

## Rapid Cross-Plot Discrimination of Commercial Potash Mineralization – Case Histories

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### ABSTRACT

Potash minerals are a source of potassium, which is used for the manufacture of gunpowder and fertilizer. Commercial potash mineralization is often discovered when petroleum wells are drilled through evaporite sequences and the Gamma Ray log “goes off scale”. This is because potassium is one of the naturally occurring radioactive elements, emitting gamma rays from the <sup>40</sup>K isotope, in its decay to <sup>40</sup>Ar.

However, not all potash minerals may be commercial sources of potassium via underground mechanical or solution mining techniques and Potassium is not the only radioactive element. For example, the mineralogy of the McNutt “Potash” member of the Salado Formation in SE New Mexico, is extremely complex, consisting of multiple thin (i.e., less than 10 ft thick) beds of six low-grade (radioactive) potash minerals, only two of which are commercial. There are also four non-radioactive evaporite minerals, one of which interferes with potash milling chemistry, and numerous claystones and Marker Beds (shales), with GR count rates comparable to the low-grade potash.

Because of this complexity, traditional wireline and Logging While Drilling Potash Assay techniques, such as Gamma Ray log-to-core assay transforms, may not be sufficient to identify potentially commercial potash mineralization, for underground mining. Crain and Anderson (1966) and Hill (2019) developed linear programming, and multi-mineral analyses, respectively, to estimate Potash mineralogy and grades. However, both of these approaches require complete sets of multiple log measurements.

In SE New Mexico, petroleum wells are drilled through the McNutt “Potash” member of the Salado Formation, with air, cased and drilled out to TD in the underlying sediments, with water based mud. Complete log suites are then run from TD to the casing shoe, with only the GR and neutron logs recorded through the cased evaporite sequence for stratigraphic and structural correlation.

As a result, numerous oil and gas wells, in SE New Mexico, have cased hole gamma ray and neutron logs, through the Salado Evaporite. Logs, from these wells

could provide a rapid Potash screening database, if used properly.

A simple screening cross-plot technique, the Potash Identification (PID) plot, utilizing only Gamma Ray and Neutron Porosity, is proposed and successfully demonstrated, as a potential screening tool. This technique can be used with both open and cased-hole petroleum well logs, as well as core hole wire-line logs, and provides discrimination of commercial potash mineralization from non-commercial (potash and non-potash) radioactive mineralization.

Case histories of the use of PID cross plots in the evaporite basins of Michigan, Nova Scotia, Saskatchewan, and SE New Mexico are described. The technique may also be useful in screening potential potash deposits in China, Europe, North Africa, and South America.

### INTRODUCTION

#### *Potassium*

Potassium is the 7<sup>th</sup> most common element in the Earth's crust. It is a common component in both commercial and non-commercial minerals. It is economically important as a food Preservative and seasoning, as well as a major component in gunpowder and fertilizer

Metallic potassium is highly reactive. Like sodium metal, potassium metal will spontaneously combust if exposed to air. Because of this, it does not exist in the native state. The most common “Potash” (Simple High Grade) Potassium Minerals are evaporites.

Potassium 40 (<sup>40</sup>K) is radioactive and decays to Argon 40 (<sup>40</sup>A), which is a stable isotope. The Potassium-Argon Age dating technique as been used to date igneous & volcanic rocks as old as 4,500,000,000 years and as young as 20,000 years. Commercial potash deposits are often discovered when GR curves in wells drilled through evaporites “Go Off Scale”.

#### **“POTASH” AND US POTASH HISTORY**

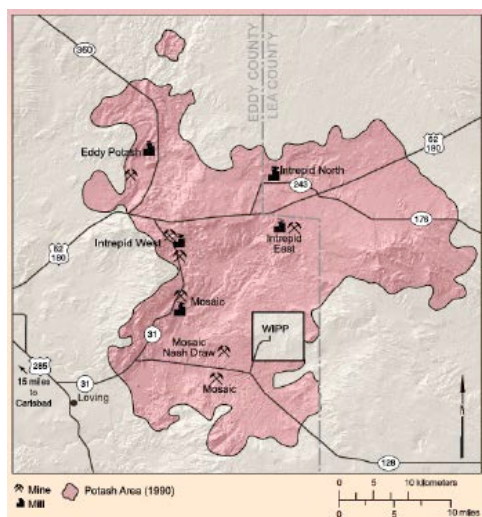
There is no Potash (K<sub>2</sub>O) mineral. The term “Potash” traces its origin to North American Colonial Times when “Potash”, used in manufacture of gunpowder, was one of the first colonial exports. The process to manufacture potash included the following steps:

- Hardwood timber was burned.

- The ashes were leached.
- The resulting black powder (the “Pot Ash”, or  $K_2CO_3$ ) was refined to  $K_2O$  and used to manufacture Gunpowder, first in the mother country, and later in the colonies.

The current use of the term, “Potash” ( $K_2O$ ) is one of convenience for commodity transactions. As a result, all naturally occurring “Potash Minerals” have been assigned “Equivalent Potash ( $K_2O$ ) values.

In spite of its North American history, by WW-I, most of the Potash used in the US for gunpowder and fertilizer, was imported from mines in Eastern Europe. Blockades of German ports, during WW-I, denied US access to these Eastern European Potash supplies and resulted in Potash shortages. As a result, the US government declared “Potash” to be a “Strategic Mineral”, and provided for the establishment of “Potash Enclaves” wherever commercial US Potash deposits were discovered. Modest Potash Deposits were discovered, between WW-I and WW-II, in SE NM, the Paradox Basin of Eastern Utah, and later, deep deposits, in the Michigan Basin, as the result of oil and gas well drilling.



**Figure 1.** SE New Mexico Potash Enclave and WIPP (after: Barker and Austin, 1993).

The 1940's discovery of the *Prairie Evaporite Potash Deposits*, in Saskatchewan, eclipsed all US Potash operations, combined, and changed the economics of the US Potash mining industry, making the US *Potash Enclaves*, superfluous. However, the US *Potash Enclaves* still exist.

## SE NEW MEXICO POTASH AREA/ENCLAVE

Low-Grade Potash was discovered in SE New Mexico oil well cores, in 1925. The US Secretary of the Interior created the SE NM Potash Area/Enclave, in 1931 (see Figure 1). The purpose of this order was to preserve this Strategic mineral resource, for future development. In spite of the *Prairie Evaporite Potash Deposits*, this Enclave still exists.

