GSCHIS-A016.pdf

Author: Lawrence W. Morley

Title: The 'Lunatic' Fringe: Geophysics Comes to the Geological Survey of Canada 1952-68

Date of this version: May 2011

Number of pages in document: 15 pages

Author Biography:
Lawrence (Larry) W. Morley enrolled in an experimental interdisciplinary course called Physics and Geology at the University of Toronto in 1938 but interrupted his studies in his third year to spend five years as a sea-going radar officer with the Royal Navy and the Royal Canadian Navy. He returned to Toronto in 1946 and following graduation in Geophysics he worked in industry pioneering the new invention, the airborne magnetometer. In 1949, he returned again to the University of Toronto and completed his Ph.D. under J. Tuzo Wilson on rock magnetism in 1952. He immediately joined the Geological Survey of Canada to lead GSC's ongoing aeromagnetic program. From then until 1969, Dr. Morley, as Chief, Geophysics Division, expanded the program to encompass many developing branches of geophysics, including aeromagnetic, seismic, electrical, paleomagnetic and airborne radiation. In 1963, he was the first to propose the theory of magnetic imprinting of the ocean basins leading to the Plate Tectonic Theory but two international journals refused to publish his ideas, and he was scooped by others later that year publishing the same concept.

From 1969-1972 he was Director, Interdepartmental Planning Office for Remote Sensing that recommended the establishment of the Canada Centre for Remote Sensing (CCRS) within the then department of Energy, Mines and Resources, later Natural Resources Canada. In 1972, Dr. Morley was appointed the first Director General of CCRS and until 1980 led the organization in the development of comprehensive national and international programs. From 1980-1982, Dr. Morley was Science Counsellor at the Canadian High Commission in London.

Following his retirement from the public service in 1982, he worked as an international consultant and was the start-up Managing Director of the Institute for Space and Terrestrial Science, one of the new Centres of Excellence established by the Government of Ontario. Dr. Morley is an Officer of the Order of Canada, a Fellow of the Royal Society of Canada and has received honorary doctorate degrees from the University of York (Toronto) and the University of Waterloo.

THE 'LUNATIC' FRINGE
GEOPHYSICS COMES TO THE GEOLOGICAL
SURVEY OF CANADA 1952 – 68

BY LAWRENCE W. MORLEY MAY 2011

INTRODUCTION

This anecdotal account describes the experiences of my colleagues and me in starting the first Geophysics Division in the Geological Survey of Canada (GSC) during the period of my tenure from 1952 to1968.

Considering that the organizational culture in 1952 was steeped for 100 years in the academic science of geology, it was surprising to me how the alien concept of this 'upstart' technology of geophysical exploration was so enthusiastically supported by the senior management—in particular, the directors and chief geologist, Drs. George Hanson, Jim Harrison, Yves Fortier and Cliff Lord. In retrospect, I think that they may have shown a touch of indulgence when it came to the ready approval of my new proposals and additional staff.

That indulgence may have led to the expression applied to the Geophysics Division, often heard in jest, as 'the lunatic fringe'. Later, as our budget began to consume an increasing proportion of the total GSC budget, we were referred to as 'the millionaires'. In writing this paper, I feel rather like Rip Van Winkle as I have been away from geophysical exploration for forty years. My reason for leaving the Survey in 1969 was that I became consumed with the development of a National Remote Sensing Program. My last major involvement in geophysical exploration was as chair of the Canadian Centennial Conference on Mining and Groundwater Geophysics, sponsored by the GSC and NRC (National Research Council). It was held in Niagara Falls in 1967. This international conference became an opportunity for Canadian geophysicists to showcase their leadership, particularly in airborne geophysical innovation including aeromagnetics, airborne EM (electromagnetic) and airborne gamma-ray spectrometry.

MY INTRODUCTION TO GEOPHYSICS

I enrolled in Maths and Physics at the University of Toronto (U. of T.) in 1938 but took the option in my second year to transfer into an experimental interdisciplinary course called 'Physics and Geology'. To my surprise, only two of us had applied and we later discovered there had only been one previous graduate in this course named Tuzo Wilson. The course consisted simply of taking half of our lectures in the Dept. of Physics and the other half in the Geology Department. At that time there wasn't any course named 'Geophysics'. The two subjects, geology and physics, appeared to have irreconcilable differences. Geologists thought geophysical exploration was something akin to water divining while the physicists thought geology was an inexact science involving the gathering of numerous rock samples and categorizing them, rather akin to 'stamp collecting'

In the middle of my third year, I joined the Navy as a radar officer where I served for the next five years. Unlike most vets, I was lucky because I came out of the service with a new trade—electronics, which served me well in my later career.

In the autumn of 1945, I returned to the University of Toronto in order to finish my undergraduate degree. By this time there was actually a branch of Physics called Geophysics and they had recruited three dynamic professors: Arthur Brant (later of Newmont Mining Corporation), Norman Keevil Sr. (later the founder of Teck Corporation) and John Hodgson, the son of the Dominion Seismologist (later to take his father's position and eventually the Director of the Dominion Observatory). All of these men were inspiring teachers.

When I graduated, Professor Keevil, who also operated a small private company (Mining Geophysics), hired me to operate a ‘Schmidt’ tripod magnetometer on a gold prospect in Northern Ontario. I spent two months working alone in a mosquito-infested muskeg, five miles from the main camp, doing geological mapping as well as the magnetometer work. I kept thinking there must be an easier and faster way to do this job. Then I remembered that Arthur Brant had mentioned in one of his lectures that Gulf Oil was developing an airborne magnetometer. After coming out of the bush, I immediately went down to Gulf Oil in Pittsburg and met with Leo J. Peters, chief geophysicist at the Gulf Research and Development Company. As I didn’t have my PhD, he said he could not hire me to do development work on the airborne magnetometer. However, he did offer me a job in seismic. I figured it would be ‘jug-hustling’, so I declined the offer. While I was starting to walk out, he said “There’s a man from Fairchild Aerial Surveys here today. You might be interested in meeting him. They have a contract with us to fly our first operational airborne survey”. Max Phillips, a small, dapper man with a commanding personality, came in and asked a few questions. He then said “Can you start tomorrow? I replied “Yes”. That ten minutes defined my future career. The job consisted of conducting a Shoran-controlled photogrammetric survey, followed by a low-level aeromagnetic survey at one mile line-spacing. Within two months, I was made party chief. We spent eighteen months flying mostly in the undeveloped llanos areas of Venezuela and Columbia.

