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50th Anniversary of the Archie Equation: Archie Left More Than Just an Equation

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Foreword

"How can you pass up this once in a lifetime opportunity?" I found myself repeating in my mind after Stephen Prensky, Editor of ***The Log Analyst***, asked me to write this article commemorating the 50th anniversary of Archie's paper. I quickly accepted Stephen's offer, then the realization hit! It had been 25 years since I had first read Archie's paper and hardly a work-week had passed since then, that I had not used or relied upon the results of this work or its progeny.

How could I ever capture this overwhelming influence in a single article? What about the background which led up to Archie's publication? I soon faced the prospect of writing an entire biography! Once this scary thought was brought under control, I began picking and choosing those parts of the larger story I felt best represented Gus Archie's design for petrophysics. It is a simple story about Archie -- the gentleman, the engineer, the innovator -- and how his quiet, proactive vision set the stage for modern-day concepts in reservoir characterization; no doubt we shall depend upon these concepts in the future as well. And this is Archie's legacy -- the principle of interdisciplinary synergism as applied to reservoir characterization.

Background

We begin this story in 1930, with Gustave Erdman Archie as a senior at the University of Wisconsin at Madison. Gus had been an enthusiastic student of electrical engineering and would soon graduate with a B.S. degree. But fate had played a cruel trick on the United States' economy, and the 1930 graduating class watched in horror as the graduates of the 1929 class were laid off from their newly acquired jobs. There would be few, if any, jobs in electrical engineering in June 1930. But Archie had a parachute: his father operated a small quarry in Oconomowoc, Wisconsin, so Archie planned to augment his field of study to include mining engineering in order to acquire the skills needed to work in the family business. The prospect of working for his father was not all that bad, as Gus would later acknowledge; his father was responsible for kindling his interest in science and engineering (R. M. Sneider, personal commun., 1992). Gus earned a B.S. degree in mining engineering in 1931, but he had become intrigued with mining engineering, and in particular, geology and petrography. Thus, he stayed on to earn a combined M.S. degree in mining engineering and geology in 1933.

After working with his father for a year, Gus joined Shell Petroleum Corporation in 1934, in Greenwich, Kansas, as an exploitation engineer (Taylor, 1990). One of the professors in the mining engineering department who may have influenced Gus to consider employment by Shell was Dr. Edwin Roy Shorey (E. R. Shorey, Jr., personal commun., 1992).

Gus was assigned to a routine Shell training program which involved well sitting. There he obtained first-hand experience examining cuttings and cores (electric coring, as Schlumberger wireline electric logs were then referred to, was not readily available in Kansas, having been re-introduced to the U.S. in June 1932). From these early training assignments, Gus learned to appreciate how difficult it was to determine formation porosity and permeability when cuttings were the only source of data. It was in this setting that Archie began to formulate a methodology to permit a schooled observer to determine qualitatively the porosity and permeability from cuttings at the wellsite. Here Archie's electrical engineering and geology background came into play as he recognized the need for downhole measurements of electrical resistivity and acoustic velocity to aid in quantifying reservoir properties (R. M. Sneider, personal commun., 1992).

From the summer of 1932 through the summer of 1938, Shell had been experimenting with Schlumberger electric logs in California, Texas, and Louisiana and felt that quantitative information could he gained from these logs. Shell's Texas-Gulf area production manager, D. B. Collins. knew of Archie's educational background and penchant for formation evaluation, so in the summer of 1938, he had Archie assigned to him in the Texas-Gulf area office in Houston, Texas, and charged him with the task of understanding electric-log responses.

Archie undertook a systematic investigation of every existing Shell Texas-Gulf area electric log together with its companion core analysis, mud log, and test data, and continued to study wells as they were drilled over the next two years. During this time, Gus had numerous discussions with the Schlumberger staff to review the physics of the measurements being offered. Gus also read extensively through the existing literature in petroleum, physics and chemical journals. All this work resulted in four definitive, internal Shell reports which laid down the fundamental petrophysical relationships, later published in his now famous article, "The Electrical Resistivity Log as an Aid in Determining Some Reservoir Characteristics" (Archie, 1942).

