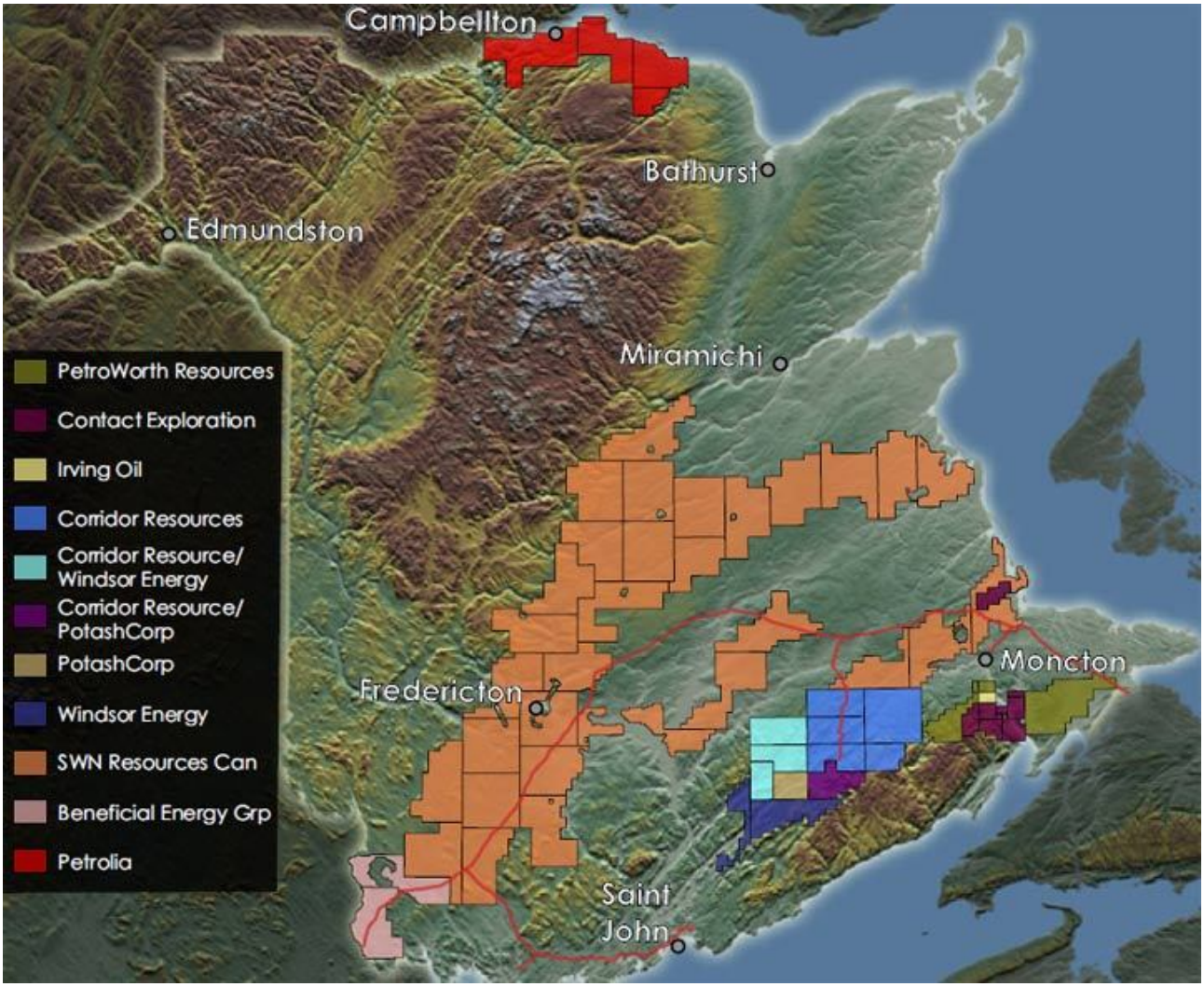
Tubing and casing leaks—Production tubing failures may present the most serious SCP problem.[8] Leaks can result from poor thread connection, corrosion, thermal-stress cracking or mechanical rupture of the inner string, or from a packer leak. Production casing is typically designed to handle tubing leaks, but if the pressure from a leak causes a failure of the production casing, the outcome can be catastrophic. With pressurization of the outer casing strings, leaks to surface or underground blowouts may jeopardize personnel safety, production-platform facilities and the environment.