I returned to Canada at the invitation of Photographic Surveys, a Canadian company working out of Toronto. It had been started by Douglas Kendall (the famous RAF officer who planned the ‘dam buster’ attack over Germany, using aerial photos). I spent two weeks with that company during their initial tests with a fluxgate magnetometer they made. It had three fluxgate sensors mounted mutually at right angles. If two of them were kept at zero output by manipulating the two levers, it meant that the third one would be aligned with the Earth’s total field which was the desired reading. I took one flight in the aircraft trying to keep the magnetometer aligned but found it impossible to do so. I suggested to Kendall that they should put servo motors onto the system to do that job. He said they couldn’t afford it. I resigned and joined Dominion Gulf. This was a new Gulf Oil subsidiary established in Toronto under Ed Westrick to exploit their unique patented airborne magnetometer for mineral exploration purposes. Two months later, Photo Surveys installed servos in their magnetometer system. I spent one year with Dominion Gulf managing the airborne program.

Having no experience in mineral exploration, Gulf contracted with Keevil’s company, Mining Geophysics, to provide the ground follow-up to aeromagnetic anomalies. They did the interesting work in interpreting the data, doing the detailed geology and recommending whether or not to begin drilling. The deal was that when an interesting magnetic anomaly was discovered, Dominion Gulf would have a year to decide if they wanted to invest in further follow-up. If they decided not to go ahead, Mining Geophysics would have the exclusive rights to do so at their own expense with subsequent rights to total ownership.

As I wanted to be more involved in the interpretation of aeromagnetic data, I decided in 1949 to go back to graduate work at the University of Toronto. By this time, Brant, Keevil and Hodgson had left and the new head of Geophysics was Col. Tuzo Wilson, freshly retired from the Army and having just commanded ‘Operation Muskox’, a large overland expedition to the Arctic Coast to familiarize the troops with the Arctic environment. Before the war, Tuzo had been a Rhodes Scholar at Cambridge studying geology and physics. In 1938, he had worked for the GSC. Later he completed a PhD in Geology at Harvard. It is interesting to note that he and Professor Hess of Princeton University coincidentally had taken a sabbatical at Cambridge at the same time in 1967. There, they met Fred Vine and the three of them came up with the basics of the new theory they called Plate Tectonics.

In the Geophysics Department of U. of T., Garland, Russell, Farquhar and West were assistant professors and were recent doctoral geophysics graduates. Tuzo Wilson’s chief interest was global tectonophysics and the growth of continents—a more academic pursuit than Exploration Geophysics.

For my Master's degree, I chose the title 'The Interpretation of Aeromagnetic Mapping' which was basically a review of the mathematical methods of analysis of magnetic data. For my doctorate, I chose 'Rock Magnetism' (later to be called 'Palaeomagnetism)', a subject more germane to the study of geomagnetic interpretation. My thesis work, which I considered not significant at the time, nevertheless enabled me, ten years later in February 1963, to be the first to submit a paper postulating the hypothesis of the magnetic imprinting of the rocks involved in 'Ocean Floor Spreading', supporting evidence to the theory of a periodically reversing Earth's magnetic field and providing a measurement supporting Wegener's long rejected theory of 'Continental Drift' and laying groundwork for the theory of Plate Tectonics. Unfortunately, my paper on this subject was rejected, first by NATURE magazine in the U.K. and then by the JOURNAL OF GEOPHYSICAL RESEARCH in the USA. In retrospect, it appeared that in all the later published articles relating to my rejected paper, the writers concluded that it must have been considered too revolutionary at that time. However, eight months later, NATURE did publish a paper by Vine and Matthews outlining the same hypothesis!

JOINING THE GSC

Shortly after receiving my degree in 1952, Tuzo Wilson received a call from George Hanson, chief geologist for the GSC. He was seeking a recommendation for a post-doctoral student to take over their aeromagnetic program. George Shaw and Tom Rowlands, who were key to the program, had left to go with the Aero Service Corporation in Ottawa. I was hired because of my experience with Gulf and Fairchild.

Upon arriving in Ottawa, I was met at the train station by Dr. Hanson who drove me around Ottawa to help me find an area where I might like to live. This was unusually kind treatment for a new employee.

The GSC was located in the beautiful old stone building called the Victoria Museum, located at the foot of Metcalfe St. in downtown Ottawa. Dr. Hanson showed me my private office with an adjoining laboratory on the main floor near the entrance to the Survey's portion of the building. The GSC occupied three floors of the western half of the Museum plus the full, dark basement where the GSC kept literally tons of rock samples—all registered and labeled, collected by the geologists on their field trips going back donkey's years. I was surprised by the comparative inequity in accommodations. About 30 of my PhD geologist colleagues were crowded into one large room on the west end of the building. (This was the room which had been used as a temporary House of Commons after the big fire of 1916 when the Parliament Buildings burned down). Each geologist had a temporary cubicle measuring about 12 feet square containing a small desk, a drafting table, a filing cabinet and a space for multiple drawers of rock samples. There was one telephone for all 30 of them. They arranged a roster amongst themselves for answering the phone—each person had to dedicate one day a month doing nothing but answering the phone. In contrast, I had this large office and an adjoining lab. I still had the nerve to ask for a secretary and to have my office re-painted. I was assigned Betty Thomas, the best typist in the typing pool as my secretary. She stayed with me my whole career in the Department and increased my output and office efficiency by 75 percent. In retrospect, I must have been regarded as the spoiled newcomer to the GSC.

BEGINNINGS OF THE GSC AEROMAGNETIC PROGRAM

The airborne magnetometer had been introduced to the Canadian Government by the United States Geological Survey in 1947. The USGS had just completed an experimental survey over the U.S. Navy Petroleum Reserve on the North Slope of Alaska. The party chief, James Balsley, had been instructed to stop by Ottawa on his return flight to Washington in order to demonstrate the system to the GSC and the National Research Council. The magnetometer was a war surplus U.S. Navy airborne submarine detector which the military had recently declassified and converted for survey work. The NRC bought two other war surplus instruments which they gave to the GSC. One was converted for survey use and the second was used for spare parts. They also transferred Tom Rowlands to the GSC as he had worked on the modification at NRC.