These four internal Shell reports are:

- Archie, G. E. and McCurdy, R. C., 1939, ***Schlumberger electric logging in the Gulf Coast***: June 6.
- Archie, G. E., 1939, ***The problem of using Schlumberger logging for a quantitative study of sands in the Gulf Coast***: June 26.
- Archie, G. E., 1940, ***Progress report on electric logging in the Gulf Coast area, June 1939 to March 1940***: May 1.
- Archie, G. E., 1941, ***Analysis of electric resistivities of the San Andres Limestone in the Wasson Pool, Texas***: January 21.

Gus was also able to draw upon Shell's work in California, published internally by R. C. McCurdy, "Schlumberger Progress," September 15, 1937.

I hope that these four reports will become available for public scholars to peruse and appreciate, they clearly show the depth of understanding that Archie had of the phenomena, not only for clean sands, but for shaly sands and limestones as well. Please allow me to quote from reference 3 above:

> "Control of well conditions and the cooperation of Schlumberger make it possible to estimate the true resistivity of formations in place underground."
>
> "The important difference in the sands is due to the variation in the amount of very fine material (less than 200 mesh) or lime contained between the larger sand grains."

"It will be seen that as the pores of a clean sand become filled with clay or lime particles, the resistivity increases. The increase due to shale will not be large for the resistivity cannot exceed that of a pure shale."

"The change in resistivity is smaller in clayey sands than in other sands, for clay particles tend to hold water in place. For this reason a clayey sand can contain considerable connate water and produce clean oil."

"Even though the porosity and permeability of an uncemented (unconsolidated) sand are greatly reduced by clay or fine sand, the electric resistivity will not be greatly increased for the electric current can still go around each individual grain.

Because these quotes have not previously been public knowledge, it is understandable that an earlier author may have misinterpreted Archie's understanding of the problem, i.e., "In 1942, however, conductive minerals and shale were not on Archie's mind" (Edmundson, 1988a). In fact, in 1942 Archie demonstrated a fair understanding of the clean-sand problem and recognized the difficulties in interpreting electric logs in clayey rocks. He later sponsored and directed research to unlock the underlying principles of the resistivity response in shaly sands (Scala, 1989); but this is getting ahead of the story.

The Development of Petrophysics

Archie's systematic study of electric-log responses was but one facet of the multidimensional approach he was undertaking. Gus had the services of Shell's Production Laboratory, under the supervision of H. S. Rockwood and M. A Westbrook; their careful measurements provided Archie the data with which to attack the underlying principles controlling the borehole logging measurements and production performance. Archie's geological and petrographic training led him to realize that it was the fundamental rock-textural parameters that governed the pore structure, which in turn governed the flow characteristics and wireline-log responses. He recognized the true heterogeneity of rocks, particularly on the reservoir scale, and advocated the development of statistical methods as a way to correlate important parameters, such as permeability and formation resistivity factor. His work culminated in the publication of his second public paper, "Electrical Resistivity an Aid in Core-Analysis Interpretation" (Archie, 1947).

One must remember that in the World War II era, the science and logging tools we now know and take for granted did not yet exist. Neutron logs had just been introduced (1941), were in short supply, and little was known about their interpretation (Brons, 1939); the induction log would not be introduced until 1947, the Microlog in 1948, the Microlaterolog in 1951, and the acoustic log in 1954. Thus, all Archie had to work with were the electric logs and a few gamma-ray logs. Porosity and permeability values could only be obtained from core measurements, but coring was costly and risky. Often, the rocks with the highest porosity were the most fragile and could not survive the coring and core-handling methods in use at that time.

Thus, Archie's work was aimed at solving one of the most serious problems of the early 1940's, that of obtaining porosity, permeability and hydrocarbon saturation from electric-log responses correlated and calibrated to core measurements. Even though Gus used statistical approaches to obtain his relationships, he did appreciate the need to understand the fundamental physics of the electric-log measurements. Shortly after his second paper was published, Gus put his ideas to the test.

The setting was western Oklahoma, near Elk City, in the summer of 1947. Shell was drilling a deep test targeted to the Springer Sands at 12,000 ft. The well, Walter No. 1, drilled quickly with no florescence shows in the cuttings, and was logged (electric log) without incident. Protective pipe was set across the Granite Wash zone and the well was deepened to the Springer sands where extensive drillstem tests found no producible hydrocarbons. The Tulsa office management wired the Houston office for permission to plug and abandon the wildcat, but met resistance from the Vice President, R. W. Bond.