Poor mud displacement—Inadequate removal of mud or spacer fluids prior to cement placement may result in failure to achieve zonal isolation. There are several reasons for mud-removal failure, including, but not limited to, poor borehole conditions, improper displacement mechanics and failures in displacement process or execution. Inadequate removal of

Improper cement-slurry design—Flow occurring before cement has set is a result of loss in hydrostatic pressure to the point that the well is no longer overbalanced—hydrostatic pressure is less than formation pressure.

Cement damage after setting—SCP can occur long after the well-construction process. Even a flawless primary cement job can be damaged by rig operations or well activities occurring after the cement has set. Changing stresses in the wellbore may cause microannuli, stress cracks, or both, often leading to SCP.[11]

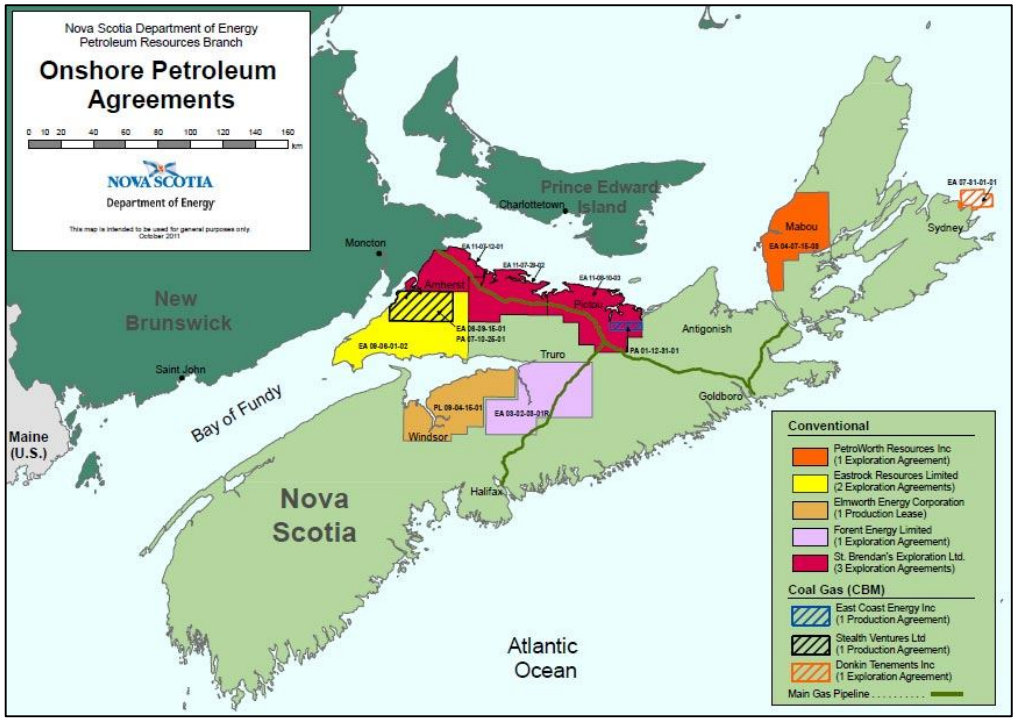
The mechanical properties of casing and cement vary significantly. Consequently, they do not behave in a uniform manner when exposed to changes in temperature and pressure. As the casing and cement expand and contract, the bond between the cement sheath and casing may fail, causing a microannulus, or flow path, to develop.



"You notice two things right away. Brand new wells fail at the rate of about five percent. One out of twenty. I submit that that's not rare. Not rare enough. Especially in the shale formation? 2.5 million acres of New Brunswick? Right now, the going rate in shale formations is one well per 80 surface acres. Do the math. (31,250 wells) One well will drain 80 surface acres. If all 2.5 million acres are developed, and that's a big if - I'm not saying it's going to happen, but engineers deal with the extremes - ... that's 30,000 wells. If five percent of 30,000 wells fail, what is that? That's 1,500 (wells). That's not rare. That's not saying that every well that fails is going to cause a problem with an underground source of drinking water, but when a well does fail, that is a necessary condition for there to be contamination of an underground source of drinking water. And, even if it doesn't contaminate an underground source of drinking water, it's going to allow gas to escape to the atmosphere for as long as there is gas down there."