George Shaw and Tom Rowlands had organized the airborne magnetometer program. A war surplus Canso aircraft was provided by the RCAF which was maintained and piloted under contract to Spartan Air Services of Ottawa. The rest of the GSC project staff were Fred DuVernet, an ex-RCAF pathfinder navigator, as head of the field staff; he was supported by two ex-RCAF navigators 'Baldy' Baldwin and Keith Owens. Steve Washkurak and Tom Ling were the two technicians. There was also a staff of twelve map compilers led by Margaret Bower and later by Ed Ready and Ray Langlois. The maps were prepared by the GSC drafting staff.

Photo: Larry Morley (left) and Fred DuVernet in front of GSC Canso aircraft, Fort McMurray, Alberta, 1952. This aircraft used on first aeromagnetic survey in Canada and in detecting the Marmora iron deposit in 1947. Photographer: Steve Washkurak.

By a stroke of luck, on their first survey, they detected a small but very intense magnetic anomaly located south of Highway 7, a short distance east of the town of Marmora in southern Ontario. It was a lucky find as the navigator had over-shot the southern boundary of the Marmora topographical map sheet which was to have been the designated limit of the survey. A partial map had to be compiled to show this anomaly. It occurred in a farm area underlain by a 200-foot layer of Paleozoic limestone which hid the source of the anomaly. At this time, there were very few prospectors or geologists who would have understood the significance of this type of anomaly and that it directly indicated the presence of a buried magnetite orebody. Also, it was not generally known that magnetite was becoming the preferred type of iron mineral over hematite, the previously desired ore for smelting purposes. A newly developed method of magnetic beneficiation had caused this change.

When the maps were released to the public, there were two men who knew the significance of the anomaly and who acted quickly. They were Louis Moyd, a freelance geologist working out of Bancroft and Gus Wahl, a local geologist working for Bethlehem Steel of Pittsburgh. However, there was a problem as to who owned the mining rights—the Crown or the person who owned the farm sitting on top of the anomaly. It turned out that, unlike the rest of Canada where the mineral rights are legally owned by the Crown, in this particular area, they were given to army veterans of the War of 1812 along with their land grants. Louis Moyd told me that he had hired a lawyer to negotiate the mining rights but that the lawyer made a mistake on the coordinates of the property so he lost out to Gus Wahl who hadn't left it to a lawyer. Gus told me he went to see the farmer early one evening. His wife said he was in the barn milking the cows. Gus spoke to the farmer under a cow's belly, asking to buy the mineral rights. When the farmer refused, Gus was ready. He had five thousand dollars in hundred dollar bills which he fanned out and handed to the farmer under the cow's udder. The rest is history. I tell this story, not only for its folklore interest but also because of its unusual and widely publicized method of mineral discovery. It played a key role in the future of the GSC and mineral exploration in Canada.

For several years after the discovery of the Marmora deposit, aeromagnetic maps released by the GSC became 'hot items'. Notices were mailed out a week in advance of the release date for each group of maps stating that they were available for sale at the GSC publication office in the Victoria Museum at 9 a.m. on the designated release date. Prospectors and mining company geologists would turn up an hour ahead of time to get to the front of the line. Having obtained their maps, they would rush down to the foyer of the museum where there was lots of room, spread out the map on the floor and do a quick evaluation of the likely looking anomalies. They would then get on the phone to contact their 'stakers' in the field who were 'axe-ready'. This would often be followed by a canoe race between competing prospectors to arrive at the anomaly site ahead of their rivals to stake their claim and get back to the registry office first.

After the move to the new building at 601 Booth Street, things became more routine as the maps began to pour out at a much greater rate. The production of these maps, along with the geological maps, proved to be a great stimulus to the mineral exploration business in Canada.

In the period between 1951 and 1960 when the GSC operated the Canso airborne Magnetometer program, Tom Ling and Steve Washkurak played a key role in keeping the old war surplus magnetometer working. They were hired in 1951 to take over Tom Rowland`s job when he left. After a quick turnover, they stuck with the job for the next 10 years as operators and maintenance technicians. Tom Ling had been a communications officer in the Merchant Marine during the war and was a survivor after his ship had been torpedoed. Steve Washkurak was a recent graduate of Ryerson College in Toronto, specializing in electronics.

In 1955, we took the Canso up to Resolute Bay in the Arctic to join 'Operation Franklin', Dr. Yves Fortier's epic geological survey of the Arctic Islands. Fred DuVernet, the navigator, had just completed an 'Arctic grid' navigational course invented by the late Air Commodore Keith Greenwood of the RCAF. In the Arctic, all the degree lines of longitude run together so normal navigational methods don't apply. Furthermore, the magnetic compass does not point towards the magnetic pole, which lies nearly straight below the aircraft, with the result that the compass needle slowly swings around uselessly. To make the story simpler, we were flying above total cloud cover thinking we were flying towards Resolute and we got lost. Fortunately there was a small hole in the clouds through which we saw the snowy cliffs of Devon Island which we recognized from having looked at aerial photographs. We dove through the hole and found that we had been 90 degrees off course headed towards Siberia! We then found our way, landed safely at Resolute and completed the mission of widely-spaced profiles flown over known sedimentary basins. We were able to estimate the thickness of these basins by mathematical interpretation. The thicknesses were roughly confirmed several years later by George Hobson who ran seismic profiles over the Beaufort Sea and the Sverdrup Basin indicating sedimentary thicknesses of more than 18,000 feet. These were the first geophysical surveys conducted in these areas which are now believed to contain massive petroleum reserves awaiting the final melting of the multi-year ice, clearing the way for exploitation.