During the time the Tulsa office had been testing the deep zones, Archie had been analyzing the electric logs for the well. Gus plotted the resistivity versus the SP and found a consistent trend, except for one zone, the Granite Wash. Gus made the assumption of constant water salinity and "m" factor across the logged intervals and reasoned that the anomaly was due to hydrocarbons. No other explanation fit the good SP response in the moderately resistive interval.

Gus was able to convince Reid Bond not to abandon the well without a test of the Granite Wash. The Tulsa staff resisted another test since the zone was drilled without fluorescence in the cuttings. Archie argued that a light hydrocarbon may not have noticeable fluorescence, and since the zone was already behind pipe, it would be a very inexpensive undertaking. On the strength of Archie's recommendation, Reid Bond instructed the Tulsa office to test the Granite Wash (P. E. Jensen and S. M. Paine, personal commun.). The zone was about 1000-ft thick, but they perforated only a few holes scattered over several hundred feet. Archie was at the wellsite for the test and a brisk Oklahoma wind blew his hat into the mud pit just as the well flowed (R. M. Sneider, personal commun., 1992). The test flowed 1500 bbls of condensate and 30 mmcf gas. Archie was right, but he lost his hat; a small price to pay for discovering the 110-million barrel equivalent Elk City Field, which later supported a 20-rig drilling program (E. R. Shorey, Jr., personal commun., 1992).

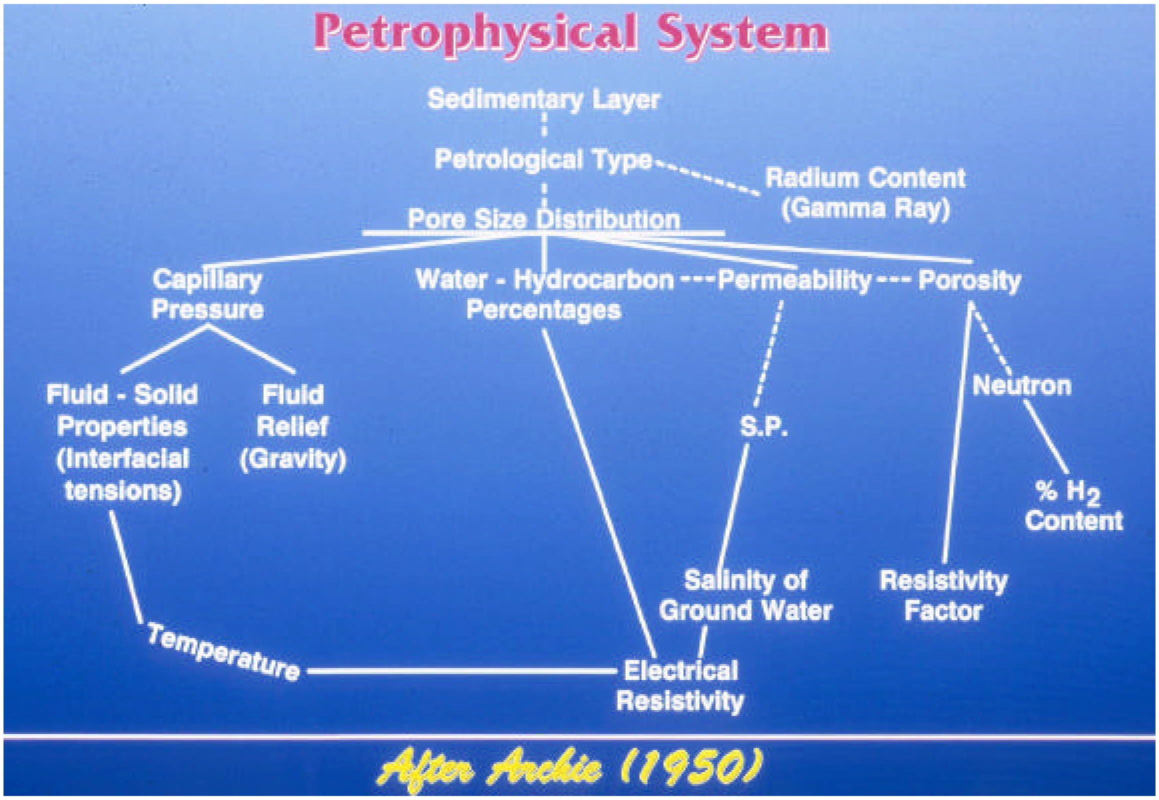
This success brought instant fame for Archie within Shell, but this was not without drawbacks. The Vice President now insisted that Archie interpret the logs on every wildcat east of the Rockies before he would concur with plans to plug and abandon (R. M. Sneider, personal commun., 1992).

