Rocky Mountain Association of Geologists
1997

Innovative Applications of Petroleum Technology in the Rocky Mountain Area

Edited by:
Edward B. Coalson, John C. Osmond, and Eugene T. Williams

Cuttings Analysis—An Integral Support Tool for Exploration and Exploitation

K. K. Stolper

Stolper Geologic, Inc. - Arvada, Colorado

ABSTRACT

Visual analysis of well cuttings is proving to be an integral part of today's project work supporting exploration and exploitation programs for Amoco Production Company in Denver, Colorado. Integrating sample examination into the prospect evaluation process is contributing to better business decisions. The visual estimation of porosity, permeability, Archie "m", hydrocarbon shows, microporosity, and natural fractures minimize exposure to technical risk and favorably impacts funding of drilling or recompletion projects.

In Garvin, Stephens, and Carter Counties, Oklahoma, drilling and development activity dates to the 1930s, 1940s, and 1950s, a time when open-hole wireline logging was in its infancy. Porosity tools were not available for characterizing and mapping reservoir parameters. In the Viola Formation of Garvin County, Oklahoma, wireline logs were somewhat ambiguous regarding reservoir quality. Detailed sample examination not only revealed intervals of better reservoir quality and natural fracturing (something not obvious on the wireline logs), but also clearly illustrated the location of the oil/water contact. Based on the cuttings analysis, the upper portion was fracture stimulated and initially produced more than 100 BOPD.

Another example is the Basal McLish Formation, also in Garvin County, Oklahoma. This formation appears to be water saturated in some areas. Visual cuttings analysis revealed a grain coating chlorite which contains bound water resulting in low resistivity readings. The cuttings analysis also revealed an oil saturated result with the "wettability" test confirming that the water is not free, movable water. The zones were completed and produce oil with little or no water.

A third example is the Mississippian Springer and Pennsylvanian Deese groups. Analysis of electric logs identified possible by-passed pay. At issue was the question of producibility and economics. From a conventional log-evaluation point of view, the zones were considered high-risk targets for recompletion. Visual rock examination provided compelling evidence for favorable reservoir. The zone was perforated, stimulated, and has been producing for over 15 months to date (March, 1997).

Sample examination also is being used in wildcat drilling programs in portions of southern Oklahoma where modern wireline logging suites are unavailable. Visual sample analyses are incorporated into a proprietary Monte Carlo risk-assessment program aiding the work team in creating and managing a prospect portfolio.

Lastly, in addition to oil shows, the examination of low porosity/low permeability rock has led to an observation which is believed to assist in identifying whether or not gas is present in the pore system. One area where this technique shows promise is the Whitney Canyon area of Uinta County, Wyoming.

INTRODUCTION

Several projects participated in, initiated by, and/or completed by Amoco Production Company, Denver, Colorado over the last two years have been enhanced by the application of visual analysis of well cuttings. This is especially true in areas where historical drilling and development activity dates to the 1930s, 1940s, and 1950s, a time when open-hole wireline logging was in its infancy and porosity tools were not available.

VISUAL ANALYSIS TECHNIQUE

The visual analysis technique used by Stolper Geologic, Inc. is based on the comparator method initiated by Canadian Hunter Exploration in Elmworth field in Canada (Hietala et al., 1984; Druyff, 1996). The techniques were proven effective more than twenty years ago. Today, expanded methods of cuttings analysis not only focus on basic lithologic descriptions, porosity estimates, and oil shows, but are also able to provide estimates of permeability, clay types and percentages, additional conductive minerals, gas shows, and Archie's cementation exponent (m), which can range from 1.4 to 2.9. Correct values for m provide significantly more accurate saturation calculations.

To accurately estimate an Archie m value from cuttings, comparators containing rock having measured m values are examined as a baseline. Then, with an understanding of the factors that effect m (e.g., surface area, cementation, compaction, clay content), m can be estimated (King, 1992, pers. comm.). For instance, the rock sample in a comparator may be similar to a rock sample for which m is being estimated except that the comparator contains kaolinite clay whereas the unknown sample contains smectite clay. Since kaolinite has a lower CEC value and greater surface area, the estimated m of the unknown sample will be lower than the measured m of the comparator.

There have been recent advances in wireline logging to assist in the identification of natural fracturing (e.g., dipole sonic logs); however, natural fracturing is difficult to determine in older wells when using conventional wireline logs alone. Visual cuttings analysis has the capacity to identify natural fracturing within a reservoir. The evidence for natural fracturing preserved in cuttings includes calcite and/ or quartz crystals. For example, well-formed crystals or druse can be interpreted as an indication of open fractures. Micro-, healed, and partially open fracture evidence can also be described from cuttings. This knowledge is critical in understanding recoverability as well as in designing an artificial fracture for a particular zone.

Visual cuttings analysis also aids in the search for low resistivity pay by identifying conductive iron-bearing (pyrite, siderite, etc.) and microporous (glauconite, other micas, clay, etc.) minerals using a binocular microscope at 20X to 50X magnification. Microporous minerals contain bound water and cause the resistivity readings on wireline logs to be low.

The accuracy of the porosity and permeability estimates are confirmed periodically each year by the petrologist, who randomly selects core plugs to be measured and compares the measured values to the visually estimated values. This process helps maintain "calibration" between measured values and the petrologists' visual estimates.

