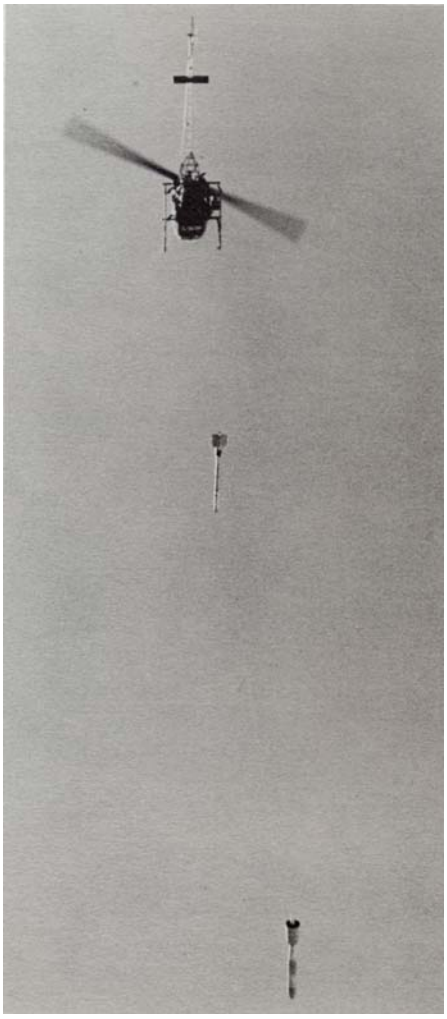
Airborne Magnetic Gradiometer for Petroleum Exploration (1967)

(Invented by Sheldon Breiner in 1961, as part of a research project for his M.S. Geophysics at Stanford University. Patent assigned to Varian Associates.)



A new geophysical prospecting device, developed by the Quantum Electronics Division of Varian, is now in use by a major oil company to map the earths sub-terranean geology. The device, known as an airborne geomagnetic gradiometer, provides outlines of the shape, size, and depth of underground formations indicative of oil deposits.

The new airborne system, which consists of two Varian rubidium magnetometers, can map several hundred miles of terrain per day to provide geologists with detailed data on which to base seismic analyses on the ground. The Quantum Electronics Division (QED) has received a $500,000 contract for the new geomagnetic instruments, which have been under field evaluation for five years. The Union Oil Company of California is Varian's licensee for airborne geomagnetic surveys.

Gradiometer Description

The airborne gradiometer, its concept and principles were conceived by Dr. Sheldon Breiner as his Master of Science research project in Geophysics at Stanford University. He applied for and received a patent, assigned to Varian Associates as a condition of his borrowing two rubidium magnetometer sensors to carry out his work. The vertical optically-pumped magnetic gradiometer consists of two rubidium magnetometers housed in separate aerodynamic pods suspended with 100 feet of vertical separation beneath a helicopter or airplane (but no horizontal separation, after correction for airspeed). Each capable of sensing a change in the earth's magnetic field of 0.01 gamma [now, 0.01 nanoTesla, or 10 picoTesla], a sensitivity equal to one part in five million of the earth's total magnetic field. The output of the lower magnetometer and the difference between the two is recorded simultaneously by instrumentation within the aircraft.

Advantages of the Magnetic Gradiometer

Whereas previous aeromagnetic studies using a magnetometer proved adequate in charting the total or regional magnetic fields, the gradiometer, by using two sensors, offers the petroleum geologist several significant advantages:

First of course, is the vertical measurement sensitivity. This enables the geologist to determine the depth and characteristics of underlying or basement structures and their probable effect on the overlying sedimentary strata in which oil is found.

Another previous stumbling block to highly accurate aerial geomagnetic prospecting was the continual change over time in intensity of the earth's magnetic field itself. The dual sensor configuration of the gradiometer automatically eliminates such changes and prevents the consequential distortion of the magnetic measurements.

The end result of the actual field survey consists of a map of the total magnetic field and a map of the vertical gradient of the field--both of which are synchronized to the position of the aircraft. To the petroleum professional, this presents a picture of the nature and configuration of the subsurface rocks which might contain petroleum.