"Second thing you notice in the data.... The older we get the worse things get - (Ingraffea is pointing to Schlumberger's data graph with his laser pointer, following the rise in the red vertical bars representing the age of the leaking wells) - ***this is an engineering artefact***. A gas well is an engineering artefact, like an automobile, or an airplane. As it ages, bad things happen more frequently. It's just the nature of the beast. So, by the time the wells get into their old age - and shale gas wells are being projected to last up to thirty years - you can anticipate that about half the wells will eventually lose their integrity. I don't think that's rare."

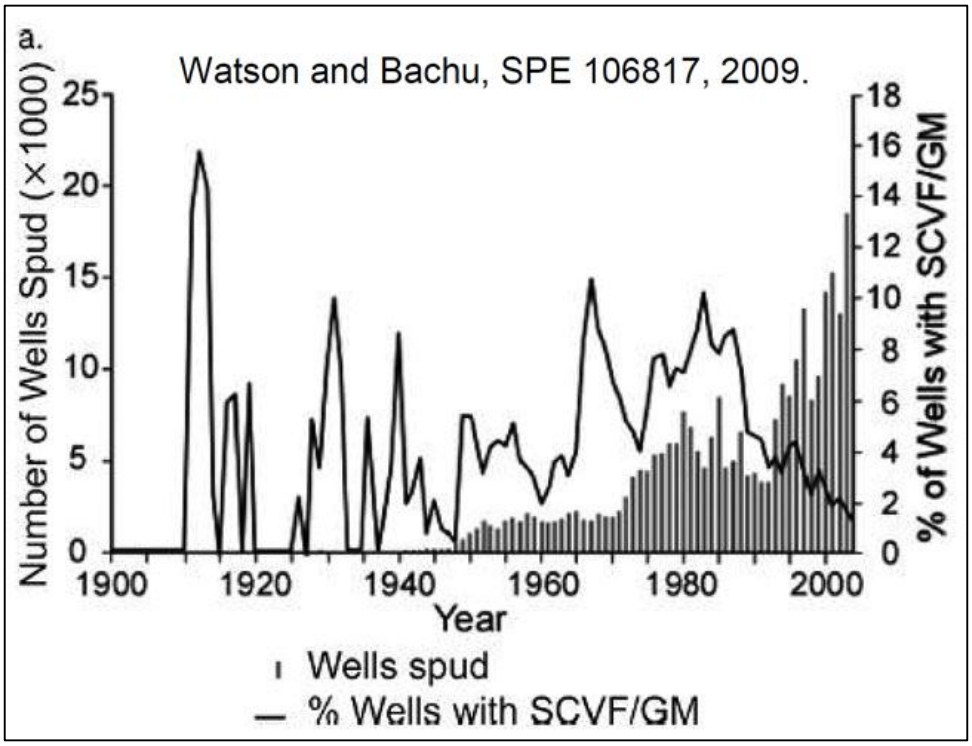
"So, when I showed this data to the Environmental Protection Agency, I said, well, it's industry data, I don't know why Schlumberger didn't show it to you. But, I did!"