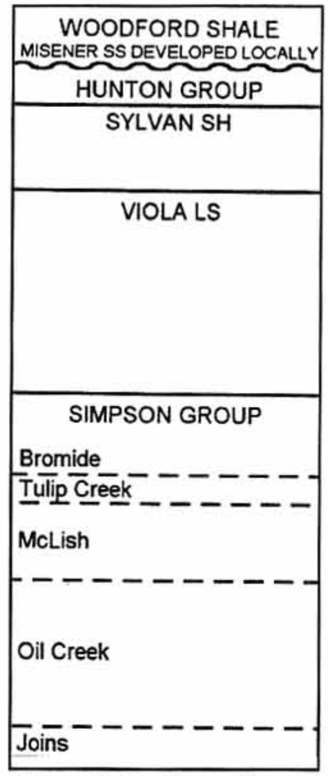

Figure 1. Stratigraphic section showing position of the Ordovician Viola and McLish formations.

VIOLA FORMATION

One example of visual cuttings analysis is in the Viola Formation (Fig. 1) of Garvin County, Oklahoma (Fig. 2). Identification of zones with better reservoir quality was difficult using wireline logs. The formation is a limestone with textures ranging from dense micro/cryptocrystalline, "chalky" microcrystalline, to sucrosic microcrystalline.These descriptive textural terms were used by Archie in his classification of carbonate rock (Archie, 1952). Chalky textures refer to rock which have an earthy or chalky appearance at 20X magnification. These rocks are usually very porous and of low permeability. Sucrosic texture refers to rock that appears sugary or crystalline at 20X magnification. Sucrosic rock is generally thought to be of good reservoir quality, having crystals that interlock ineffectively and create good porosity and good permeability.

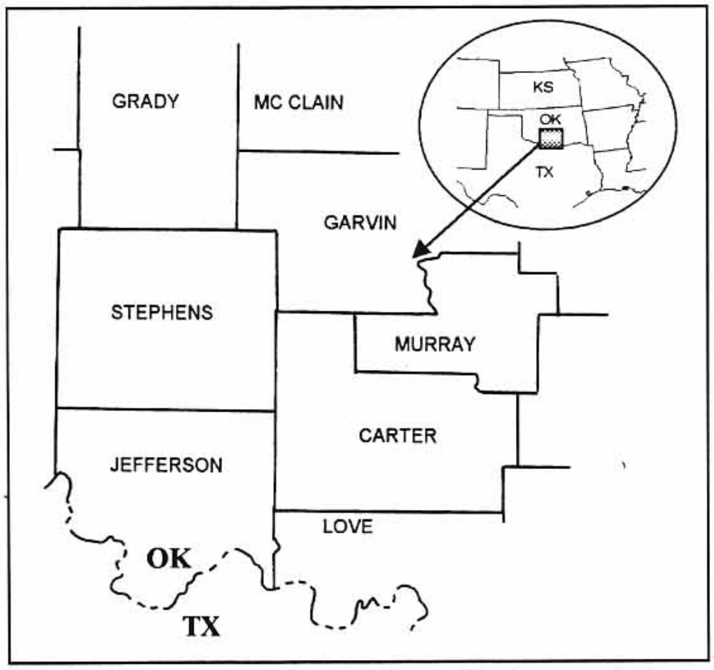

Figure 2. Location map showing Carter, Stephens, and Garvin counties of southern Oklahoma.

Cuttings examination revealed that a rock-type change coincided with an increase in porosity (zones with greater than 20% chalky limestone coincide with porosities of greater than 8%). Visual cuttings analysis also revealed evidence of natural fracturing throughout, something not seen on wireline logs.

Sample analysis also provided an understanding of where the oil/water contact was to be found. Using a technique called the oil wettability test (Fig. 3), the oil/water contact was defined. Based on the results of the visual cuttings analyses (Fig. 4), the upper zones were fracture stimulated, with the result that the well initially produced more than 100 BOPD.

BASAL McLISH FORMATION

The next example area of visual cuttings analysis is also in Garvin County, Oklahoma. There is a great deal of folding and faulting in this area. According to conventional wireline log analysis, pay zones in the Basal McLish Formation can appear to be wet. On wireline logs from a well (Fig. 5), the Basal McLish is repeated by an overturned anticline. The upper sandstone appears from logs to be wet; the overturned Basal McLish appears to have the lower lobe wet (Fig. 6). In reality, the entire section is productive, and there is little mobile water. Under 20X magnification, the apparently wet sandstone contains sand grains coated with pale green chloritic clay. This clay contains bound water that significantly reduces the resistivity readings on the wireline logs. The clay is believed to be detrital rather than diagenetic and shows little crystal structure in SEM

