SPECIAL APPLICATIONS 10

This chapter includes some miscellaneous devices and applications not covered in previous chapters. A number of other miscellaneous special-purpose devices and services have also been discussed in Chapter I-18.

EXAMPLES OF MINERAL INTERPRETATION

Evaluation of mineral deposits was discussed in Chapter I-18. In this section we will give a brief outline of evaporite (potash) interpretation and show examples of computer-produced sulfur and coal logs.

SIMULTANEOUS-EQUATION SOLUTION

Lithological interpretations may be computed from a set of simultaneous equations involving usually the Sonic, Density, and Neutron readings and a knowledge of the minerals present in the formation. Thus, for illustration, for the case of a dolomite-limestone-sandstone mixture these equations could be:

$$\rho_b = 1.0\,\phi + 2.87\,V_{dol} + 2.71\,V_{ls} + 2.65\,V_{sd} \quad \text{(FDC Density)} \qquad (10\text{-}1a)$$

$$\phi_{SNP} = 1.0\,\phi + 0.02\,V_{dol} + 0.0\,V_{ls} - 0.035\,V_{sd} \quad \text{(SNP Neutron)} \qquad (10\text{-}1b)$$

$$\Delta t = 189\,\phi + 43.5\,V_{dol} + 47.5\,V_{ls} + 55.5\,V_{sd} \quad \text{(Sonic)} \qquad (10\text{-}1c)$$

$$1 = \phi + V_{dol} + V_{ls} + V_{sd} \quad \text{(Material Balance Equation)} \qquad (10\text{-}1d)$$

where V_{dol}, V_{ls}, and V_{sd} represent the bulk-volume fractions of the respective minerals, and ϕ is the fractional porosity, and where the numerical coefficients in the equations are the fluid values (ρ_f, $(\phi_N)_f$, and Δt_f) and the matrix-mineral values (ρ_{dol}, ρ_{ls}, ρ_{sd}, $(\phi_N)_{dol}$, $(\phi_N)_{ls}$, $(\phi_N)_{sd}$, Δt_{dol}, Δt_{ls}, and Δt_{sd}).

For given log values, ρ_b, ϕ_{SNP}, and Δt, the four simultaneous equations above are solved in the computer for the four constituents, ϕ, V_{dol}, V_{ls}, and V_{sd}. Only if non-negative values are found for each constituent fraction can the solution be acceptable.

The above type of solution is known as the Tri-Porosity solution,[1, 2] since three porosity logs are involved. In setting up these linear simultaneous equations the assumption is made that the effective parameters of a mineral mixture are given by a linear combination of the matrix parameters of the constituent minerals.

In the following, simultaneous equations similar in form to those in Eqs. 10-1 are written and solved for other sets of mineral constituents.

EXAMPLE OF EVAPORITE INTERPRETATION

Interpretation of radioactive evaporites was touched on in Chapter I-18. What follows is a summary of an interpretation for evaporite deposits consisting of sylvite, carnallite, halite, and insoluble* materials. Logs used are Gamma Ray, Sonic, Neutron, and Caliper. The Density Log may also be used to check the results.

Sylvite (KCl) and carnallite ($KCl \cdot MgCl_2 \cdot 6H_20$) are radioactive because of their potassium content. An empirical correlation between gamma ray activity and the apparent K_20 content of a potash bed is shown in Fig. 18-4 of Chapter I-18. Fig. 10-1 illustrates a nomogram derived from the same data which facilitates conversion of gamma ray activity from logging tools listed in the figure to apparent K_20 content. If the beds are thinner than 2 ft, a bed thickness correction must be made to the Gamma Ray reading using an empirical chart such as that of Fig. 10-2.

The apparent K_20 ratings of the three evaporites and the insolubles are listed in Table 10-1. Thus the total apparent K_20 content (P_t) of the formation would be given by

$$P_t = 0.17\,V_{car} + 0.00\,V_{hal} + 0.63\,V_{syl} + 0.05\,V_{ins} \qquad (10\text{-}2)$$

*These are residues remaining after a sample is dissolved in hydrochloric or acetic acid, chiefly composed of shale, chert, quartz, and various other insoluble detrital materials.