Euler's Equation

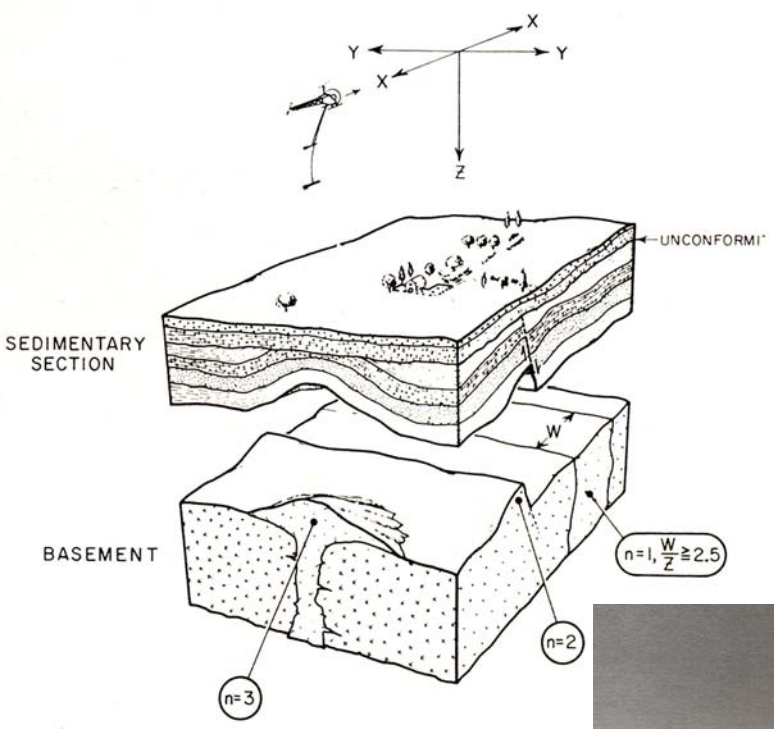
A key attribute and the basic impetus for the gradiometer was Breiner's innovation in the April, 1961 whereby he used the three components of the gradient and the magnitude of the total magnetic field of the earth to compute the distance between the magnetometer sensors (actually, the midpoint between them) and the upper surface of the magnetic (crystalline) basement rocks which underlie all petroleum basins. The mathematical relationship between these magnetic field attributes is described by what is known as Euler's theorem on homogeneous functions. A constant, called, "n" in the equation (also the rate of 'fall-off' of the magnetic field of the anomaly source) is an important descriptive parameter which characterizes the physical nature of the magnetic source, be it a semi-infinite block, a dike, anticline, a volcanic plug or a dipolar source, all of whose dimensions are small relative to the distance between the gradiometer sensors and the source minerals, namely, magnetite.

According to Varian, the tens of thousands of field survey miles flown have indicated the gradiometer will provide a profitable shortcut in preliminary prospecting stages over much of the earth's surface.

The rubidium magnetometers comprising the Varian gradiometer have been under development and refinement by the Quantum Electronics Division since 1957, licensed from the inventor of optically-pumped alkali-vapor magnetometer, Professor Hans Dehmelt of the University of Washington and subsequently a Nobel Laureate.

Breiner near Monument Valley, Arizona, testing the first rubidium airborne magnetic gradiometer, October, 1961

DIAGRAMMATIC CROSS-SECTION AND
SIGNIFICANCE OF THE "n" AS IT RELATES TO
THE CHARACTERISTICS OF THE GEOLOGY



Magnetic Airborne Magnetic Gradiometer Patent

1. US PATENT REFERENCE:

TITLE:	METHOD FOR DETERMINING DEPTH AND FALLOFF RATE OF SUBTERRANEAN MAGNETIC DISTURBANCES UTILIZING A PLURALITY OF MAGNETOMETERS
INVENTOR(S):	**BREINER SHELDON**; RUDDOCK KENNETH A; SLACK, HOWARD A
PATENT ASSIGNEE(S):	PURE OIL CO THE (68744) VARIAN ASSOCIATES INC (88480)

	NUMBER	DATE
PATENT INFORMATION:	US 3263161	19660726
	(CITED IN 010 LATER PATENTS)	
EXPIRATION DATE:	26 Jul 1983	
FAMILY INFORMATION:	US 3263161	19660726
DOCUMENT TYPE:	UTILITY; REASSIGNED	

THE METHOD OF DETERMINING THE DEPTH Z AND FALL-OFF RATE N OF A SUBTERRANEAN MAGNETIC DISTURBANCE BELOW AN AREA TO BE SURVEYED, COMPRISING: DETERMINING THE MAGNETIC INTENSITY H AND THE VERTICAL GRADIENT $H/$Z OF THE EARTH'S MAGNETIC FIELD FOR AT LEAST TWO POINTS OF SUBSTANTIALLY CONSTANT ELEVATION LYING WITHIN THE AREA TO BE SURVEYED; LOCATING THE HORIZONTAL COORDINATES X, Y OF SAID POINTS WITH RESPECT TO THE CENTER OF SAID SUBTERRANEAN DISTURBANCE; CONSTRUCTING AT LEAST ONE PROFILE OF THE TOTAL FIELD H; DETERMINING THE HORIZONTAL SPACE DERIVATIVES $H/$X, $H/$Y FROM THE SLOPE OF SAID PROFILE AT SAID