In 1968 during my last year before leaving GSC, the Director, Yves Fortier, allowed me to go on leave from the Geophysics Division to work in the Program Planning Office for Remote Sensing. I gave Steve Washkurak some of my field travel money and asked him to go to New York to purchase a war surplus infrared line-scanner of the type used by the U.S. Military in Vietnam. He did so and got it working. This was the first encouragement to help the Planning Office on its way. Al Gregory who was head of the Remote Sensing Section of the Geophysics Division had just resigned to join the Geological Staff of Carleton University. As his last job, I asked him to go on a month's tour of the few remote sensing labs in the U.S. to see what we could learn. This knowledge, together with what Washkurak learned at the first ever remote sensing symposium in Ann Arbor Michigan in 1968, gave us an early start in Remote Sensing.

After I left the GSC, Washkurak undertook a number of innovative projects. He obtained a satellite dish and built a receiver to be able to read out data from the first NOAA weather satellite. He used it to provide weather data for the aircraft operated for George Hobson's Polar Shelf Operations in the Arctic. He also provided technical information to HMCS BONAVENTURE, the Canadian Navy's aircraft carrier, for their meteorology unit to be able to obtain local meteorological data while at sea—an important function for aircraft carriers.

After the beginning of the Federal-Provincial Program, when the job was contracted out, Ling and Washkurak both devoted their careers to instrument development along with a new employee, Peter Sawatzky, an electrical engineer. After the development of the airborne proton magnetometer, they were involved in building magnetometers—Sawatzky with the ship-borne magnetometer and Washkurak with an installation in a Beaver aircraft. Washkurak had the idea of transmitting the fixed-ground station magnetic readings (which recorded the disruptive diurnal variations of the Earth's magnetic field) directly via H.F. radio to the aircraft in order to automatically subtract those readings from the aircraft data in 'real time', thereby saving hundreds of hours in compilation time. He took the idea further by suggesting that the Beaver aircraft could fly along the topographical contour lines while recording in order for the aircraft to be able to fly at nearly a constant height above ground, making mountain surveying a lot more accurate and very much less dangerous. Nowadays this is done using helicopters but that was considered too expensive at that time.

In 1962, I was visited by Dr. Bimal Bhattacharyya who was seeking a job after having just finished a post-doctoral fellowship at the National Research Council. He had completed his doctorate at Hyderabad University in India in geophysics. His interests and particular expertise were in mathematics and theoretical physics. He was someone I figured we needed. Within a year of joining the Geophysics Division, he had become internationally recognized as a leader in the field of mathematical interpretation of aeromagnetic data. His arrival at the GSC coincided with that of the digital computer. He pioneered in the development of algorithms for compiling and interpreting aeromagnetic data which assisted the GSC and industry in the conversion from analog to digital handling of aeromagnetic data. He left in 1970 to accept a tenured position at Berkeley, California. He passed away prematurely there in 1977.

'BEHIND-THE-SCENES' STORY OF THE APPROVAL OF THE FEDERAL-PROVINCIAL AEROMAGNETIC SURVEY OF CANADA

The plan nearly failed on several counts, but was finally approved. In the GSC, we had been making slow progress with the old Canso aircraft for about eight years, flying about 40,000 line-miles a year in various parts of Canada, in the same mode as was originally set up by George Shaw and Tom Rowlands in 1947. We had been trying to choose areas which we knew were going to be geologically mapped in the following year in order that the mapping geologists would be able to use the magnetics to extrapolate their mapping under the extensive overburden in the Canadian Shield. WRONG! This was against tradition in the GSC. Nothing was to be put on a GSC geological map unless a geologist had identified the rock or the structure on the ground. Even photo geological evidence was not allowed on a geological map unless the evidence was later confirmed on the ground. This idea was never used. Anyway, Cliff Lord, with the innovative use of helicopters for field mapping, increased the production rate so dramatically that they got away ahead of us and this idea never happened. Later, with the subsequent development of the G.I.S. system, perfectly-registered overlays between different types of maps became routine in modern exploration methods.

The old Canso eventually became too expensive to operate, so we did what none of the air survey companies could afford—we purchased a small modern aircraft, the 'Aero Commander' which was a light, business twin-engine aircraft. It was converted for aeromagnetic surveying. This saved about 50 % of our operating costs. The air survey companies shortly followed suit.

In 1959, a very serendipitous event occurred. The late Tom O'Malley, head of Aero Service Corporation in Ottawa, came to my office and asked "How much per line-mile does it cost your division to carry out aeromagnetic surveys?" I replied: "About five dollars a mile". I did not tell him that salaries, map compilation, drafting and reproduction of the maps were not included. He replied they could do it for four dollars a mile and that did include compilation, drafting and map reproduction. He did not tell me that the one-dollar per mile required to pay the Gulf royalty on their patent was not included. His proposal was definitely food for thought.

When I arrived home that evening, I had a thought: "Why not do the whole Canadian Shield under contract to the air survey industry and ask the Provinces to pay half the cost for the surveys within their own provinces?" The air survey companies had obviously run into hard times and were stuck with too much capacity and competition. They would have had to cut back on staff and aircraft. At the time, there were six companies in this business in Canada. I became so excited about the idea that I phoned our director Jim Harrison at home that evening. He told me to write it up and let him have a look at it. When he read the proposal, he immediately passed it on to the Deputy Minister, Marc Boyer, who apparently was just as excited as I. He said he would have to take it up with the provinces at the Provincial Mines Ministers' annual meeting which was coming up early the next month. The provinces all agreed that they would pay for half the cost for areas flown within their respective provinces, provided they could chose the areas to be flown each year. It remained only for both the Federal and Provincial cabinets to approve the proposal. I was called to the deputy minister's office to meet with the Minister who would have to sign the proposal, as a cabinet document. The Deputy Minister and I both waited with bated breath while the Minister read the title out loud "GEOLOGICAL Survey". He then said "very logical" and signed the paper without reading it. He was new to the Ministry and had little background in resource development. Later I thought "If he is the one person who is going to have to present the idea to Cabinet – it's going to die!"

I knew about the Government's "Roads to Resources" initiative which envisioned the building of several new roads leading northward into the Shield where several mineral deposits had been newly discovered. I figured that the aeromagnetic program could ride in under that umbrella. Alvin Hamilton, the Minister of Northern Affairs and Natural Resources, was the idea man for the roads initiative. I knew him as he was a member of our church in Manotick where I lived. At that time, it was definitely against protocol, and probably still is, for a civil servant to 'go above his superior's head' by talking directly to a Minister and not going through proper channels. But luck was with me. I was on a TransCanada Airlines flight, coming back to Ottawa from Toronto when I spotted Alvin Hamilton a few seats ahead of me. He was alone and the aisle seat was vacant. I went up to say hello and he invited me to sit down. I eventually unleashed the idea of the Federal-Provincial aeromagnetic survey plan which he had not heard of but was very interested in because he said his brother was a geologist. He asked a lot of questions.