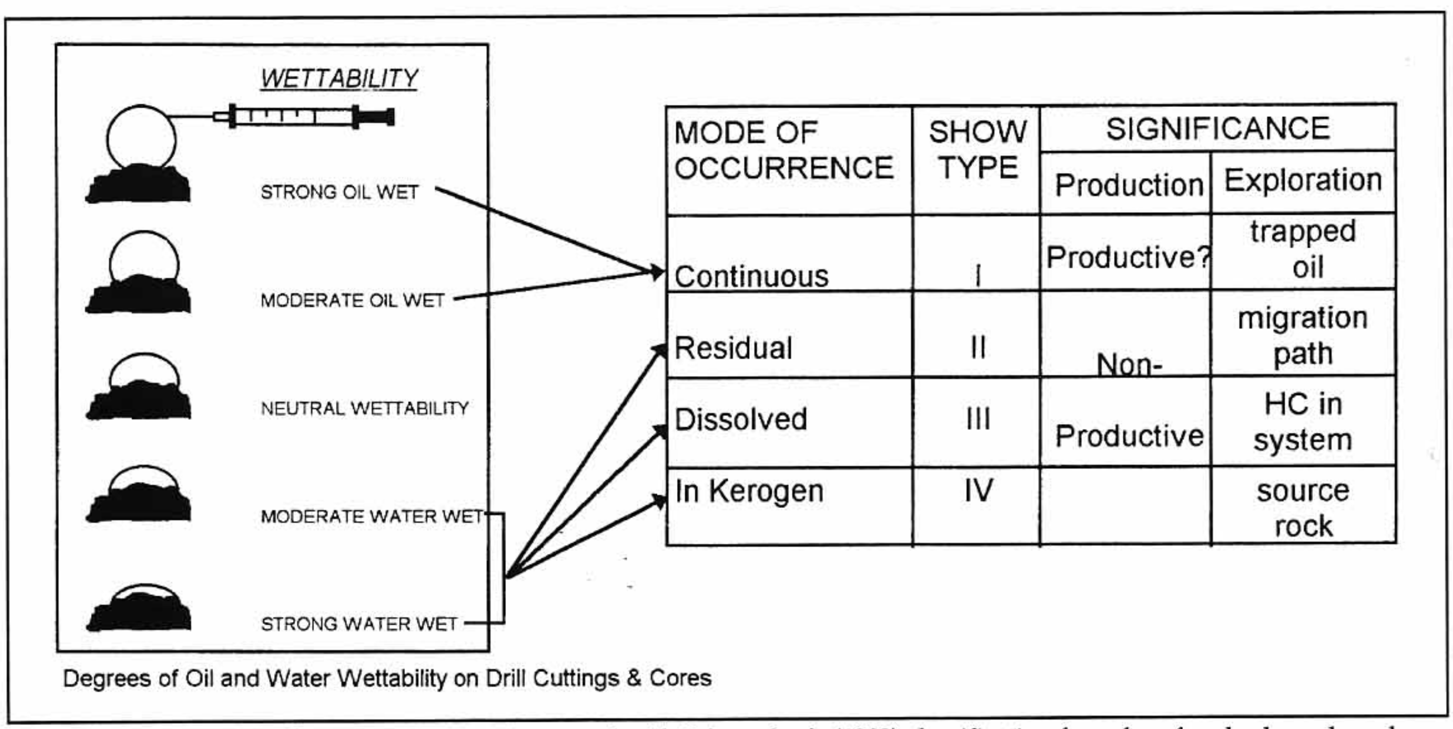

Figure 3. Oil "wettability" or saturation test integrated with Schowalter's (1982) classification for subsurface hydrocarbon shows (Druyff, 1996).