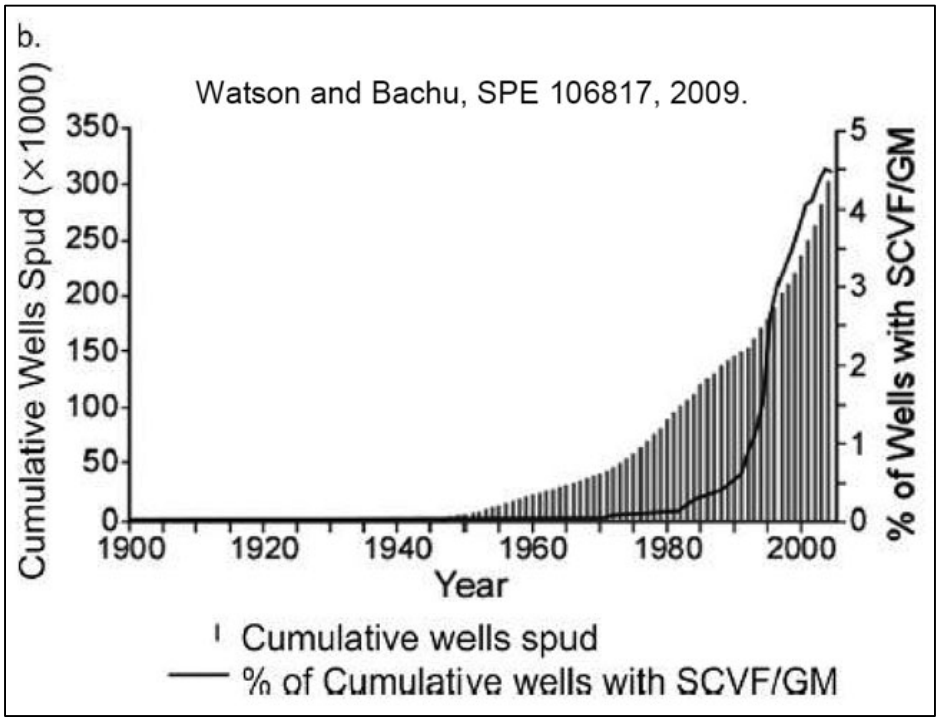
"The guy standing behind me was from Halliburton. And he said: "Ah! *That's data from offshore wells*." This is the summer *after* the problem in the Gulf of Mexico, where Halliburton did the cement job in an offshore well. And, this guy has the arrogance to tell me that it's irrelevant data!"

"So. I said fine. How about this data. Home grown Canadian data, by the way. This is data taken from 352,000 oil and gas wells in your country. I'm going to interpret it for you."

"What you need to be looking at is the solid lines. Starts in the year 1910 and goes all the way up to the year 2005. The paper was published in 2009. And, it shows a high variability in the percentage of wells which sustained casing vent flow for gas migration. Notice there have been times when 12% of the wells are failing. Notice when it caves down to about 2% (bottom right). That's because these are the new wells. Right. The older the well gets, the more likely that they are going to fail. But, even if we take the integral over the last, what, 80 years, or 90 years ...