Archie was then given the opportunity to select and train promising young exploitation engineers in his log-interpretation methods. Later he was instrumental in establishing a separate training department to teach these skills to all Shell engineers. Housed in the same Houston office was the fledgling E&P research group, and in 1946 a new hire named W. R. (Bob) Purcell joined the staff to work with M. King Hubbert. Hubbert suggested that Bob needed Archie's training, so Purcell was taken into Gus' group. After logging wells at Black Bayou field, Bob went to the core-analysis group under M. A. (Westy) Westbrook. Here Purcell got the approval for building his mercury-injection capillary-pressure apparatus which led to his famous 1949 paper (Purcell, 1949). This was just an example of the Archie style of training and management. He supported Bob in all his efforts, even when Bob's paper was criticized at the AIME meeting. Archie did this because he could see the importance of Bob's mercury capillary-pressure work in characterizing pore distributions. Gus quickly adopted this new core-analysis technique into his methodology of interpreting logs. In July of 1947, the E&P Research group moved into their new laboratory on Bellaire Boulevard, but this did not end Archie and Purcell's interaction.

During the post-war years Archie was not alone in developing theories about the interrelations of porosity, permeability, saturation and resistivity. Many other oil companies were doing parallel research and had come to similar conclusions. The literature of the time was alive with controversy about the exact form of the equations, and the history of these developments has been beautifully captured in a series of articles by Henry Edmundson in ***The Technical Review***, (Edmundson, 1988a, b). My only addition to this well-crafted story refers to the personal relationship of M. R. J. Wyllie and Gus Archie. While they may have published conflicting proposals, Gus respected the work that Wyllie had done and the two of them visited often for scientific discussions (S. M. Paine, personal commun., 1992).

Gus now drew together all of the pieces of the process he had been developing and set the foundation for a new branch of petroleum technology. In September 1949, Gus presented before the Houston Geological Society, and later published in the Bulletin of the American Association of Petroleum Geologists, the paper which forever married geology and physics: 'Introduction to Petrophysics of Reservoir Rocks" (Archie, 1950). In this seminal work, he introduced the term **"petrophysics"** to express the physics of rocks. The word itself had been coined earlier in discussions about the subject with Gus' counterpart with the Royal Dutch Shell Group, J. H. M. A. Thomeer, during a quiet evening in The Hague (Abbott, 1986; J. H. M. Thomeer [his son, Bert, also a Shell petrophysicist], personal commun., 1990).

But Archie wanted to emphasize the concept that through understanding the geological parameters of a rock, one could explain all of the resulting physical properties of a given rock type. Gus showed that formations that had been deposited under similar conditions and had undergone similar processes of later weathering, cementation or re-solution would have similar physical properties. He demonstrated that these processes would lead to rock types with similar pore-size distributions which in turn governed their porosity, permeability, water saturation and capillary-pressure behavior. One can see in this paper that one key step in the process was utilizing Purcell's mercury capillary-pressure tests to characterize the rock types. Gus then showed that for a given rock type one could use



electrical resistivity, spontaneous potential, and neutron response to obtain porosity, permeability and fluid saturation through indirect correlation with numerous core measurements to establish trends.