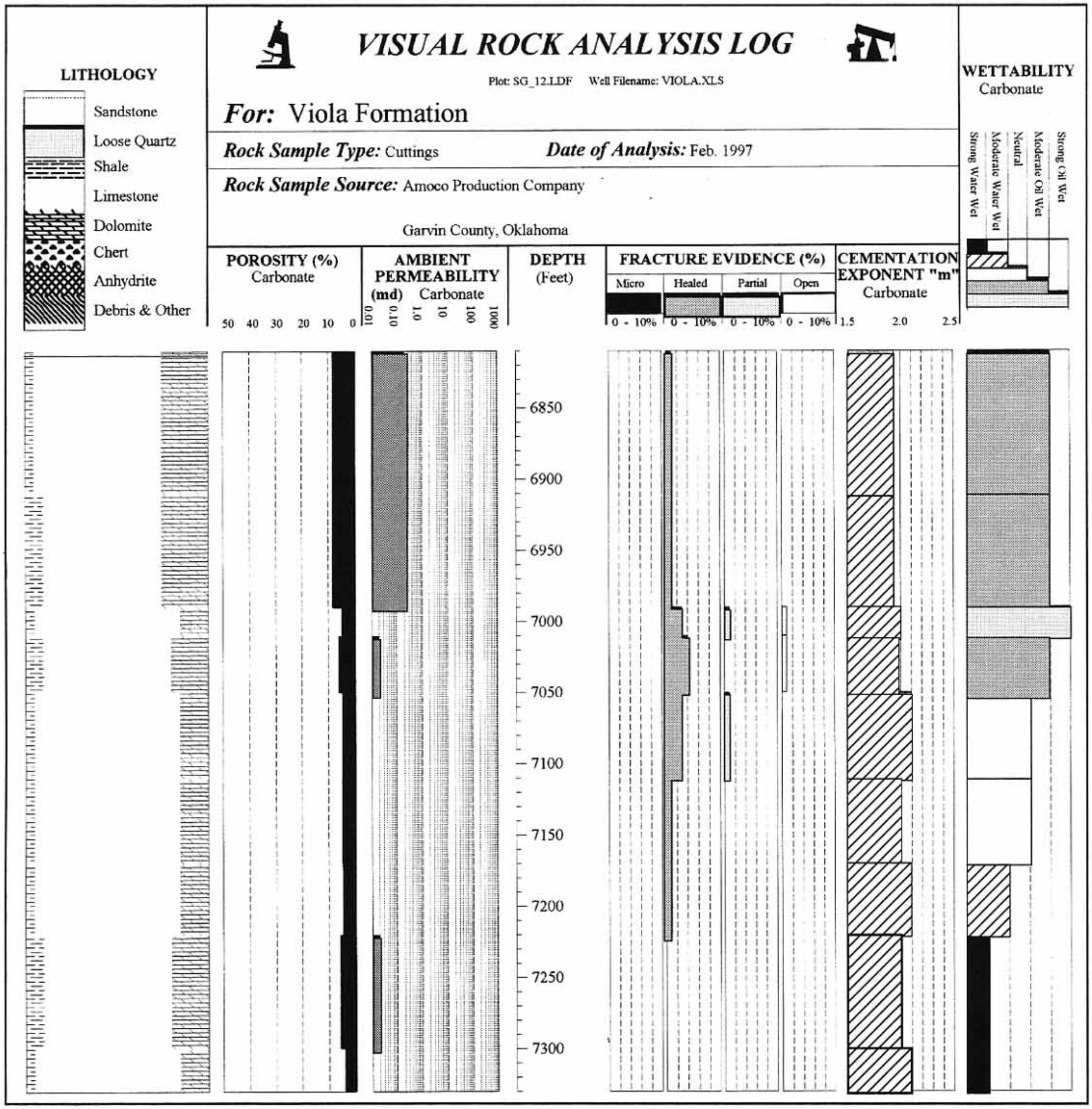

Figure 4. Graphical summary log showing results of visual analysis of Viola Formation cuttings.

(Fig. 7). Similar sandstones in other areas, e.g., the Nugget sandstone in Wyoming, may contain the same detrital clay coating with similar results.

In contrast to the apparently wet sandstone bed, in the bed with higher resistivities the chloritic clay is absent or present only in minor amounts. The oil saturation test used in our visual cuttings analysis had strong positive results in both beds, being strongly to moderately oil saturated. This helped to confirm that the bound water of the clay is causing the low resistivity. The positive outcome of visual analysis (Fig. 8) here provided the confidence to complete all of the pay in these zones that produce oil with little to no water.

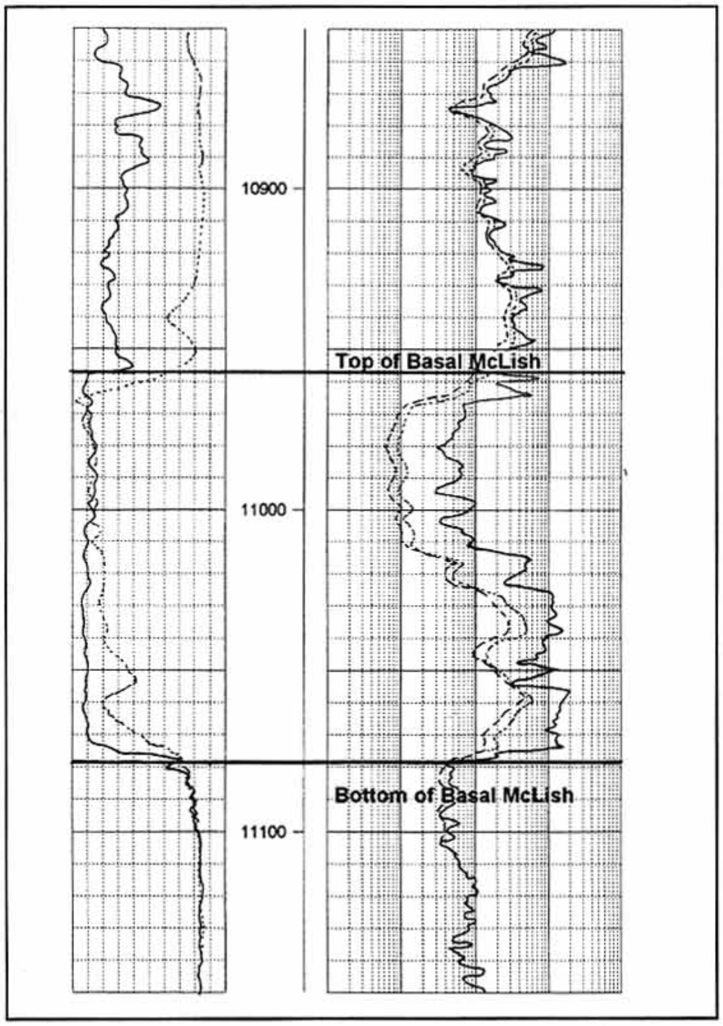

Figure 5. Typical wireline log of normally positioned (not over turned) Basal McLish Formation.