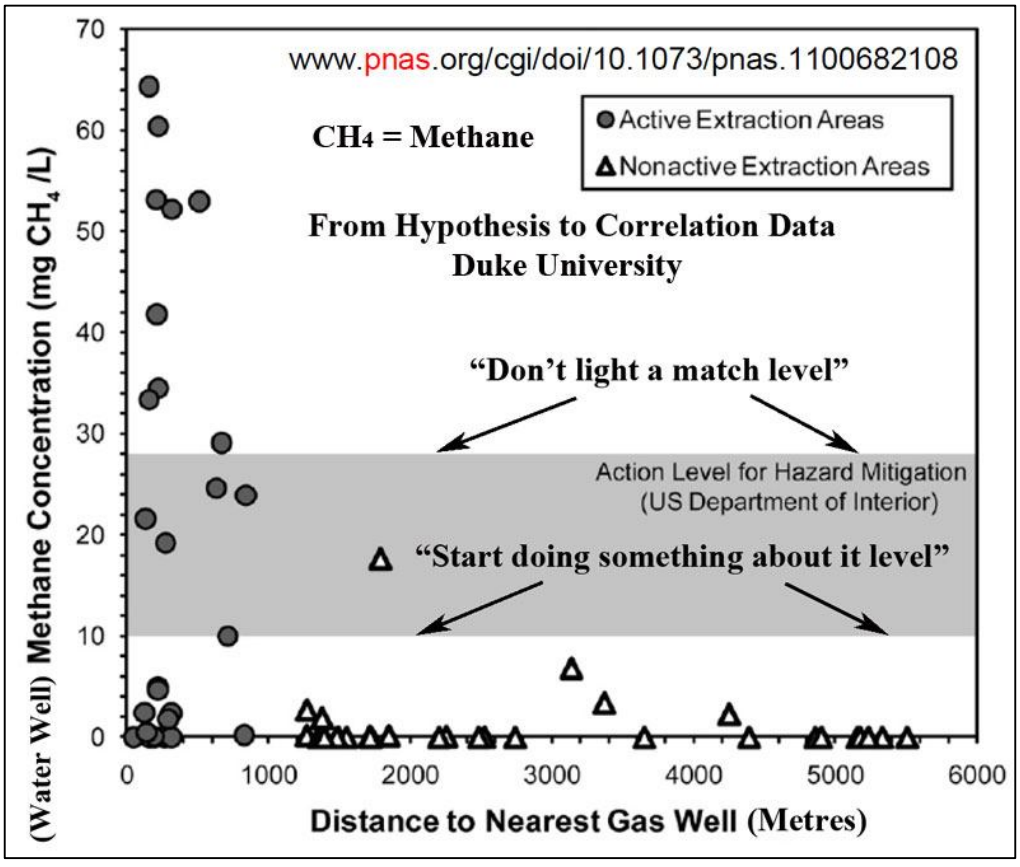


"Look over here and it says: "the percent of cumulative wells that have failed." Between four and five percent. These are *onshore* wells, not offshore wells. Canadian wells. So, pick a number - 5%? 20%? - it's not rare."



"More recent data. Colleagues of ours at Duke University did a study in Pennsylvania and New York that they published earlier this year, that examined the following scientific hypothesis. We hypothesized that there is a relationship between the distance between a water well and the nearest gas well, shale gas well. We hypothesized that there was a relationship between that distance: let's see if there is. So, they went out and they tested well water of 68 wells, where the wells were at a variable distance from the nearest gas well. So, let's see what the data says."

"The horizontal axis (below) is the distance to the nearest gas well, in metres. The vertical axis is the methane concentration in the water well, this is milligrams of methane per litre. What they see is, if your water well is on the order of 3,000 metres away from the nearest gas well, the probability that you are going to have a hair concentration is pretty low. There is also the possibility that you could be only 1,500 or 1,200 metres away and you still might have a little concentration. But,



"Engineers work with problems. All engineering problems are: I've got a choice of doing this, this, this, or this. I can't do them all. How do I optimize the situation that ultimately is never going to be perfect, but I control things. Like: I want to make sure the cement doesn't set up too soon or too late; I want to make sure the cement is sufficiently strong but not so strong that it is going to crack; I want to make sure the cement doesn't shrink when it cures, but I don't want it to expand too much either; and I want a cement that will bond perfectly to the steel casing and to all different kinds of rock. What kind of cement is that? We call it, **UNOBTANIUM**."

by the time you get to being about 1,000 metres away, the probability of you having a high concentration goes up! That's called correlation data. It doesn't prove causality, but it is correlation. A scientist looks at that and says, well, we formed a hypothesis that there is a correlation. There is. Now we have to go and figure out why. Why is that data saying what it is?"

"And, by the way. This grey area. These are the action levels for Hazard Mitigation for methane. At this level (the bottom) you are supposed to do something about the methane concentration in your house or your water well. At this level (the top), don't light a match, or force any kind of spark, because you are now going to have an explosion. So, as you can see, there is a significant number of wells in the danger level for wells that are within a thousand metres, 3,000 feet, of the nearest gas well. This research is ongoing."

"**The industry has data on over 2,000 water wells that they tested in Pennsylvania. They will not release the data. These researchers are colleagues of ours, and they have told us, to my face, that the industry will not release the data to them**."

Dr. Ingraffea then summarized all the points he made in examining Myth 2: *Fluid Migration from Faulty Wells is a Rare Phenomenon*.

"Okay. Summary on this data. The Truth is, Fluid Migration from Faulty Wells is a well-known problem - it shouldn't be a surprise to any company. It's a chronic problem that's occurred ever since they started drilling wells. It's an un-fixable problem, in the sense that you can never guarantee that any well will *not* have a loss of integrity. But you can guarantee, statistically, a predictable number *will*: on the order of five percent initially, higher later. Whose data did I just show you? Not mine."

"What's the health impact? One has to expect, statistically, that there will be contamination of Underground Sources of Drinking Water (USDW) *wherever you have drilling*. Whether it's for unconventional gas, conventional gas, oil, whatever. If you are going to poke holes into the ground, and you are going to install casing, install cement, and you are going to frack - even if you don't frack - you are going to have an underground source of drinking water contaminated, because the wells fail at a predictable rate. And, that means that you are going to have either drilling fluid, and/or frack fluid, and/or released hydrocarbons, migrating up outside the well with the potential for going into an underground source of drinking water or migrating all the way to the surface and in the atmosphere."