Within two weeks I had a phone call from our Deputy Minister, Marc Boyer, who informed me that the project was approved by Cabinet and asked if I would join him for dinner at the Chateau Laurier Grill to celebrate. It turned out that this was the first time I was thrown out of a restaurant. We had both had a couple of drinks and he liked to sing. So did I. We sang along with the band and, after about three or four of our favorites, the head waiter came over and asked us to leave as we were disturbing the other diners. What a perfect ending to a glorious celebration!

That's not all. Two years earlier I became concerned that, at any time, Gulf Oil might come after us for the dollar-a-mile royalty they claimed we did not pay for previous surveys. I knew that Gulf was supposed to have an exclusive patent on the airborne magnetometer concept, even though we were using a war-surplus airborne submarine detector. They claimed to have been the inventors before the war and had agreed to turn over the idea of their patent to the U.S. Navy as a secret submarine detector. Bell Laboratories were chosen by the Navy to mass produce the airborne magnetometer in the USA. They made several improvements to the Gulf patent. In 1960 our Department received a letter from Gulf's lawyer, who happened to be the Conservative's Toronto constituency president, who indicated that the government owed them one-dollar royalty for each mile of survey we had completed. This would have cost the government about half a million dollars since the start of the program in 1947. Furthermore, Gulf insisted we stop using our own magnetometer and purchase a Gulf magnetometer on which we would be expected to pay one dollar per mile for all future surveys. They would forgive the royalty on the previous surveys if we agreed to this. This turn of events could have closed down the proposed program.

It was a good thing that we had anticipated this. Two years earlier, looking through 'Physics Review', I had noticed an article by Dr. Martin Packard of Varian Associates in San Francisco reporting that they had invented a proton precession magnetometer. It was very simple to make. It consisted of a small tube of water around which a coil of wire is wrapped. Short, strong pulses of current are passed through the coil which has the magnetic effect of aligning the spin of all the single electrons in the many hydrogen atoms in the water into the direction of the coil's axis. When the magnetizing electric pulse stops, the spinning electrons, for a few seconds, would precess in unison and induce in the same coil an alternating frequency that is inversely proportional to the total Earth's magnetic field. The pulses are applied about every second. All one has to do is to measure the frequency to calculate the Earth's field. The main advantage is that it is not necessary to keep the sensor aligned in the total Earth's field. The precessing electrons handle that automatically.

I phoned the inventor of the proton magnetometer, Dr. Martin Packard, and he said: "Come on down. I have an instrument I can demonstrate to you." In San Francisco he took me out into a park to demonstrate the magnetometer. It had the tube of water fastened to the end of a four-foot wooden stick. We walked around, taking individual readings of frequencies and he demonstrated that the readings could be reconfirmed when we came back to the same spot to repeat them. I immediately knew that this instrument could easily be used as an airborne magnetometer and asked if the GSC could purchase a non-exclusive license. He replied that unfortunately, he had sold the exclusive airborne rights to a Los Angeles company, and so I returned home empty handed. But then I asked my friend in the Canadian Patent Office, Peter Presunka, what I could do about it. He looked up the Varian Patent and discovered that the U.S. patent had been registered for more than a year but, although they had patented in many countries, they had failed to do so in Canada. This meant we were free to use it if we could make it.

Steve Washkurak was assigned the job. Try as he might, Steve couldn't get the system to work for two or three months. Then one day he phoned and said he got it to work. "How did you do it"? I asked. He replied that he lifted it off the floor and got a signal! So that was why Martin Packard had it on the end of a stick. It would work only when the ambient field was reasonably uniform and therefore not near the earth or any metal on the bench or floor.

There was another major problem. The output of the instrument is a frequency, inversely proportional to the Earth`s field, measured in five figures. Therefore the cost of compiling the maps, which normally equals the cost of flying, would be doubled by having to calculate the reciprocal for each five figure reading, once a second, for every two seconds of flight to convert to field strength. I asked Computing Devices of Ottawa if they could make a simple analog computer to do this. Digital computers were not then available. I asked their technical sales representative to come and make us a proposal. I also asked Paul Serson to the meeting because he was the most informed electronics person I knew. (Dr. Paul Serson of the Dominion Observatory was developing a unique three-component airborne fluxgate that he later used each year in a chartered commercial aircraft to map the vertical, horizontal and variation of the Earth's magnetic field for publication on marine and aviation navigational charts. He was the first person to accomplish this and his mapping services were used internationally.) The representative said they could make a specialized analog computer to do the job and his cost estimate was one million dollars! I think I laughed out loud but Paul was quite annoyed. He went home that night and thought of a simple circuit to do the job. He wired it up the next morning and found it would work. He patented the idea and we had the world's first direct-reading proton precession airborne magnetometer. Steve Washkurak, Len Collett, and Peter Sawatzky made up two magnetometers, one airborne and one for the towed-fish in what was to become a ship-borne magnetometer. The technology on the direct-reading proton magnetometer was transferred to Canadian industry. Both Barringer and Scintrex models became commercially available.

Spartan Air Services had won the first bid under the Federal-Provincial Aeromagnetic Program. It was for the complete southern half of Northern Ontario. The company was also the first to use an airborne proton magnetometer. That instrument then became a world standard and pretty well made the Gulf magnetometer obsolete.

There were six technically qualified air survey companies in Canada that could do this work but any single one did not have the capacity for such a large program. Their managers and I had a meeting at which I suggested they form three partnerships to bid on the contracts, which they did. In general the plan was as follows:
1. The program would last 17 years and each contract would be for 3 years so that companies could plan ahead.
2. Only two contracts would be let, every three years, to the partnership with the two lowest bids.
3. Each contract would have a clause, linking their initial bid to the official cost-of-living figure for each of the subsequent two years of the contract.