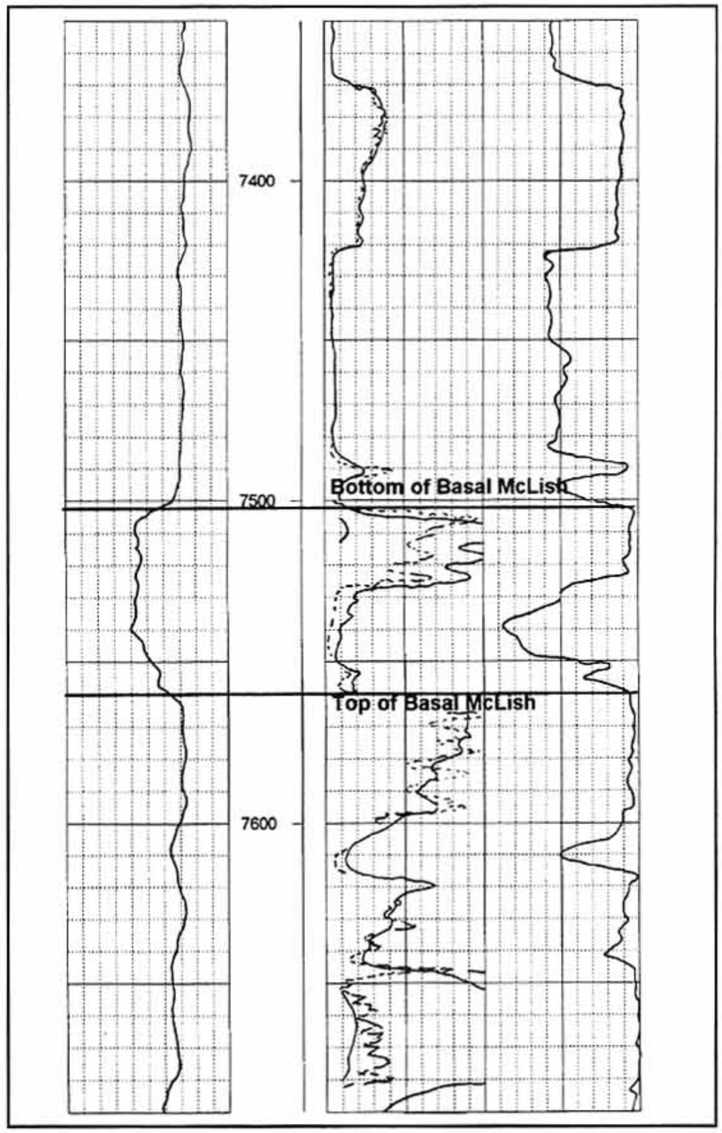

Figure 6. Typical wireline log of over turned Basal McLish Formation.

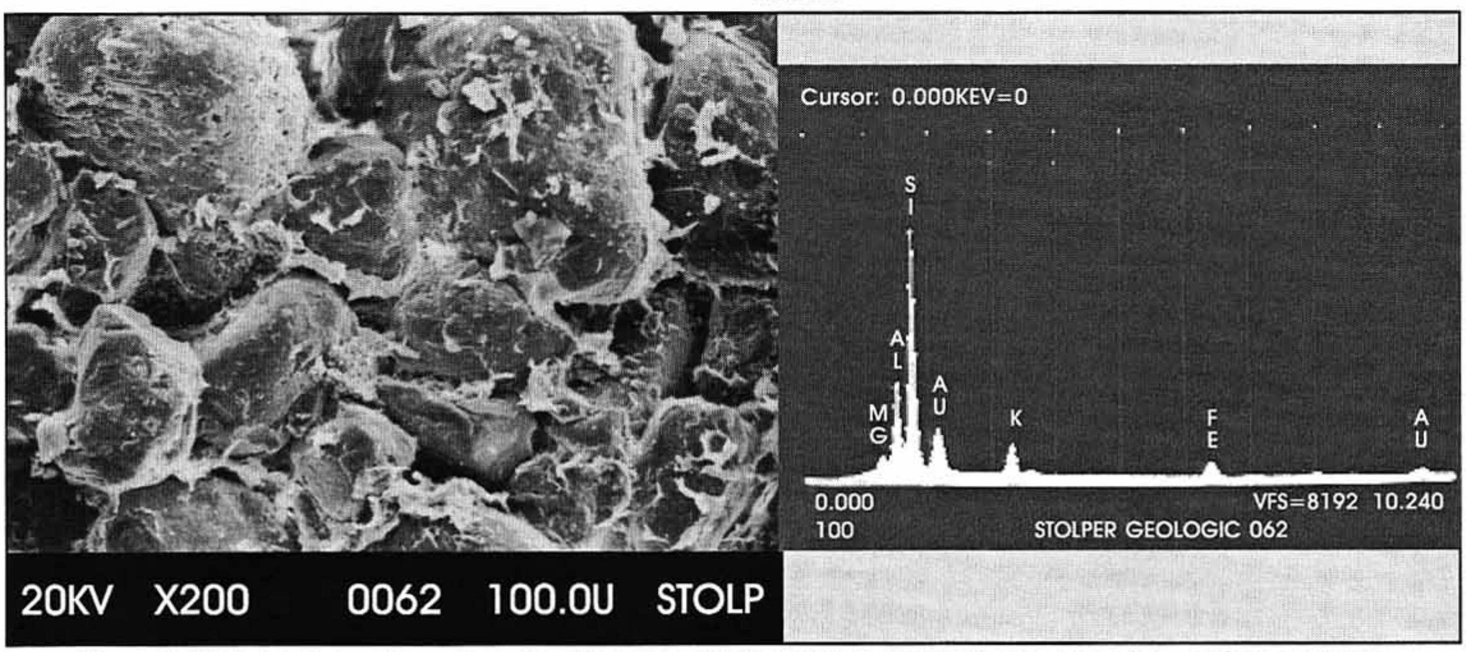

Figure 7. SEM showing grain coating chloritic clay and EDS spectrum confirming the type of clay as being chlorite.