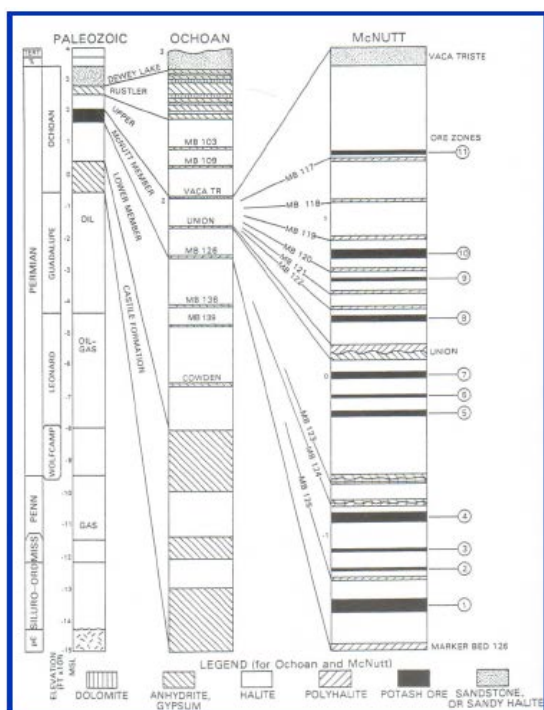
In 1973, the US Atomic Energy Commission (AEC, now Department of Energy, DOE) condemned a 16 square mile area within the New Mexico Potash Enclave, as a Waste Isolation Project Pilot Project (WIPP), for storage of radioactive waste. As part of this action, the AEC drilled, cored and logged, with complete sets of commercial and USGS wireline measurements, 21 coreholes.

## SE NEW MEXICO OIL/GAS WELL DRILLING, LOGGING & CASING PROTOCOLS

Most SE New Mexico oil and gas reservoirs are below the Salado Evaporites, which include the 11 Potash zones of the McNutt Member. Over time the typical petroleum well drilling, logging, & casing programs have developed to:

- Air drilling through the Salado Evaporites.
- Cased and cemented to the surface, without logging.
- Drilled to TD, using water based muds.
- Complete set of FE logs run from TD to the surface casing shoe.
- GR and Neutron *only*, run through the cased interval.

As a result, the only Evaporite wireline measurements available from most SE NM petroleum wells will be cased-hole GR and Neutron logs.



**Figure 2.** Regional Stratigraphic Column for the SE NM Potash Area (after: Griswold, 1982).

### SE NEW MEXICO McNUTT MEMBER, SALADO FORMATION LITHOLOGY AND MINERALOGY

The SE NM potash resources are confined to the McNutt Member of the Salado Formation of the Ochoan Evaporites. Figure 2 shows the regional Stratigraphic Column of the SE NM Potash Area, with expanded Sections of the Ochoan Evaporite, and the McNutt Member of the Salado Formation. Along with the 11 Potash Ore Zones and associated USGS regional Marker (most probably ash) Beds. For example, the 11<sup>th</sup> Potash Ore Zone is located between USGS Marker Beds 119 & 120. Potash salts are among the last to precipitate from a bittern. As a result, not every “Ore Zone” contains commercial Potash, at every location.

**Table 1.** SE New Mexico McNutt Member, Salado Formation Major Rocks & Minerals.

Mineral Name	Formula	Crystal Class	%K	Equivalent %K <sub>2</sub> O	Gamma Ray (API)
Sylvite	KCl	Isometric	53.45	63.18	953
Langbeinite	K <sub>2</sub> Mg <sub>2</sub> (SO <sub>4</sub> ) <sub>6</sub>	Isometric	18.84	22.7	342
Carnallite	KMgCl <sub>2</sub> •6(H <sub>2</sub> O)	Orthorhombic	14.07	16.95	256
Kainite	MgSO <sub>4</sub> KCl•3(H <sub>2</sub> O)	Monoclinic	15.07	18.92	287
Leonite	K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> •4(H <sub>2</sub> O)	Monoclinic	21.32	25.69	387
Polyhalite	K <sub>2</sub> Ca <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>6</sub> •2(H <sub>2</sub> O)	Triclinic	12.97	15.62	236
Anhydrite*	CaSO <sub>4</sub>	Orthorhombic	-	-	-
Gypsum	CaSO <sub>4</sub> •2(H <sub>2</sub> O)	Monoclinic	-	-	-
Halite	NaCl	Isometric	-	-	-
Kieserite**	MgSO <sub>4</sub> •(H <sub>2</sub> O)	Monoclinic	-	-	-
Marker Beds	Variable	-	-	?	Variable
Claystones	Variable	-	-	?	Variable

Table 1 summarizes the major rocks and minerals of the SE NM McNutt member of the Salado Formation. Those entries in red are the commercial potash minerals. The minerals in Green are potash minerals that are not considered commercial, for underground mining. Those minerals in violet are the non-potash evaporite minerals. Finally the non-evaporite rocks, which are often radioactive, are in black. While there are six potash minerals in the McNutt Member, only two of them are considered to be commercial for underground mining.

### SE NEW MEXICO POTASH COMMERCIAL STANDARDS

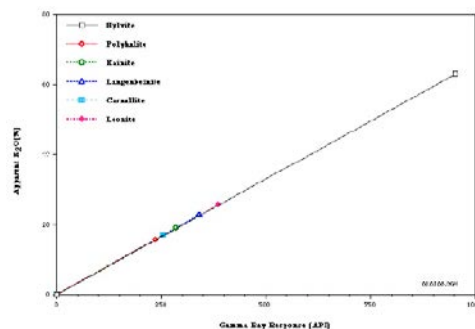
At the time of the current study, commercial Potash reserves standards were in flux. However, based upon a 1986 Secretary of the Interior Order, the following standards were generally accepted:

- At least one bed of  $\geq 4$  ft thickness with,
- Sylvite and/or Langbeinite grade  $\geq 4\%$  concentration.

### WIRELINE ANALYSES

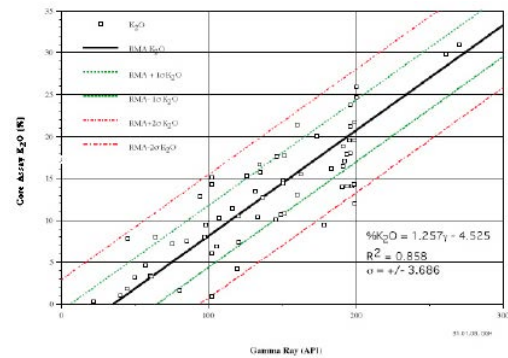
#### Initial Wireline Analysis Validation Attempt

Ignoring the variable gamma ray responses of the marker Beds and the Claystones, plotting the pure mineral GR vs. equivalent %K<sub>2</sub>O yields the linear relationship of Figure 3.