This idea was probably the first of its kind in the Federal Government. The program continued from 1960 until well into the 1990s. I had predicted in the initial proposal that the data which, ultimately consisting of more than 5,000 aeromagnetic maps at a scale of 1:50,000, would be used by prospectors for the next 50 years. The 50^{th} anniversary was last year in 2010 and the data is still in demand. (Note: At that time, each department had its own purchasing section unlike the present system where all purchases and attendant negotiations are managed by Public Works and Government Services Canada. In practice, this meant that all major purchases and contracts were left to the Technical Division. They could not only write the specifications but also negotiate directly with the potential suppliers. This gave considerable freedom to determine the qualifications of the bidders and also to recommend the winner. In my opinion, it was much cheaper, faster and generally a more efficient way to work.)

Canada was the first country, followed by Australia, to have such comprehensive coverage available to the public at low cost. There is no doubt that these data, when combined with the geological maps, gravity maps, airborne EM and natural radioactive radiation data, provide an excellent starting point for the modern prospector. Aid agencies of several countries, as well as the U.N. Development Agency, have been using this Canadian expertise to help developing countries assess their mineral resources and attract international investment. These technologies are now especially advanced amongst Canadian companies which, over the years, have spearheaded mineral exploration projects worldwide.

SHIP-BORNE MAGNETOMETER SURVEYS

The proton magnetometer offered a chance to do ship-borne surveys. Herb Gray, the Dominion Hydrographer who was a member of our Department (Mines and Technical Surveys), was planning to use the last of the retired RCN Corvettes 'HMCS SACKVILLE' to do routine bathymetric surveys of the Grand Banks off Nova Scotia and Newfoundland. He would use an electronic echo sounder and planned the survey lines to be one nautical mile apart. Accurate ship-positioning was to be done by Shoran navigation which used fixed ground stations located onshore. I thought this would be an excellent chance to do ship-borne magnetic surveys by towing a 'fish' behind the ship to measure the magnetic field. I arranged with the RCN Captain of the Halifax Dockyard to make us a small wooden cabin to be placed on the ship's fantail to house the magnetometer reel and cable and electronics. Peter Sawatzky, our electronic engineer and Len Collett designed and manufactured the 'fish' to contain the magnetometer as well as the rest of the system. Peter then did the field work for four consecutive summers, completing about 50,000 line miles of data followed by published maps. These maps, together with George Hobson's seismic investigations, were the first indication of the underlying geology of the East Coast waters, which later attracted the oil companies to do further exploration.

OFFSHORE AEROMAGNETIC MAPPING

Offshore aeromagnetic mapping was not a priority for the GSC at that time. However, the RCAF was interested because of the possibility of confusing geomagnetic anomalies with submarines. We had very good relations with Lee Godby of the National Aeronautical Establishment (NAE), a division of the National Research Council. His instrument development section operated a Northstar aircraft which they used for testing their very successful magnetic compensation system which became a standard for 'tail-stinger' magnetometer installations used in maritime reconnaissance aircraft for submarine detection. Lee Godby and Peter Hood arranged, through the RCAF and NAE, to use the aircraft to do an aeromagnetic survey of the Scotia continental shelf off Halifax. Margaret Bower was also seconded to the project for data processing. This cooperative project was very successful and was carried on with RCAF support for three years.

Peter Hood has described these surveys in his well-documented 'History of Aeromagnetic Surveying in Canada' published by the Society of Exploration Geophysicists in their 'Leading Edge Magazine' of November 2007, vol. 26, No.11. Another paper by Peter entitled 'History of the Development of the GSC Aeromagnetic Gradiometer' is posted on the NRCan library website as GSCHIS-A013 (http://gsc.nrcan.gc.ca/hist/friends_e.php).

AIRBORNE EM

Shortly after joining the Survey in 1952, I placed a high priority on airborne methods, arguing that the GSC could have little or no national impact by supporting a few scattered ground geophysical parties in the field. With the success of the airborne magnetic program and the detection of the Marmora anomaly, we naturally thought of getting involved in airborne EM (electromagnetic). Both Len Collett and I had some familiarity with the beginnings of airborne EM at U. of T. We were students together with Stan Ward who worked with McPhar Engineering, the inventors of the first operational airborne EM system. We thought that the GSC should also carry out airborne EM surveys on a quadrangle basis as was done with the airborne magnetometer. I suggested this to George Hanson who thought it was a good idea but thought I should speak to the Deputy Minister, George Hume. In a few days, I was summoned downtown to Dr. Hume's office and was surprised to see that Mr. Parker, the exploration manager for International Nickel was there. Dr. Hume had spoken to him on the phone in Copper Cliff about the proposal. He was so concerned that he decided to come to Ottawa to oppose the idea. I understood why. INCO had funded McPhar to develop the airborne EM. system and they owned the exclusive patent. Furthermore they had just had two very successful discoveries with the system: the Thompson nickel deposit in Manitoba and several good discoveries in New Brunswick. They had the monopoly on the system and they did not want competition. The meeting was very short. Mr. Parker literally pounded the table with the remark “The Government will not do airborne EM!” and as far as I know, they have not done so ever since.

In 1953, there was a staking rush in New Brunswick for base metals because of the discovery of the Brunswick No. 6 orebody near Bathurst. Many companies hired geophysicists to do ground-based EM surveys which were slow and expensive. The rumor spread that INCO moved in with their airborne system and ‘creamed off’ all the important EM anomalies while their ground-based competitors could only shake their fists at the aircraft as it flew overhead. A few years later, several new competing systems were developed which pretty well broke INCO’s monopoly.

MAGNETOTELLURICS

Professor Alex Becker of the University of California, Berkeley (ret.) recently reminded me of his work in our Geophysics Division at the GSC which he joined in 1965. Much of his time was spent seconded on leave to Ēcole Polytechnique in Montreal where he joined Dr. Ted Koulomzine, Professor of Geophysics, in the study of magnetotellurics. This technology uses the very low frequency of naturally-occurring electromagnetic energy released by distant thunderstorms and has the advantage over conventional EM of deeper penetration. In their research, they had a number of ‘firsts’ using an instrument they designed and made. Prof. Telford used this instrument in several projects he conducted abroad. Becker conducted the first successful fault detection in Canada using a very low frequency method over the Gloucester fault near Ottawa. The equipment consisted of old lend-lease radios returned from Russia. Eventually, this led to a Canadian patent which was licensed to Geonics in Toronto. On another project, they borrowed a receiver from Tony Barringer’s famous INPUT airborne EM system. They digitized and calibrated it in order to do quantitative interpretation of the data. Later, Becker (with Erik Schwartz) also conducted the electromagnetic analysis of lunar soil samples returned on the NASA Apollo Mission.