He diagrammed in his 1950 work what he called the "Petrophysical System." It tied together all the known logging-tool responses to the desired parameters of porosity, permeability and water saturation through the controlling physical properties of capillary pressure, interfacial tensions, temperature, gravity, salinity, and hydrogen content. It is still valid; all we have to do is include the current suite of logging tools and their responses, add grain density and you have a modern recipe for log analysis. When Archie discussed his "system," he pointed out that it revolved mainly around the pore-size distribution, but that a pore-size distribution did not necessarily define the type of rock by itself, because several rock types may have essentially the same pore-size distribution. This single point is the essence of modern formation evaluation; one must never expect all rocks from the same area or same geological age to have the same petrophysical parameters, because it is neither area nor age that governs physical properties; it is the pore-size distribution that matters, e.g., if a Miocene sand from south Louisiana and a Jurassic sand from the North Sea have the same pore-size distribution, one could expect similar porosity and permeability, while two east Texas Cotton Valley sands only 10-ft apart in the wellbore may have vastly different values of porosity and permeability.

But Archie also realized that the mineral composition of the rock should not be neglected in the study of rock interrelationships. He recognized that the type and amount of clay minerals present would play an important role. He also mentioned that logging of drill cuttings played an important part of his "Petrophysical System." He expected the well-sitter to provide a lithologic description as well as a pore-size distribution. How he expected this to be done was published later (Archie, 1952).

An Advocate for Production Geology

Archie's training in geology and petrography always provided him the ability to see formation evaluation from a different perspective than the average petroleum engineer. His early Shell training doing well sitting and cuttings-logging in Kansas led him to appreciate the difficulties in finding the thin pay zones imbedded in thick non-porous intervals. He also came to appreciate how difficult it was to correctly predict drillsite locations for appraisal wells following a wildcat discovery. Gus believed that some of the exploration department geologists should be made available to the production department to aid the exploitation engineers in their jobs. Archie felt he needed to work side-by-side with someone who could help him describe the rocks and develop methods for examining cuttings in the field. In turn, Archie felt he could aid the geologist in understanding the connectivity of formations from well-to-well, based on log responses, and so aid in predicting appraisal-well locations. Archie also felt log responses could be related to depositional environments and he vigorously supported research programs in this area. **Archie believed that engineers should specialize in order to maximize understanding in a particular area, but work together in teams to solve exploitation problems.**

Archie's dream was to develop a system to estimate porosity and permeability from cuttings. Methods for describing sandstone cuttings depended upon understanding grain size, sorting, shaliness, cementation, and degree of consolidation. Correlations of these parameters with porosity and permeability proved to be useful. However, these methods were not fruitful for many types of carbonate rocks. A standard description that provided color, fossils, bedding, etc. provided no petrophysical information. What Archie needed was a completely different approach and so he developed his method for typing carbonate rocks based on pore types.

In April 1951, Archie presented "Classification of Carbonate Reservoir Rocks and Petrophysical Considerations," to the St. Louis meeting of the American Association of Petroleum Geologists. The paper was later published (Archie, 1952) and in it he gave full credit to the contributions of geologists who had aided him in developing his ideas namely: C. G. Cooper, R. C. Spivey, and Doc Wilhelm. The idea of classifying carbonate rocks in such a manner to convey as much as possible about the essential pore characteristics of a reservoir was revolutionary, and met with much skepticism in the geological community. It proved to be a valuable technical advantage for Shell. Archie showed that by classifying carbonate rocks based on the texture of the matrix and the character of the visible pore structure, one could easily separate rocks into permeability ranges (qualitatively) and semi-quantitatively predict porosity. "I didn't need the logs when I used Archie's classification system. All I had to do was stay awake, capture representative ditch cuttings, examine them carefully for shows, and use Gus's method and I never missed a pay zone. Hell, the electric logs were usually so bad in the dense carbonate reefs that I felt better using the Archie method anyway" (H. J. Hill, personal commun., 1992).

The Foundations of Research and Training

In 1951 Shell established a Technical Services Division in the Houston office under the direction of Joe Chalmers. There, specialists like Archie in petrophysics, George Dickenson and Doc Wilhelm in geology, and Tony van Everdingen in reservoir engineering worked as a team to solve subsurface evaluation problems for all of the operating divisions. This group also trained the most promising of Shell's engineers and geologists to use the newest technological advances perfected at Shell E&P Research labs. Archie was a strong advocate of specialized training and he spent considerable time and effort to develop training manuals for petrophysical engineering; some of his training documents are still used in Shell's E&P training center!