**Figure 3.** Linear Relationship between Potash Mineral Matrix API Response and Assigned %K<sub>2</sub>O (after: Hill, 2019).

With this in mind, a Geologist with a SE NM mining company developed an empirical relationship of based upon seven SE NM wells and coreholes with McNutt Member core assays and modern GR API unit logs, to develop a Least Squares (LSQ) Core based %K<sub>2</sub>O Transform. A review by Petrophysicist with extensive Potash experience suggested that a Reduced Major Axis (RMA) model, such as that in Figure 4, which distributes the fitting errors equally between both variables, be used instead of the LSQ Regression Model, which places all fitting errors on the Dependent variable. The rationale for this change is that for petrophysical data, such as this, neither variable data can be considered to be *noise-free*. A second review, by an experienced mining geophysicist, echoed these comments and added that the model be based on Grade-Thickness, as is done for Uranium evaluation (Nelson, 2007).

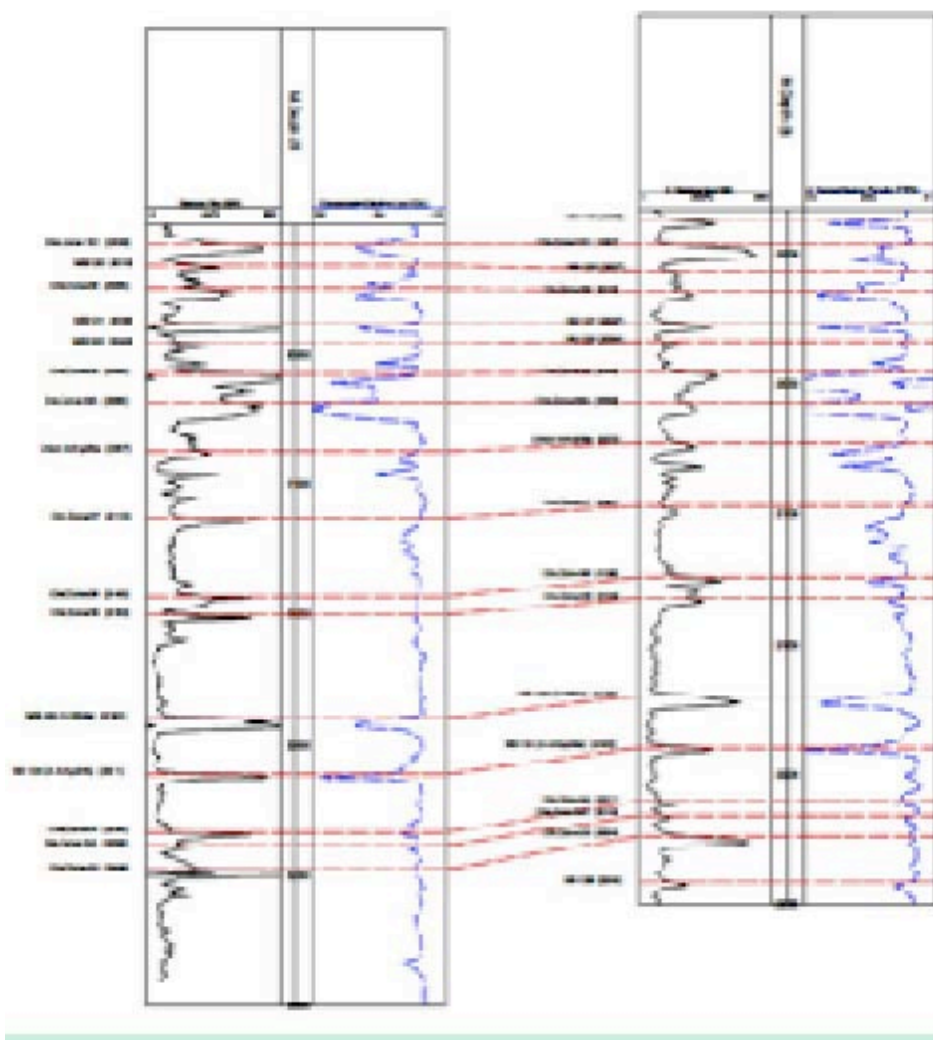


**Figure 4.** RMA GR to %K<sub>2</sub>O Relationship from 7 SE NM Well cores and GR Logs (after: Hill, 2019).

#### Evaluation of the RMA Model

To evaluate the SE NM GR to %K<sub>2</sub>O transform, a corehole was drilled and logged 200 ft, from a cased well, with modern API GR logs and a Potash evaluation using the RMA GR. The resulting core was evaluated and wet chemistry assays conducted on the recovered core. Figure 5 shows the correlated GR & Neutron logs between the corehole, on the left, and the well on the right. The correlation between various beds in the two is excellent, as it should be for two closely spaced (200 ft) wells in a stratiform evaporite deposit.

Table 2 summarizes the results of this Validation Test. Obviously, more than GR alone is needed for a McNutt Member evaporite Potash Screening tool.



**Figure 5.** RMA GR to %KO Transform Evaluation: Cased well on Left & Corehole on Right (after: Hill, 2019).

**Table 2.** SE New Mexico McNutt Member, RMA GR to %K<sub>2</sub>O Model Validation Test Results (after Hill, 2019).

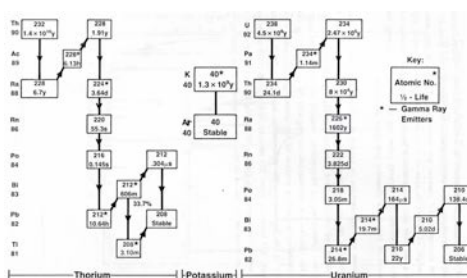
Potash Ore Zone	Mining Co Cased Well Log Predictions			Corehole Assay Analysis			% Error of Log Predicted Grade x Thickness
	Thickness (ft)	Grade (%K <sub>2</sub> O, S/L)	Grade x Thickness (%K <sub>2</sub> O/ft, S/L)	Thickness (ft)	Grade (%K <sub>2</sub> O, S/L)	Grade x Thickness (%K <sub>2</sub> O/ft, S/L)	
10c	5.4	29.0 S	156.6	4.5	7.7 S	34.7	351
8A	5.1	4.0 S	20.4	none Reported	none Reported	-	-
6	2.5	16.0 S	40	0.5	11.7 S	5.9	578
5	5.3	14.0 S	74.2	1.5	7.8 L	11.7	534
3	4	26.0 L	104	3.5	12.3 L	43.1	141

L = Langbenite S = Sylvite



The Wet Chemistry Core analysis of the Validation Core (Table 2) did not measure up to the predictions of the SE NM GR to %K<sub>2</sub>O transform from the adjacent Oil well. The obvious question is why?