Kathy Stolper
Stolper Geologic, Inc. - Arvada, Colorado

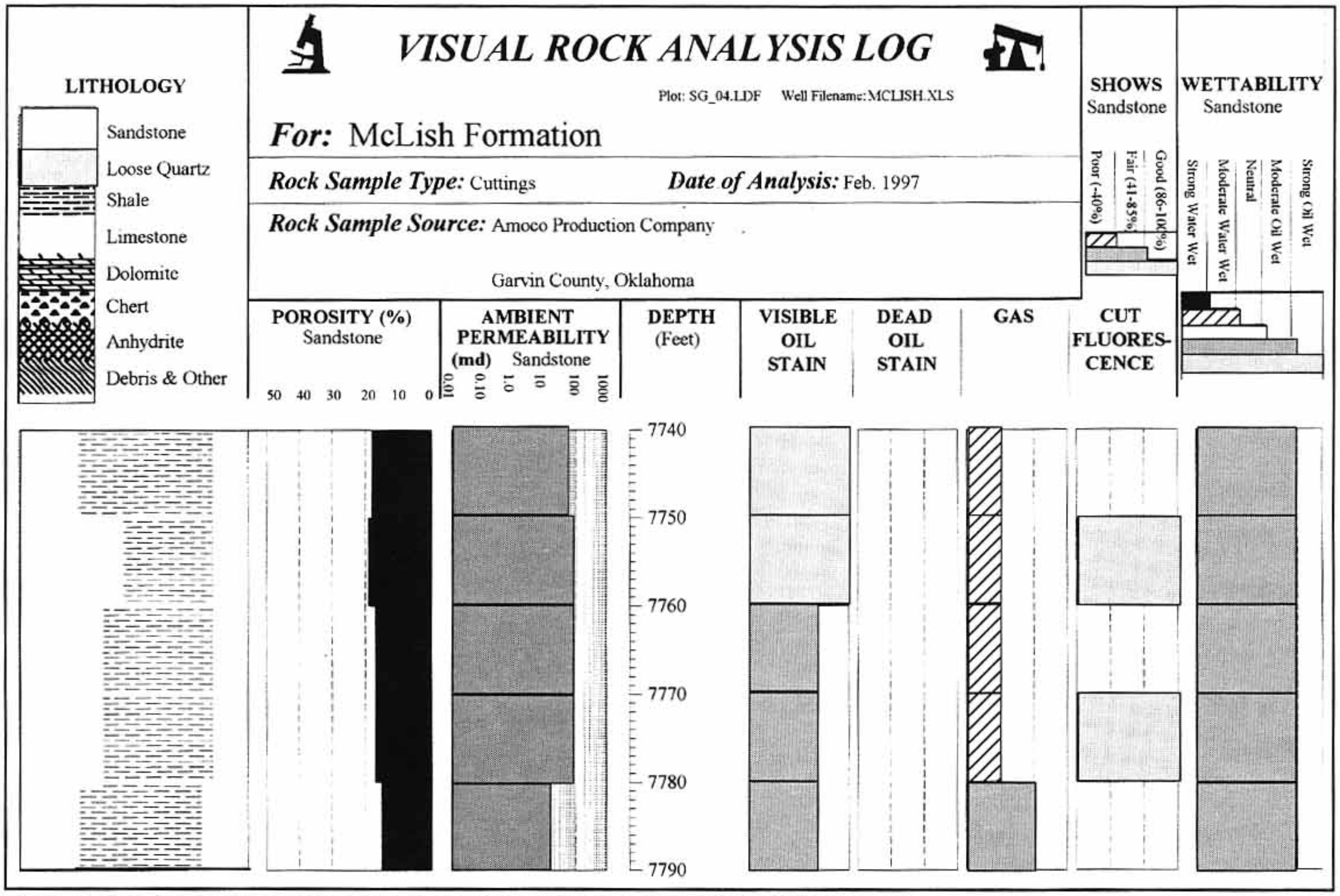

Figure 8. Graphical summary log showing results of visual analysis of McLish Formation.

SPRINGER AND DEESE GROUPS

A third example is found in the Mississippian Springer and Pennsylvanian Deese groups (Fig. 9). In T2S, R4W of Oklahoma, Amoco workers identified possible bypassed pay using old electric logs. The questions of producibility and economics were cause a concern. The Deese zone had poor SP development and was considered a high-risk target for recompletion. This zone had been interpreted as stacked lower-shoreface sandstones; however, from the logs they could have also been interpreted as low permeability carbonates.

Visual cuttings analysis (Fig. 10) provided the needed confirmation that these were indeed thinly interbedded sandstones of adequate porosity, permeability, and hydrocarbon shows. The zone was perforated, stimulated, and has been producing for over 15 months (as of March, 1997). The interval is making about 10 to 20 BOPD plus 3 MCFGPD; the rates are not astounding due to partial depletion.

In the same general area, upper Springer sands appeared prospective from conventional wireline- log analysis. However, reservoir quality of the sandstone was in question. Cuttings were available in one well. Visual analysis indicated better porosities than interpreted from the logs alone (Fig. 11). This provided confidence in the play concept, with the result that the project was funded and a new-zone

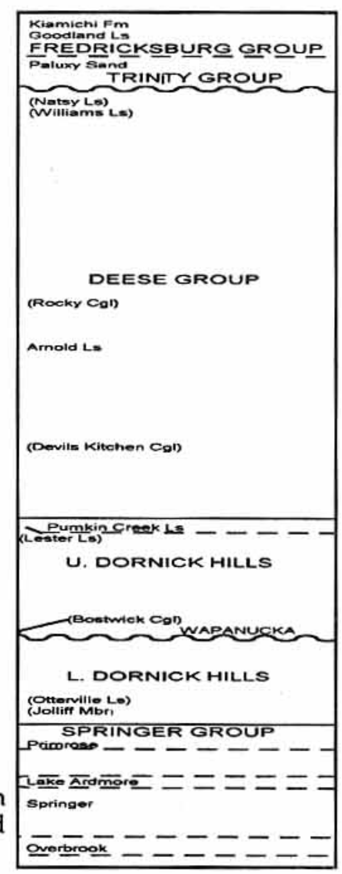

Figure 9. Stratigraphic section showing position of the Deese and Springer groups.

discovery was made with initial pumping rates of 180 BOPD.