RADIOACTIVITY

We were lucky to be involved at a time when iron ore, uranium and copper/nickel were in worldwide demand. In prospecting for uranium, the gamma ray Geiger Counter was used until Prof. Brownell and his colleagues at the University of Manitoba invented what they called the ‘Scintillometer’. It was based on a transparent sodium iodide crystal being monitored by a sensitive photoelectric cell which would detect the scintillations caused by gamma rays being absorbed in the crystal. Lee Godby of the National Aeronautical Establishment had published a report on the use of such an instrument from an aircraft to detect uranium ore. Len Collett and I decided to equip the GSC Canso with a scintillometer which could be used alongside the magnetometer. This worked very well and we mapped plenty of large anomalies. Unfortunately, when investigated on the ground, the rocks turned out to be large exposures of ordinary granites which contained a lot of naturally radioactive potassium. With further investigation, we learned that uranium and thorium emitted gamma rays which were much stronger than those emitted by potassium. We then argued that the uranium rays would be slowed down by the atmosphere and that in any event, at the height of 500 feet, there would simply be a cloud of indistinguishable scattered gamma rays. We were about to give up until Hans Lunberg, the famous geophysics pioneer, came up with a device that he claimed could separate the rays coming from uranium vs. potassium and thorium. He recorded the more energetic uranium gammas by ticks on an edge-pen on the paper recorder while the full gamma count was recorded on the main pen. This gave us hope that it would be possible to cut out most of the soft scattered rays by using a lead cone with the open end pointing downward. After a few calculations, we decided that this would be too heavy to carry in a small aircraft.

In 1949, the Canso was flown over a large portion of central Newfoundland. The scintillometer recorded large radioactive anomalies during most of the flights. At first we thought that the instrument was faulty but when tested later, if appeared to be OK. Shortly after it was revealed in the press that Russia had exploded their first nuclear bomb test which was not an underground test. As our survey had been conducted shortly after the test, we concluded that the spurious readings must have been caused by nuclear fallout. I reported this to Atomic Energy of Canada but received no answer. I felt like the originator of a 'conspiracy theory'. After Chernobyl, 'I told you so' is a very good feeling.

I had heard the name of Al Gregory, a geologist working for Eldorado Nuclear who had a lot of experience in this field and, as that company was about to close, he agreed to join the GSC. To clear up this problem, he borrowed a rather cumbersome laboratory gamma ray spectrometer from Frank Senfle in the Mines Branch. He set up the spectrometer at the top of a 50-foot tower which the NRC had at their field station. From the Eldorado company in Port Hope, he borrowed separate large bags of potassium, uranium and thorium, put them in a pick-up truck and placed them at a slant distance of about 500 feet away from the top of the tower. Sure enough, he was able to distinguish the contents of the truck by separating the three different energies of gamma rays coming from potassium, uranium and thorium. This experiment provided confirmation that we should continue to try to develop an airborne gamma ray spectrometer.

We employed a summer physics student from McGill, Ron Doig who had done research in this field. He designed and made a light-weight portable field instrument which could be used on the ground to determine the K, U and Th content over a rock outcrop. The next step was to design an airborne instrument to do the same thing from the air.

Then, to my disappointment, Al Gregory resigned from the Survey to accept a professorship at Carleton University. Eventually I found a qualified replacement – a Cambridge geochemist Dr. Arthur Darnley. He joined the Survey in 1967 and very quickly took charge of the airborne project. He hired Dr. Bob Grasty, a geophysicist from London's Imperial College in the U.K. and consulted with Quentin Bristow of Atomic Energy of Canada to design the spectrometer. Darnley acquired a SKYVAN aircraft with sufficient payload to carry the heavy equipment. It could be loaded and unloaded very easily. Quentin Bristow, who later joined the GSC, has written a detailed and interesting account entitled 'Airborne Gamma Ray Spectrometer: A Canadian Success Story' 24 pages, 2009, posted as GSCHIS-A012 on the NRCan library website. This is an authoritative account of the technical and administrative difficulties the group faced in bringing this development to fruition. The technology was transferred to Canadian industry and has become a world standard. 'Gamma' Bob Grasty used the system to detect the remains of the nuclear power generator used in the Russian satellite that crashed in the Northwest Territories. He has published an account *The search for COSMOS-954* in the Proceedings of the NATO Conference on Search Theory and Applications, Portugal 1979, Plenum Press, New York and London, pp.211-220, 1980.

SEISMIC

Seismic exploration had never been carried out by the GSC previously, as it was considered too direct a prospecting method and should be left to the oil companies. However, this placed the stratigraphers and Pleistocene geologists at a great disadvantage vis-a-vis their university and private company geologists who did have access to seismic data. The GSC geologists had to deduce the buried structures by extrapolation of surface evidence.

An experienced seismologist, George Hobson, whom I had met as a grad student at U. of T. in 1946, joined the Geophysics Division in 1958. He had a Maths and Physics degree from McMaster and an M.A. in Geophysics from U. of T. which was followed by 12 years experience in the Western oil patch ending up as chief geophysicist for Merrill Petroleum in Calgary. He was a great catch for the Geophysics Division. There was only one problem. There was no room in the Victoria Museum or in any nearby building we could afford for him and his two technicians, Hugh McCauley and Ron Hodge, with all the instruments and equipment they would need. The only nearby place we could find was underneath the stands in the nearby Auditorium on Catherine Street. Unfortunately, there were no windows in that dark hole. We had to look much further afield. Then we heard that there had been an explosion at the Auditorium caused by cleaning fluid left in the room beneath the stands. Curiosity took me over to look at the damage and guess what. The explosion had blown a huge hole in the brick wall right where we had wanted a window. I told the owners that if they put a large window there, we would rent the space. There was room for both George Hobson and his crew as well as for Peter Sawatzky with his ship magnetometer equipment. They all moved in and had lots of light with a huge picture window in their space, just two minutes away from the museum.