## ALTERNATIVES TO THE RMA GR TRANSFORM



**Figure 6.** Potassium, Uranium, and Thorium, KUT, decay series (after: Guo, 1982).

### *Non-Potash Radioactive Sources*

First of all, Potassium is not the only naturally occurring radioactive element, in the Earth's crust. Figure 6 shows the Radioactive decays for the three naturally occurring radioactive elements,  $^{40}\text{K}$ ,  $^{238}\text{U}$ , and  $^{232}\text{Th}$ . While the  $^{40}\text{K}$  to  $^{40}\text{Ar}$  decay is direct, both  $^{238}\text{U}$  and  $^{232}\text{Th}$  decay through a series of radioactive Daughter Products before reaching a stable Pb, isotope.

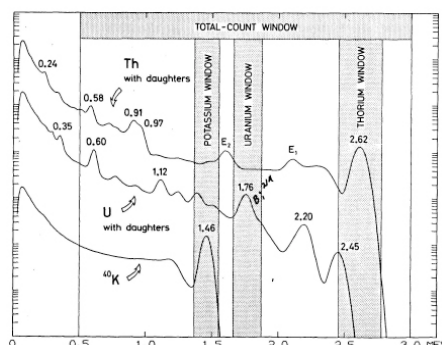
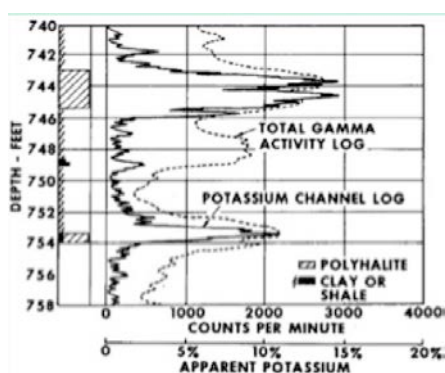


Figure 7. Gamma Ray Count Energy Windows for Total Count and K-U-T Spectral GR Windows (after: Guo, 1982).

Common WL GR sondes measure the total decay counts over a large Energy Window, as shown in Figure 7. The SE NM Claystones and Marker Beds, contain clay minerals, which often contain trace uranium and/or thorium, as well as potassium, raising the possibility of all three types of radioactive elements being present to contaminate the GR to Potash transform. Special K-U-T Spectral GR sondes attempt to separate the effects of the higher energy decays of the  $^{238}\text{U}$ , and  $^{232}\text{Th}$  decay series from that of the single  $^{40}\text{K}$  to  $^{40}\text{Ar}$  decay. Because daughter product decays of both the  $^{238}\text{U}$ , and  $^{232}\text{Th}$  series also occur within the “Potash” window, these effects must be removed to get the true Potassium signal. This is done, either by *Stripping* or *Kalman Filters* (Fertl, 1979 and Mathis, et. al., 1984).



**Figure 8.** SE NM Total Count and K Channel GR Response Example (after: Fertl, 1979).

Figure 8 shows an example from SE NM, with both the Total Count and Potassium Channel of a K-U-T spectral GR sondes. While a K-U-T Spectral Gamma Ray Sonde might eliminate Marker Beda and Claystones, it would not eliminate the non-commercial Potash minerals, or potassium clays.

Crain and Anderson (1966) used Gamma Ray, Neutron and Sonic logs, with linear programming, to successfully discriminate between Sylvite and Carnallite, in the Prairie Evaporite of Saskatchewan. Hill (1993) used Gamma Ray, Density, Neutron, and Sonic logs, with Multi Mineral Analysis for the Winsor Evaporate, of Cape Breton Island. However, the only well logs available for most SE NM oil and gas wells will be cased hole GR and Neutron.

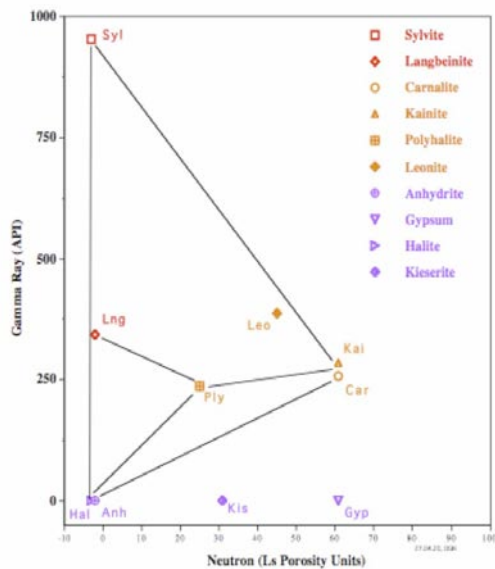
**Table 3.** SE New Mexico McNutt Member, Salado Formation Chemistry, Gamma Ray, and Neutron Responses (after Hill, 2919).

Mineral Name	Formula	Gamma Ray (API)	NPHI (%LS)
Sylvite	KCl	953	-3
Langbeinite	$K_2SO_4(MgSO_4)_2$	342	-2
Camallite	$KClMgCl_2 \cdot 6(H_2O)$	256	61
Kainite	$MgSO_4 \cdot 2H_2O$	286	61
Leonite	$K_2SO_4 \cdot MgSO_4 \cdot 4(H_2O)$	387	45
Polyhalite	$K_2SO_4 \cdot MgSO_4 \cdot (CaSO_4)_2 \cdot 2(H_2O)$	236	25
Anhydrite*	$CaSO_4$	-	-2
Gypsum	$CaSO_4 \cdot 2(H_2O)$	-	61
Halite	NaCl	-	-3
Kieserite**	$MgSO_4 \cdot (H_2O)$	-	43
Marker Beds	Variable	Variable	Variable
Claystones	Variable	Variable	Variable