The Technical Services consulting group was so successful that Shell management felt they could benefit from being closer to the E&P Research staff and thereby enhance rapid technology transfer. Thus, when the new research building was completed on July 16, 1956, the Technical Services Division moved to its new home in the E&P Research community. Archie began in earnest to build a group of highly talented scientists who could be problem solvers. Let me quote one of the individuals hired at this time, Professor Ray Murray, University of Montana:

> "In hiring, he had an extremely broad vision. He almost never hired someone who was 'trained for the job.' **He hired people who were broadly trained and who he perceived could he directed toward those issues that he saw as important to the future.** His guidance and direction was extremely subtle. Everyone had the feeling that they were working on or doing what they wanted to do. However, when you looked at the entire organization, everyone was moving in the same direction as part of Gus' larger vision" (R. C. Murray, personal commun., 1992).

Technical Services flourished in this environment and in 1958 became part of Shell Development Company with Gus Archie named Manager of Exploitation Engineering Research. His research group contained three sections: Reservoir Engineering, Petrophysical Engineering and Production Geology. From this position Archie was able to recruit and direct research that had far reaching and long-lasting effects: Harold Hill and John Milburn's paper on SP and resistivity of shaly sands (Hill and Milburn, 1956); Harold Hill and A. Anderson's paper on streaming potential and SP (Hill and Anderson, 1959), Monroe Waxman and Lambert Smits' paper on resistivity behavior of shaly sands (Waxman and Smits, 1968); and George Klein, Harold Hill and O. J. Shirley's paper on bound water in shaly sands (Hill et al., 1979); just to name a few. Of course, most of the research done in this group was held confidential, applied by oil company engineers, then discarded as newer research lead to better methodology.

One of the classic unpublished field experiments performed by this group was in cooperation with Schlumberger. Archie and Schlumberger disagreed on the magnitude of the mudcake-filtrate effect on the SP response. Shell Oil furnished a suitable test well near Scott's Bluff, Nebraska, where a thick Dakota sand was penetrated. Mike Gondoin of Schlumberger, Monroe Waxman, and Harold Hill of Shell Development spent a week logging the zone with different surface pressures and different salinity mud filtrate. The results confirmed Shell's Position. Harold phoned Archie the good news, then proceeded to throw a party for the Shell and Schlumberger participants. Harold turned in a bill for $180 which Archie approved perfunctorily. Only later during a dinner with Gus and a production vice president, Ed Christensen, did Archie remark that the living costs in

Scott's Bluff were "high" and Ed said, "Real high" (H. J. Hill, personal commun., 1992; M. H. Waxman, personal commun., 1990).

An Archie innovation to foster technology transfer between the research group and the engineers in the field was to cross-transfer Ph.D. scientists from the lab out into the oil company and select technically strong engineers from the field to come into the research lab for a one-year assignment. This provided new perspectives for each individual and provided personal contacts for future technical problem solving. This process continues today (W. R. Purcell, personal commun., 1992).

The photo above was taken on a field trip to Shell's Williston Basin fields in 1953 by, from left, Tom Barnes, Loy Charter, Sam Paine, Gus Archie, and Charles Rabe.

Gus managed this research group until 1966 when he was made an assistant to the Vice-President of Research. His last publication was written at this time. Gus was invited to contribute to the National Petroleum Council document, "Impact of New Technology on the U.S. Petroleum Industry 1946-1965," (Archie, 1967a, b, c). It is understandable that Gus was asked to write the section on Formation Evaluation, but more remarkable, he was also asked to write the section on Production Geology, and the section on Properties of Reservoir Systems. While these sections were designed to be reviews of the technology, Gus was able to weave into the story his vision for both production geology and petrophysics. Much of what he recorded was, or later became, Shell methodology.

Archie (1967a) laid out the definition of the role for a production geologist: "The interpretation of the geologic history and the prediction of the limits and the distribution of the internal rock fabric of an accumulation is called production geology." He expected the production geologist to locate appraisal wells "in such a way as to obtain the greatest amount of geological information for predicting extensions and limits of the reservoir and to achieve the most efficient production." The production geologist was to understand the internal fabric and heterogeneities of the reservoir sufficiently well to aid the reservoir engineer in his design of more productive secondary and tertiary recovery operations.