WILDCAT DRILLING PROGRAMS

Visual cuttings analysis also is being used in wildcat drilling programs in portions of southern Oklahoma where modern wireline logging suites are unavailable. Results of sample analyses are incorporated into a Monte Carlo risk-assessment program enabling the work team to create and manage a prospect portfolio. Many of the risk-assessment programs call for the explorationist to make assumptions (often using only log interpretations) regarding reservoir quality. One key parameter needed is permeability, which can be estimated from visual cuttings analysis.

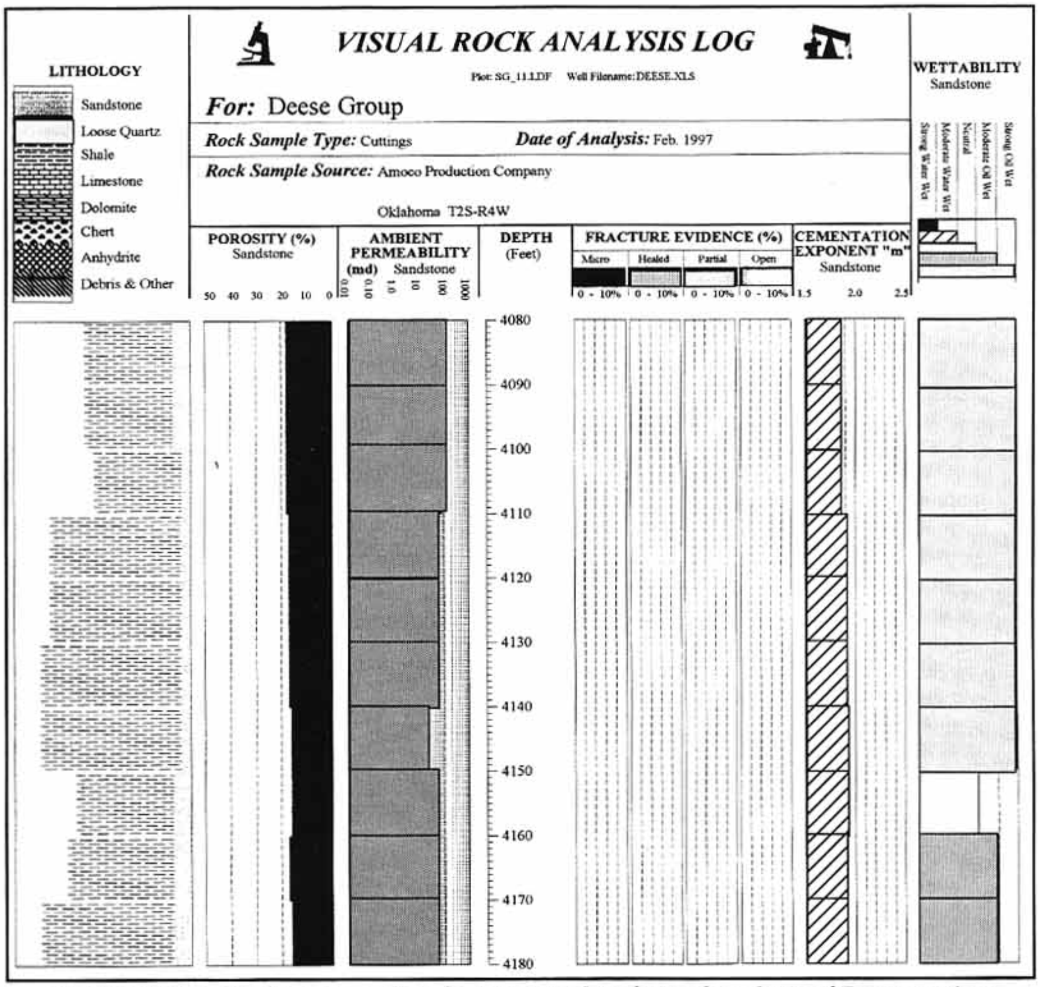

Figure 10. Graphical summary log showing results of visual analysis of Deese section.

TIGHT GAS PLAYS

Observation of cuttings from multiple wells in tight gas sandstones and carbonates suggest that subtle gas shows can be recognized from cuttings. As cuttings are placed in a 10% solution of hydrochloric acid, bubbles will form and remain for lengthy periods of time on the bottom and sides of the spot plate. These bubbles are different from those generated from carbonate material that rather quickly escape to the surface. It has not as yet been proven what type of gas is contained in these bubbles. However, the technique is useful simply in that an abundance of the bubbles correlates to gas-producing zones; a lack of these bubbles correlates to very poor to non-producing zones.

One area where this technique shows promise is Whitney Canyon Field in Uinta County, Wyoming. Ten wells were initially submitted for visual analysis with "gas shows" being noted when present. Out of those ten wells, nine of them show good agreement between the "gas shows" and mudlog shows and/or gas production. This technique seems to be less useful in rock of higher porosity and permeability. The technique is also affected by the age of the sample, so that a set of cuttings from a well completed fifteen years ago will have a diminished "gas show".