### THE POTASH IDENTIFICATION (PID) PLOT

Table 3 compares the Gamma Ray and Neutron responses for the most common minerals and rocks in the McNutt Member of the Salado Formation, in SE New Mexico. The obvious difference between Sylvite and Langbeinite, which are commercial for underground mining, and Carnallite, Kainite, Leonite and Polyhalite, which are not, is that the first two are anhydrous, while the other four are hydrated. The SE NM Claystones and Marker Beds

contain Hydroxyl ions and, often Water, both of which contain hydrogen ions. The Neutron Porosity Log really responds to hydrogen ions, in the adjacent wall rock, which makes it a good second discriminator,



**Figure 9.** SE NM Potash Identification (PID) Plot Master

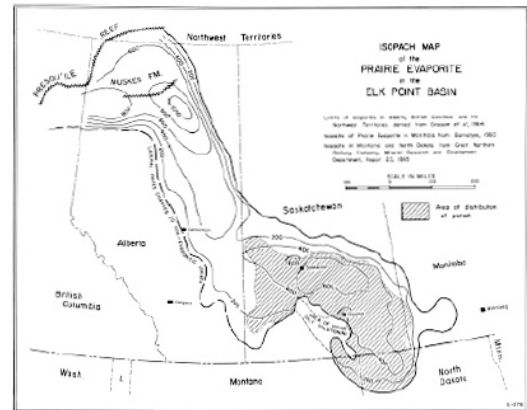
Dewan and Greenwood (1955) may have been the first to recognize the utility of using both GR and Neutron logs to identify potential economic Potash deposits. Interestingly enough, they were considering this for SE NM. Alger and Crain (1965) Showed a Prairie Evaporite log suite, which contained both GR and Neutron logs, along with Sonic and Density, but did not go into any detail. Grain and Anderson used GR, Neutron, and Sonic logs, with Linear Programming to estimate Sylvite, Carnallite, and Insolubles for Prairie Evaporites. Tixier and Alger (1967) pointed out that using Neutron logs could eliminate Carnallite, because it is hydrated. However they did not go much beyond this statement and suggesting that GR Neutron, Density, and Sonic all be used in a joint interpretation. All of these authors were using early (including GNT and SNP Neutron logs) second generation logging measurements. Hill (1993) used modern GR, Density, (CNL) Neutron, and Sonic logs, with Multi-Mineral Analysis to estimate Sylvite, Halite, Anhydrite, Carnallite, and Insolubles, for the Windsor Evaporite, of Cape Breton Island. Unfortunately, the only logs available from most SE NM oil and gas well are Cased-Hole GR and Neutron, which eliminates the more sophisticated analyses.

With insight gained from the information in Table 3, a simple graphic, the *Potash Identification* (PID) plot was designed (Figure 9), for GR and Neutron data, which can be used with either digital data or hand picked points from the printed field, or processed, log prints. Figure 9 shows the PID Master for SE NM, which

shows all 6 SE NM potash minerals, as well as the 4 SE NM non-potash evaporites. The only pre-processing required is environmental corrections.

### PID PLOT VALIDATION

With the PID Plot defined, it was validated, using wells from four North American Potash locations.



**Figure 10.** Prairie Evaporite (after Holter, 1969)

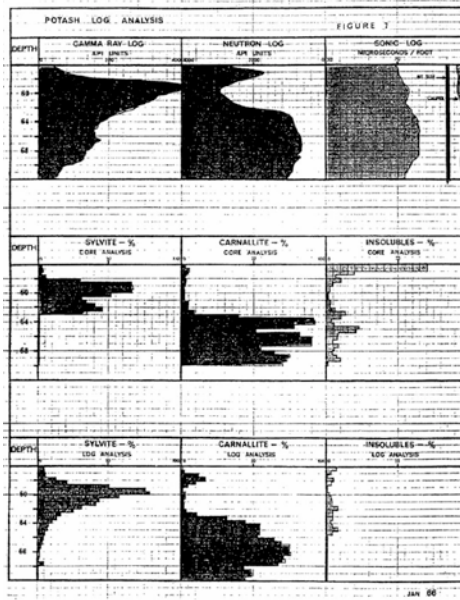
### Prairie Evaporite, Saskatchewan

The Prairie Evaporite, of Saskatchewan, discovered in during the 1940's and continuously produced, since 1962, could easily be dubbed "The Saudi Arabia of Potash" (see Figure 10). The geology and mineralogy is quite simple:

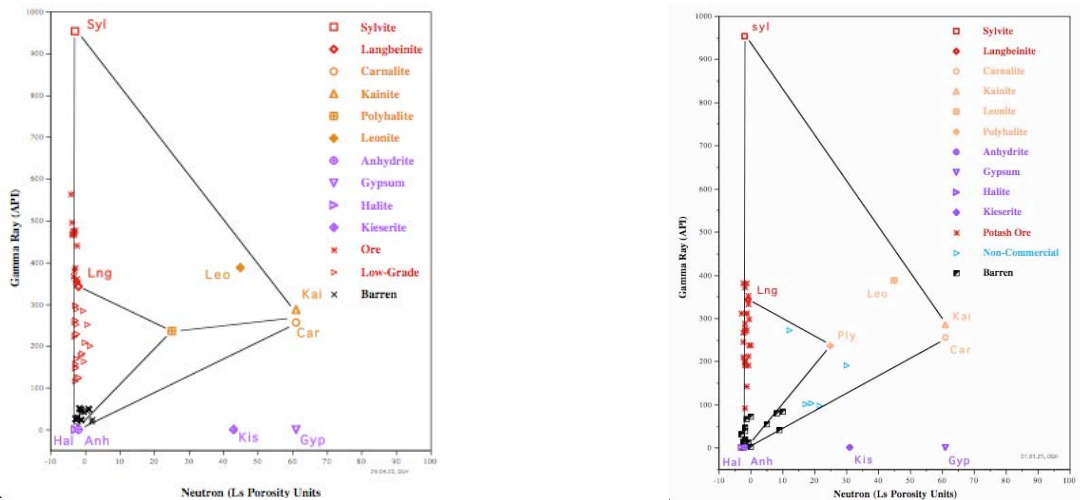
- Simple structure and mineralogy.
- Distinct Sylvite and Carnallite intercepts with only minor dolomite and claystone stringers.
- Massive (up to 15m thick) beds.
- High Grade (up to over 50%) Sylvite.
- Uniform (can correlate over several miles, using Seismic reflection).
- Extensive (covers roughly the SE quarter of the province of Saskatchewan, see Figure 9).