Their first job was to tackle southwestern Ontario, near Petrolia, the birthplace of the petroleum industry in North America. Oil companies were interested only in the West at the time. Hobson and crew tried reflection methods for a couple of years but were unable to resolve the layering beneath the high velocity dolomites which were near the surface.

After moving to the new GSC building on Booth Street, we decided that it would be best to continue to work in some area where the oil companies had no interest. Hobson suggested that the Arctic Islands would be a good choice, since he could get logistical support from Fred Roots, the first Director of the Polar Shelf project. Besides, as seismic work had never been done in the Canadian Arctic, nothing was known about the subsurface. Instead of doing reflection work, George suggested refraction. It would be more representative of a larger area for each shot and he would end up at least with an estimate of the thickness of the sedimentary basin. He decided on the Sverdrup Basin, which covered large parts of Ellef Ringes and Melville Island. He discovered that this Basin deepens towards the south end from about 15,000 feet in the North end to more than 18,000 feet in the south.

In the second year, Dr. George Sander was hired by the Seismological Section of the Dominion Observatory which had also become interested in explosion seismology. He and George Hobson worked together in the Arctic. Oil company interest in the Arctic was aroused for the first time. The Panarctic consortium was formed and they actually produced oil from Melville Island but were unable to produce it economically as there was too much competition from less expensive southern oil.

In the early 1960s Hobson worked in the offshore around Newfoundland and later in Hudson Bay in cooperation with the newly-formed Bedford Oceanographic Institute. They worked from the new oceanographic research vessel BAFFIN and discovered that the sedimentary basin in Hudson Bay was only about 4000-5000 feet in depth (which confirmed Margaret Bower’s approximate determination from an aeromagnetic profile we had flown in 1953). This finding resulted in a diminished interest from the oil companies. In the late 1960s, Hobson turned his focus to Pleistocene and groundwater work. Through Norman Paterson, he learned about the hammer seismic method that had been invented in South Africa. Hobson worked in the Yukon helping prospectors by measuring the depth to bedrock in some of the river valleys. Hobson became involved in helping the designers of the famous Winnipeg Floodway by defining depth to bedrock information. In Ottawa, he provided information for the building of the National Art Centre tunnel. He also saved the new Department of Environment from putting their new building in the wrong place over a geological fault near Dow’s Lake.

This work encouraged industry to use hammer seismic, later to be replaced by ground–penetrating radar, as an urban infrastructure design tool. It is interesting to note that Peter Annan, founding president of Ncubed, was one of the originators of ground-penetrating radar. He had worked as a summer student in the Geophysics Division in the late 60’s which was where he first decided to work on Ground Penetrating Radar as a career. This technology has now become a billion dollar a year business worldwide.

When Jim Harrison was planning the Calgary sedimentary geology office, I wanted to include a substantial seismic section, but Jim said he had to drop that if the Calgary branch were to be approved. I was disappointed by that decision.

PALAEOMAGNETISM

This was the subject closest to my heart as it was my thesis subject at the U. of T. It was a lonely subject because at the time I was doing my thesis, there were so few people in the world who were involved in such an arcane subject—and that continued for some time at the GSC. Ten years later, it became one of the hottest specialties in Earth Science.

In 1957 Phillip Dubois, an American who had done his PhD at Cambridge under Keith Runcorn, joined the Geophysics Division. I was very pleased. He was the first palaeomagnetist to show that the polar wandering curves from Europe and North America, plotted against the geological age of the rock samples, showed a maximum separation of 60 degrees of longitude over a period of 30 million years. This figure was approximately the same amount that the two continents of Europe and North America appear to have drifted apart according to Alfred Wegener's theory of Continental Drift. This was the first independent physical measurement supporting continental drift. I was hoping that he would be able to add more evidence to this idea, as I belonged to the smaller 'Drifter' group of palaeomagnetists who favoured the theories of continental drift and periodic reversing of the Earth's magnetic field. Unfortunately, he stayed only a short time before leaving to teach in the U.S.

Shortly after Dubois left in 1957, André Larochelle, who had just graduated from the University of St. Louis, was employed by the GSC to re-examine some oil company seismic records to assist in mapping stratigraphy in Alberta. He felt dissatisfied with his inability to glean any significant results in this work. He requested a transfer to the Geophysics Division and this was granted. I suggested to him that he might like to seek leave of absence to do graduate work in palaeomagnetism. I had observed from an aeromagnetic survey that Mt. Yamaska, one of the Monteregion plugs in the Eastern Townships, had what I figured to be a core of rock that was negatively polarized. I suggested that this could be part of his practical field work towards his doctorate. Andy agreed and spent the next three years at McGill studying palaeomagnetism and completing his PhD. He proved that the core rock in Yamaska was negatively polarized.

He returned to the Survey when we were in the new building at 601 Booth Street. He decided he would build what would be the first astatic remanent magnetometer in Canada, fashioned after the original one at Imperial College invented by Nobel Prize winner P.M.S. Blackett. Andy Larochelle not only made a beautiful instrument but also a 'tumbler' type 'magnetic washer' for demagnetizing the soft spurious magnetic component, a necessary operation before measuring rock samples. He also developed a portable electric core-drill which enormously increased the rate of obtaining oriented rock samples in the field.

Some GSC geologists became interested in palaeomagnetism. Dr. Walter Fahrig took many oriented samples of different swarms of diabase dikes and measured their remanence. This was after I left the GSC so I have never seen the results. I would still be very interested to know whether some of them were reversely polarized, as well as knowing their age. If they are Precambrian in age, they could add significant information about the Earth's magnetic field in Precambrian times about which nothing is known.

CONCLUSION

In retrospect, I feel that I was greatly privileged to have the opportunity to work in such a distinguished and venerable organization as the Geological Survey of Canada, particularly at a time of its extraordinary growth.

The enthusiasm of the staff in their work as witnessed by the fact that many often continued their studies at the office in the evenings and over the weekends—not to mention their long absences working in the field—all of which put an extra strain on family life.

It was not just a job. It felt that it was indeed a real service to the development of the Canadian Nation.