CONCLUSIONS

Log analysis alone often gives an incomplete picture of what to expect from a recompletion or a prospect even with the recent advances in log interpretation. There are no logs that directly measure permeability, describe pore structure, or indicate potential completion problems. In the case where there are only old electric logs, it is difficult to derive a reliable porosity value; without a reliable

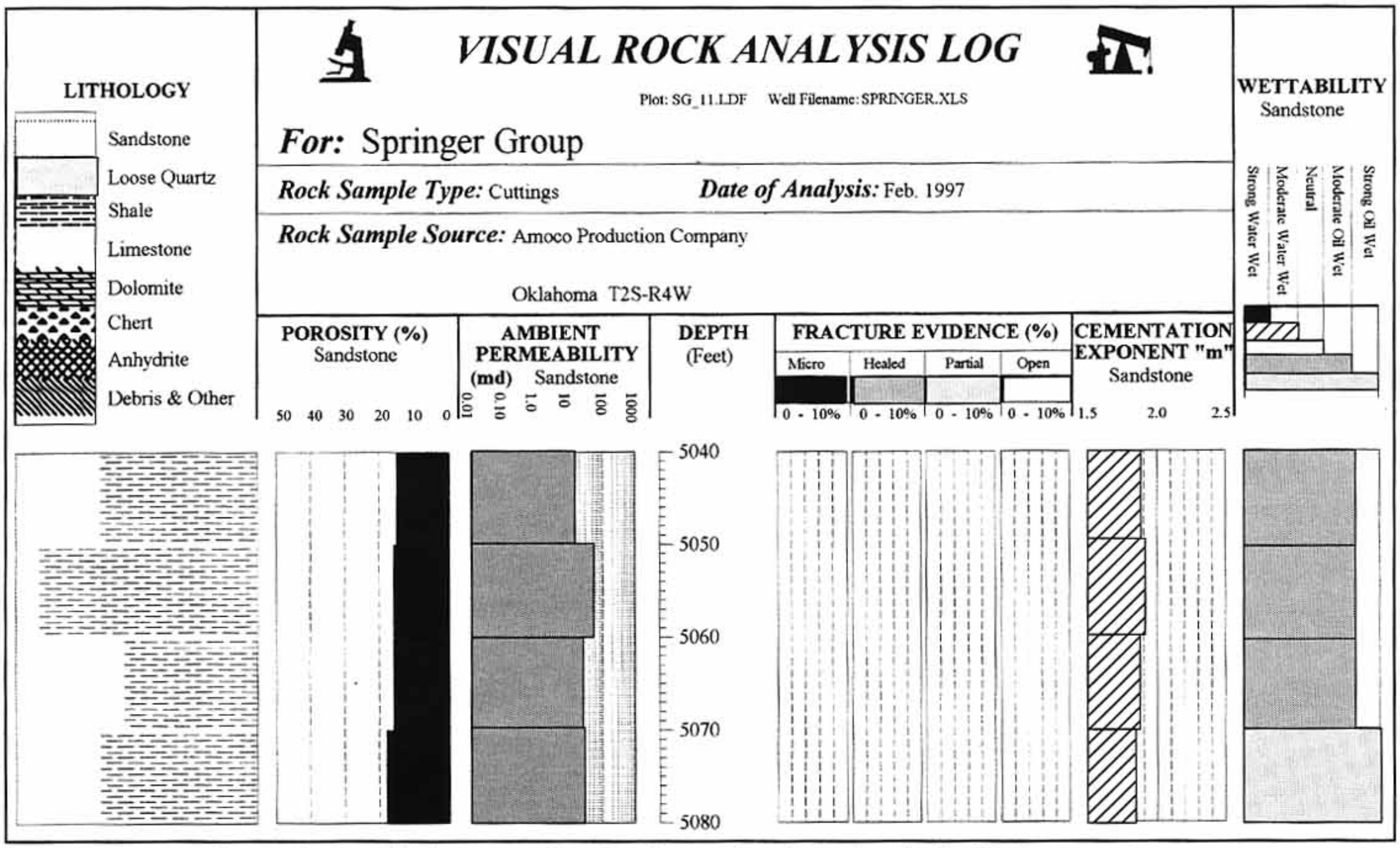

Figure 11. Graphical summary log showing results of visual analysis of Springer section.

porosity value, calculations of water saturation are nearly impossible. Analyzing wellbore cuttings can provide insight into these questions as well as other important reservoir parameters.

Many of today's exploration and exploitation projects are concerned with low-grade pay that would have been condemned just ten years ago. The ability to accurately estimate low-end porosity and permeability assists in identifying such pay. By paying more attention to the subtle detail contained in cuttings and using that information to enhance any vintage of wireline log, Amoco Production Company (for one) has been successful in decreasing risk on several exploration and exploitation projects.

ACKNOWLEDGMENTS

Grateful acknowledgment is hereby made to Thomas Olson, Elliott Simonberg, Noel McInnis, and Amoco Production Company (Denver, Colorado) who contributed data and made this paper possible.

REFERENCES

Archie, G.E., 1952, Classification of carbonate reservoir rocks and petrophysical considerations: AAPG Bull., v. 36, p. 278-298.

Druyff, J., et al, 1996, Petrophysical properties determined from analysis of drill cuttings, *in* E. Dolly and J. Mullarkey, eds., Hydrocarbon Production from Low Contrast, Low Resistivity Reservoirs, Rocky Mountain and Mid-Continent Regions, Log Examples of Subtle Pays: RMAG, Denver, Colorado, p. 17-28.

Hietala, R. W., E. T. Connolly, H. R. King, and R. M. Sneider, 1984, Selected examples illustrating integration of rock-log data to determine reservoir petrophysical characteristics, *in* J. A. Masters, ed., Elmworth-Case Study of a Deep Basin Gas Field: AAPG Memoir 38, Tulsa, Oklahoma, p. 205-282.

Schowalter, T. T., and P. D. Hess, 1982, Interpretation of subsurface hydrocarbon shows: AAPG Bull., v. 66, p. 1302-1327.