At the time of the current study, the Prairie Evaporite was supplying roughly 25 – 30% of the world's potash demand and 70% of the US demand, with sufficient reserves to do so, for several hundred years. Figure 11, from Crain and Anderson (1966) is one of the earliest linear programming attempts to estimate Potash assays from wireline measurements which used the GR, GNT, and sonic logs, when were available, then. Crain (2014) further described the steps needed to accomplish this with the older wireline measurements





**Figure 11.** Prairie Evaporite Well Logs, Core Assays, and Linear Programming Log Assays (after Crain and Anderson, 1966).



**Figure 12.** PID Plots for Two Prairie Evaporite Wells (after Hill and Crain, 2020).

Figure 12 shows PID displays from two Prairie Evaporite wells. The one on the left is from a section that is high-grade Sylvite, with all points plotting on the PID Sylvite - Anhydrite/Halite line. The one on the

right is from a well with lower grade Sylvite, and some Carnallite. The PID separates the Sylvite from the Carnallite nicely.

with little contamination by Carnallite, associated with Halite, and minor amounts of Gypsum and Anhydrite.

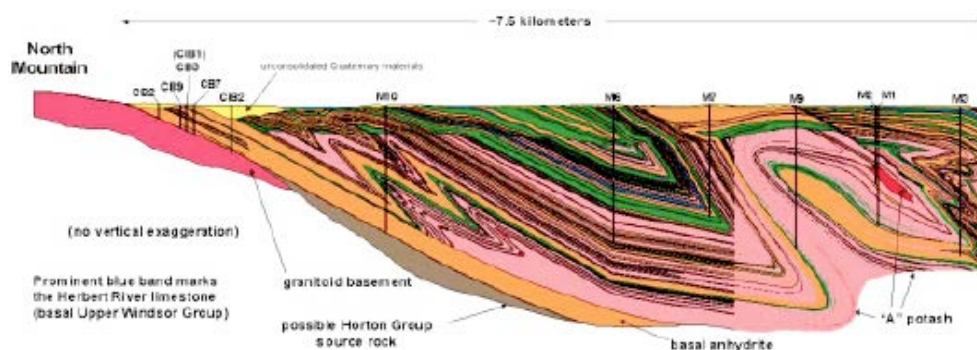
The mineralogy is essentially Sylvite, with little contamination by Carnallite, associated with Halite, and minor amounts of Gypsum and Anhydrite. Hill (1993) conducted multi-mineral analysis, using

#### ***Windsor Evaporite, Cape Breton Island***

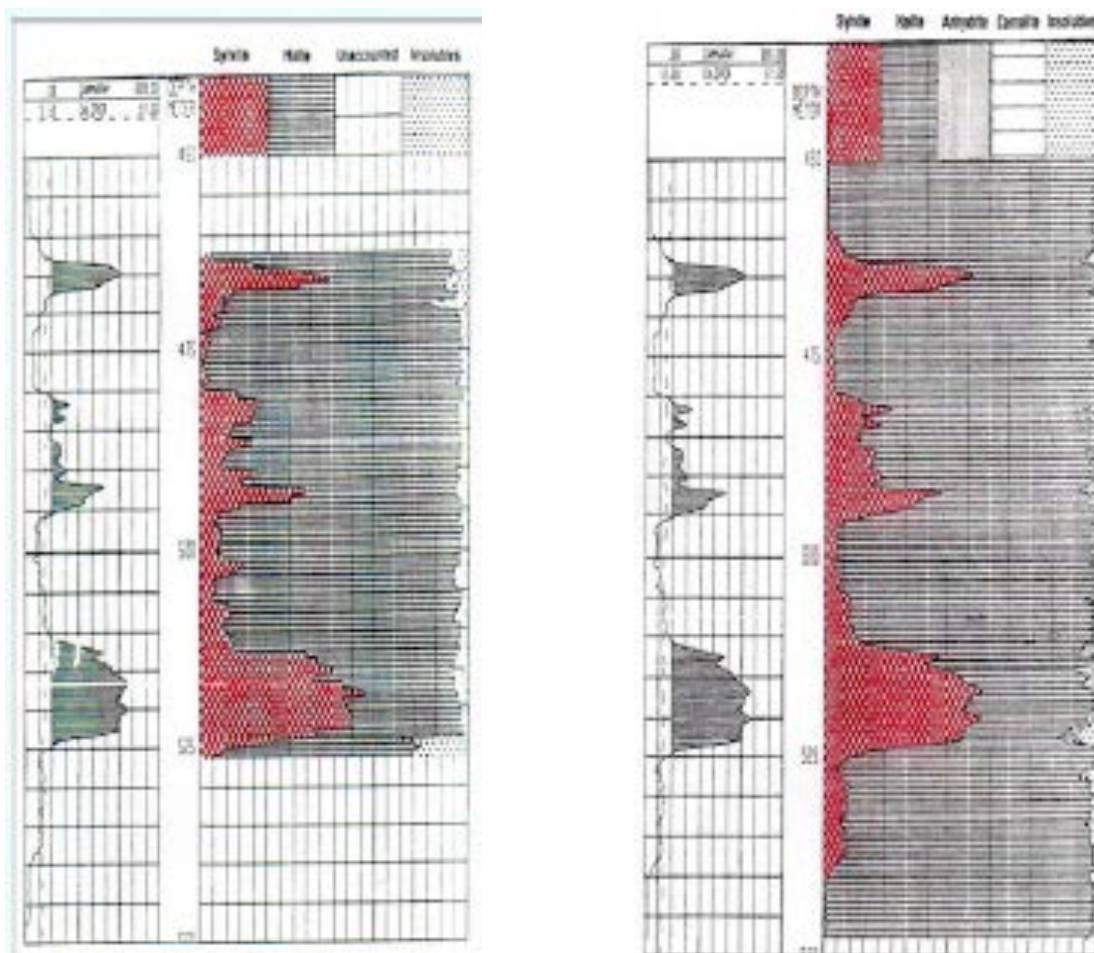
A minor high-grade Potash deposit, in a complex structural setting, was discovered in the Windsor Evaporite of Cape Breton, Island, Nova Scotia (see Figure 13). The mineralogy is essentially Sylvite,

modern GR, CNT Neutron, FDC Density, and BHC Sonic. Figure 14 compares the core wet chemistry