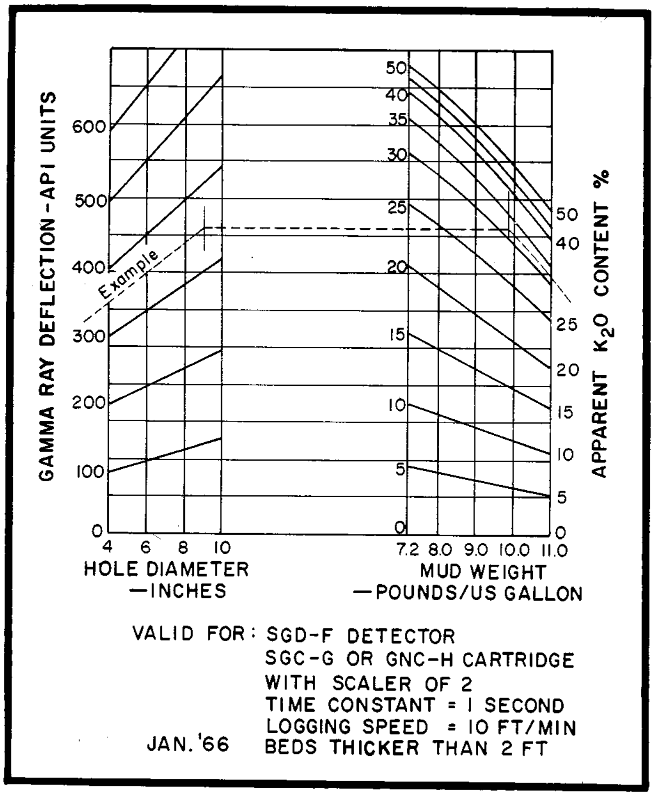

*Fig. 10-1 — **Nomograph for potash content.** (From Ref. 3, courtesy of J. Can. Pet. Tech.)*

where V_{car}, V_{hal}, V_{syl}, and V_{ins} are the volume fractions of carnallite, halite, sylvite, and insolubles in the formation.

The logging parameters listed in Table 10-1 can be used to write similar expressions for Neutron porosity, ϕ_N, and Sonic transit time, Δt.

$$\phi_N = 0.65\, V_{car} + 0.00\, V_{hal} + 0.00\, V_{syl} + 0.30\, V_{ins} \qquad (10\text{-}3a)$$

$$\Delta t = 78\, V_{car} + 67\, V_{hal} + 74\, V_{syl} + 120\, V_{ins} \qquad (10\text{-}3b)$$

An additional relation is

$$1 = V_{car} + V_{hal} + V_{syl} + V_{ins} \qquad (10\text{-}3c)$$

When P_t, ϕ_N, and Δt are available from logs the above four equations can be solved for V_{car}, V_{hal}, V_{syl}, and V_{ins}. A computer program has been developed to perform this solution.

A simple crosscheck of the results can be accomplished by use of a Density Log. The density reading from the log can be compared with a density value computed from the results according to

$$\rho_{calc} = 1.57\, V_{car} + 2.03\, V_{hal} + 1.86\, V_{syl} + 2.60\, V_{ins} \qquad (10\text{-}3d)$$

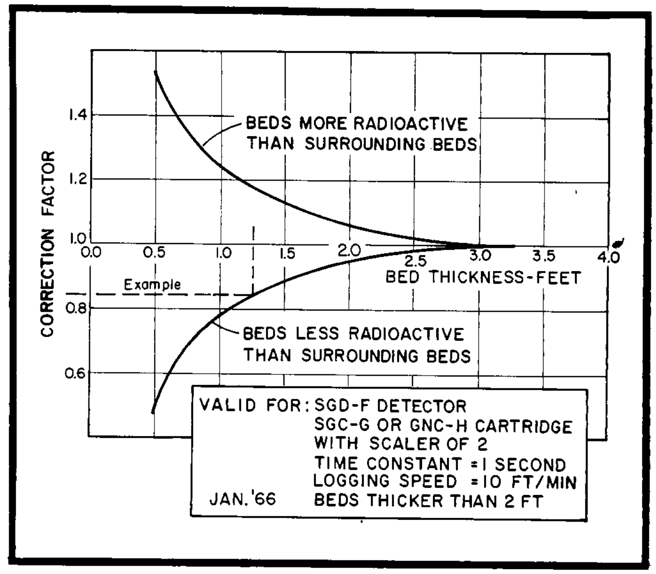

*Fig. 10-2 — **Gamma Ray bed-thickness correction chart.** (From Ref. 3, courtesy of J. Can. Pet. Tech.)*

SULFUR LOG[4]

Fig. 10-3 shows a Sulfur Log, computer-produced from Neutron, Density, and Sonic Logs. The computation is based on solution of simultaneous equations, with bulk-volume fractions of water-filled porosity, sulfur, limestone, and a selectable third mineral (usually silt or shale) as the variables.

When present, gypsum is easily detected because it leads to computations of absurdly high values of porosity and negative fractions of sulfur. Anhydrite, when present, leads to negative values for both porosity and sulfur content. The program is adapted to handle these cases.

TABLE 10-1

MINERAL	APPARENT K_2O RATING Percent	APPARENT NEUTRON POROSITY Percent	APPARENT DENSITY Grams per cubic centimeter	TRUE DENSITY Grams per cubic centimeter	SONIC TRAVEL TIME Microseconds per foot
Carnallite	17.0	65.0	1.57	1.61	78
Halite	0.0	0.0	2.03	2.16	67
Sylvite	63.0	0.0	1.86	1.98	74
Insolubles	5.0	30.0	2.60	2.60	120