Gus then defined the role of the petrophysical engineer (Archie, 1967b): "The process of using information obtained from a borehole to determine the physical and chemical properties of the rocks and their fluid content, especially hydrocarbons, is known as formation evaluation. The complexity and importance of formation evaluation have led to the establishment of a new technical position in many companies -- the formation analyst or petrophysical engineer, who brings into play a knowledge of physics, chemistry, geology, and engineering in developing and using physiochemical and petrological relationships." Gus said that the goal of the petrophysical engineer was the accurate determination of reservoir thickness, porosity, permeability, and oil saturation, at a reasonable cost. He advocated use of all the available data: cores and core analysis, mud logs and cuttings analysis, formation tests, and wireline logs. We still recommend this methodology.

The last section, on properties of reservoir systems, was perhaps the most profound. Here he explained (Archie, 1967c) how crucial it was to know the properties and performance of both the rock and its fluids at all scales in the reservoir, and how each level must be integrated into the overall performance and reserve prediction for the reservoir. He chose three scales: "(1) the reservoir as a whole, (2) a unit cube of the reservoir, and (3) a single pore." He discussed how important it was to understand the fluid systems, the pore structure of reservoir rocks, the rock-fluid system and the reservoir rock system. His final recommendation was: **"It is important to continue the basic research of microscopic phase distribution of hydrocarbon-water systems in porous media in relation to mineralogy, wettability, diffusion, and oil trapping, particularly from a dynamic point of view."** These words predicted the course of research in most every oil company and university petroleum-engineering lab for the next 20 years, but Archie only lived one more year and did not get to see his predictions come to pass.

The Two-Fold Legacy

Archie's work lives on in two ways; through the ideas and equations he published in the open literature, and through the engineers and scientists he hired and/or trained in Shell. In the latter case these engineers have propagated Archie's ideas and methods to this very

day; we still hear the words **"Have you looked at the Rocks?"** every time we evaluate a wireline log.

Archie had an uncanny ability in being able to sense an individual's capability for innovation and intuition. He carefully choose the engineers whom he made into petrophysical engineers and many rose to prominent positions within and without Shell. These include Phil Jensen, Sam Paine, Charlie Blackburn, Frank Richardson, Harold Hill, Bob Sneider, Ray Murray, Dick Pickett, George Stegemeier, Bert Thomeer, Jim Jorden ,and Denny Loren, just to name a few. In many ways Gus was like a university professor who attracted good graduate students who would go on to be as famous, or more famous, than their mentor.

But the other part of the legacy is just as important; almost without exception, Archie's ideas are either being practiced routinely or they're being further developed by the petroleum industry (Abbott, 1986; Paine, 1988). His concept of holistic formation evaluation, rather than just log analysis, is fundamental and now recognized as a separate technological entity by the Society of Petroleum Engineers. His concept of multiple measurements and trend analysis, as opposed to mathematical rigor, has proved successful in every producing basin, and even today, these statistical methods are yielding to stochastic methods running on powerful computers. You can't argue against his dictum of using "all the available data to arrive at the solution which best fits these responses."

Epilogue

After interviewing more than a dozen of Archie's co-workers and trainees, and reading over 40 of his technical reports, a clear picture of Gus' personality emerged. He was a quiet and modest gentleman, easy to work for, genuinely concerned about people and their cares, tolerant of other's ideas, he let people make their own mistakes, and he fostered teamwork. When asked what Gus' hobby was, Bill Hurst replied, "His family" (W. Hurst, personal commun., 1992). Archie objected when others called his equations, "Archie's Laws." He steadfastly refused to make sweeping claims for his "trends," and was very careful to stay within the bounds of his empirical correlations. His degree of modesty can best be explained by relating that his departmental secretary from 1958-1966 did not know of his international fame until she read his obituary in 1968. Pomp and flair were not in his repertoire; integrity, empathy, intuition, credibility, determination, and perception most certainly were. He deserves every award and accolade given him and more.

And it is most fitting that the Archie Conference, named in his honor, focuses on interdisciplinary studies of geology, geophysics and petrophysics (Sneider, 1990). Gus had the knack of identifying important problems, bringing together the right people to solve the problems, then backing away and letting the scientists and engineers work to find a solution. Gus's approach to managing people set an atmosphere that encouraged cooperation and exchange among the various disciplines. The concept of teamwork may be his greatest legacy. Only those of the future will know.

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