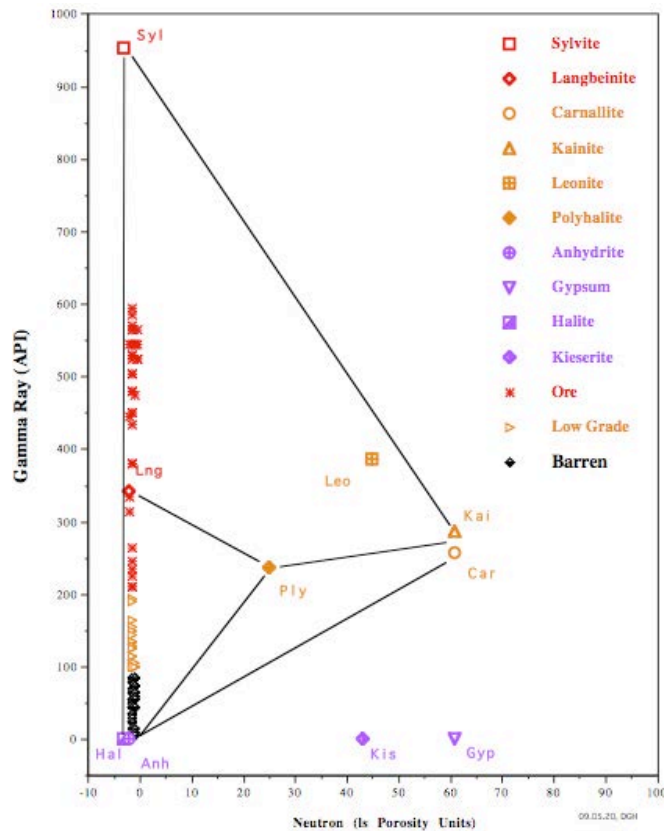
analysis (left) to the Multi-Mineral analysis (right). The results are very good.



**Figure 13.** Cape Breton Island Structural cross section showing the Windsor Evaporite Potash Deposit (after Anon., 2007).



**Figure 14.** Cape Breton Island Well Core Assay, on Left, and Multi-Mineral Assay, on Right (after Hill, 1993).



**Figure 15.** Cape Breton Island Well PID Plot (after Hill, 2019).

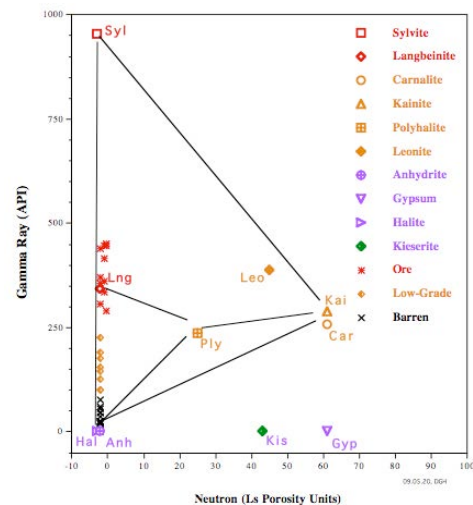
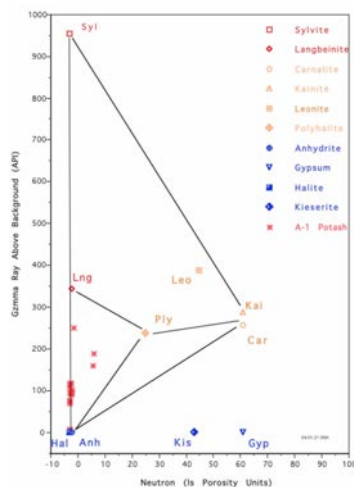
While there was little, if any Carnallite in this well, the PID plot shows all points (both hi-grade and lower grade Sylvite) plotting on the Sylvite – Anhydrite/Halite line, as they should.



**Figure 16.** Michigan Basin Salina A-1 Evaporite Extent (after Hill, 2019).

### *Salina A-1 Evaporite, Michigan Basin*

The Paleozoic geology of the Lower Peninsula, of Michigan is much like a “Stack of Bowls”, sitting on the Pre-Cambrian basement. Deep Potash salts were discovered in the Salina A-1 Evaporite of the Michigan Basin (see Figure 16) when wells drilled with saturated NaCl brines washed out. Subsequently at least one solution mining project was developed, near the township of Hershey, in NW Lower Peninsula of Michigan.



**Figure 17.** Two Deep Michigan Basin Salina A-1 Evaporites PID Plots.

Figure 17 shows PID plots for two Deep Michigan Basin Salina A-1 Evaporite wells. The well on the left may have either low grade Sylvite and Carnallite or

Shales. The one on the right appears to have only low-grade sylvite.

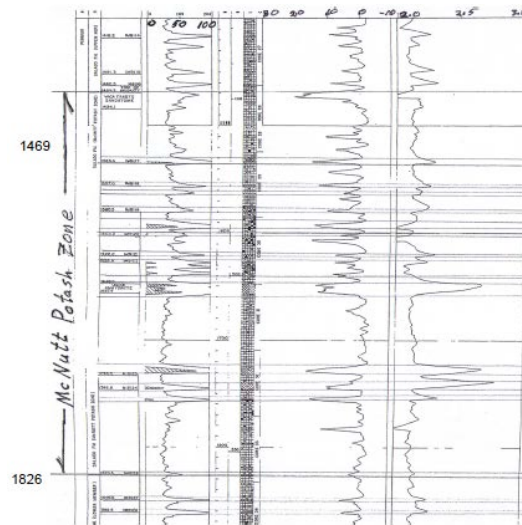


Figure 18. AEC-8 McNutt Member, Salado Formation, SE NM, Log & Lithology (After; Griswold, 1982).

#### ***McNutt Potash Member of the Salado Formation, SE New Mexico***

The AEC condemnation of a 36 mi square area in the SE NM Potash Enclave, for the Waste Isolation Project for deposition of Radioactive Waste, resulted in a coring and assay campaign to determine the value of the condemned land for settlement with the then current minerals holders.

The resulting public domain data offer an excellent option to evaluate the PID, for SE New Mexico.

Figure 18 Shows the AEC-8 McNutt Member Stratigraphy, GR, Core Graphic, Neutron, and Density logs for the AEC-8 Evaluation Corehole, drilled to evaluate the WIPP acreage. The Salado Formation has 49 “Marker Beds”, which can be correlated regionally across the SE NM Basin, containing the Potash Enclave. Many of these non-potash Markers have  $\geq 189$  API units, which are comparable to, or greater are less than 8 ft thick than the 11 potash zones. All of the potash zones, in AEC-8, are 8 ft thick.

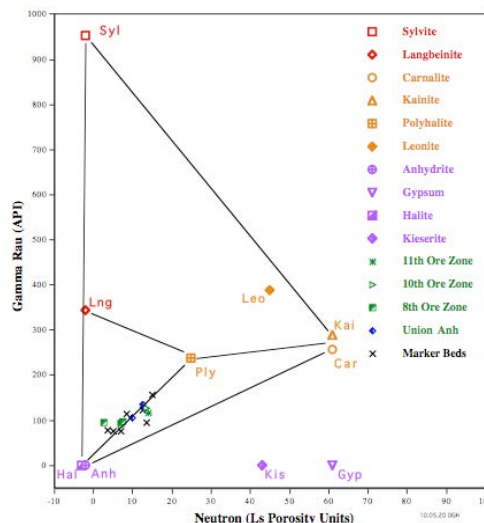


Figure 19. AEC-8 McNutt Member, Salado Formation, SE NM, PID Plot (After; Hill, 2019).



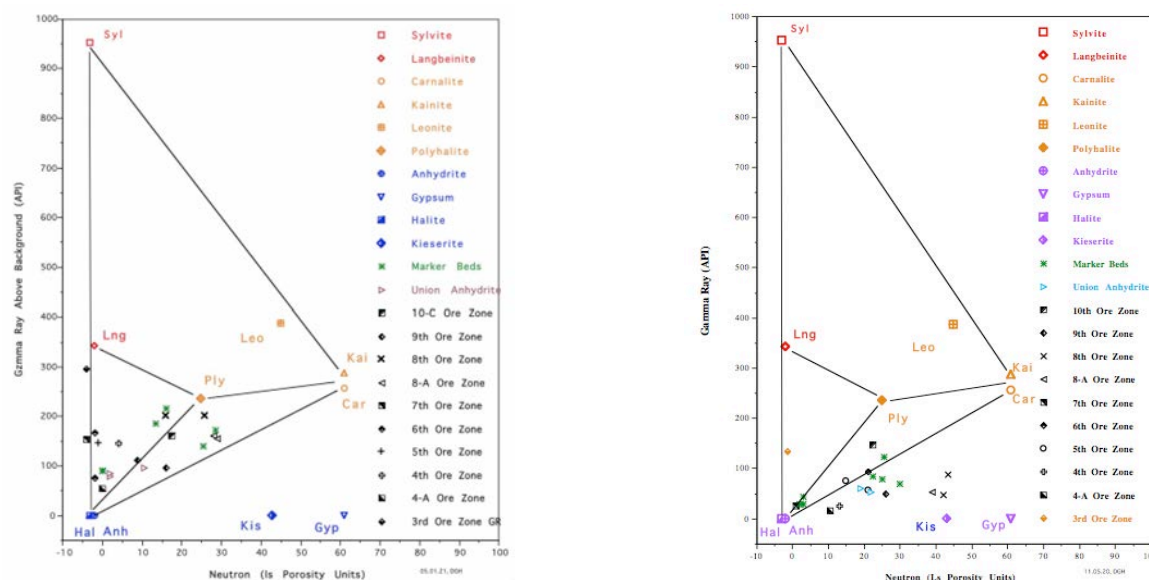
Figure 19 Shows the AEC-8 McNutt Member PID Plot. All of the data plot along the Anhydrite/Halite – Poly Halite matrix points, far away from the Anhydrite/Halite –Sylvie line. Review of the

### VALADATION TEST OIL WELL AND COREHOLE McNUTT PID

With this background, we can now look at the PID, from the GR Transforms Validation Test (Figure 19). The Oil well (on the right) was drilled with air, through the evaporite, cased and cemented, without logs, prior to drilling to TD. The GR and Neutron logs were, run as part of the TD log suite and, thus, cased-

Griswold (1982) report indicates that the most commonly identified Potash mineral in the WIPP well cores, was Polyhalite.

hole logs. The Project Geologist claimed that the vendor was instructed to do Cased Hole Environmental Corrections, *In the Cab*, which can be done with modern systems; a claim which was collaborated via a telephone call to the Roswell wireline vendor Station Manager. The Core Hole (on the left) was a slim-hole project, as most mineral coreholes are, and logged with modern slim-hole wireline equipment.



**Figure 19.** Validation Test PID (Corehole on Left, Oil Well on Right) McNutt Member Salado Formation (after; Hill and Crain, 2020).

Figure 20 shows the PID Plots For this test, with the Core Hole PID on the left and the Oil Well PID on the right. Only one point, in the oil well PID, plots near the Sylvite-Anhydrite/Halite line, which may correspond to the Validation Test Core hole Assay, for the Langbenite 3<sup>rd</sup> ore zone wet chemistry assay. However, the zone thickness (2.5 ft) is under the “Minimum 4 ft thickness SE NM economic standard.

The increased number of peaks posted along the Sylvite-Anhydrite/Halite line, for the Core Hole PID, may reflect the different wireline equipment, including a shorter GR detector, the smaller borehole, and the lack of casing & cement. The data point plotting near 300 API, may well correspond to the 10c<sup>th</sup> ore zone.

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While this would pass both the grade & thickness hurdles, for SE NM, it is doubtful that it would support a mine and it did not show up on the cased well PID, with the longer GR detector.

### CONCLUSIONS

The PID plot has proven to be a simple and rapid method to screen for potential low-grade commercial Potash mineralization in the presence of high GR shales, and non-economic Potash minerals. This technique could prove extremely useful in any evaporite basins with extensive oil wells drilled through the evaporite to access underlying petroleum resources.

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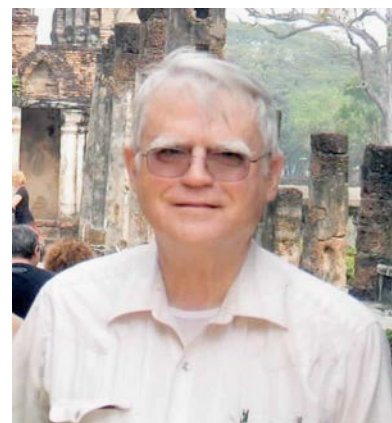
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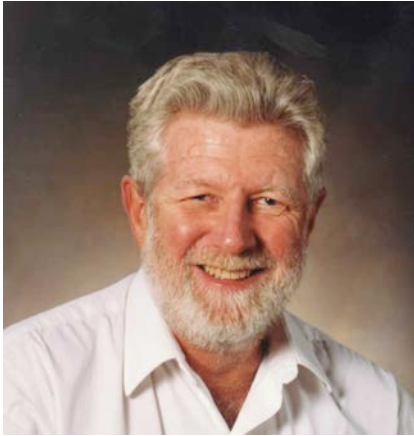
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