ENVIRONMENTS OF DEPOSITION IN THE MINNELUSA AND THEIR INTERPRETATION FROM GAMMA SONIC LOGS

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ABSTRACT

Over 230 cores were examined and compared with Sonic Logs in the Powder River Basin of Wyoming. Surface sections were examined around the rim of the basin and related to the subsurface study. Surface work at Natural Bridge Section in the Black Hills (Fig. 1), demonstrates an ideal weak transgression for a particular sandstone in the Minnelusa formation. Sandstone trends are linear (longitudinal) ripple buildups of composite cross-bed units having a frequency of about three miles and an amplitude of as much as 100 feet.

A proper understanding of well-to-well facies distribution requires a logging tool with the ability to differentiate lithology precisely. The Sonic Log is clearly demonstrated as ideal for this use, particularly for environmental applications because energy and porosity are believed to be related functions. Comparison of hundreds of cored sandstones with corresponding interval transit times suggests the following outline of environments arranged in a sequence of increasing travel times.

dolomite —*Shallow Marine to Tidal Flat Transition* very high velocity, smooth Sonic Log expression) light gray, sublithographic, with algal "mats", pellets
Shallow Marine (slightly slower velocity, serrate Sonic Log expression)—dark gray, sublithographic; more chert, shale, and anhydrite inclusions

anhydrite—*Marine Embayment* (massive bedded, rosette) or *Tidal Flat* (laminated—slower than clean dolomite, serrate Sonic Log expression)

shale —*Estuarine "Fill in" to Subaerial* (high velocity, serrate Sonic Log expression which is related to proportion of clay-choked sandstone)—red, very anhydritic
Euxenic Basin (smooth "scissor tails" Sonic Log expression)—richly carboniferous, black to maroon, excellent source beds

sandstone—*Shallow Marine* (serrate, low travel time Sonic Log expression—small-scale ripples filled with clastic carbonates, heavily cemented with anhydrite and dolomite; colors generally darker; reworked
Eolian or Dune (smoother, high travel time Sonic Log expression)—large-scale ripples, clean, coarser, less cement, light colors

An excellent match of lithology and Sonic Log expression is demonstrated by the Raven Creek Field well. (Fig. 2) Normally, the large-scale rippled sandstones will exceed 10 percent porosity (70 microseconds interval transit time) for the shallow play. Good porosity and permeability are found *only* in this facies. Due to secondary cementing factors the large-scale rippled sandstone may not be porous, e.g., generally only clean, coarse, and thick sandstones will survive the normally destructive secondary modifications.

Porosity trends are related to (1) the distribution of the original large-scale ripple buildups, an orientation of south-southwest for forset-bedding directions, and southeast for thickness trends, and (2) secondary cementation factors that are very obscure. For example, presence of clastic fine-grained dolomitic constituents, and increasing depth are generally adverse to porosity.

A type of sandstone buildup is demonstrated in the Camp Creek Field where five cores were available for study. (Fig. 3) Here, also, was a simple paleowarp and correlation relationship. A southeasterly trend is shown by an isopach of porosity greater than 10 percent. This trend is also subparallel to an isopach of total sandstone. Updip wells along the leading edge of this small sandstone buildup are very tight. Cores demonstrate that this poor porosity is related to the small-scale rippled facies. Where the sandstone is thicker (Fig. 4) cross-bedding units are thicker, higher angled, and there is little interstitial material. Hence, this is a reservoir trap (granting minor Opeche Fm channeling) due to the original facies distribution. Experience has shown that a 15 percent increase of the small-scale ripples causes a serious corresponding porosity loss.

From surface work and subsurface field studies the following sequence from center of a mound to periphery is expostulated: (1) large-scale cross-bedding,

high-angled forsets (2) small-scale cross-bedding, low-angled forsets (3) thin laminations of anhydrite or gray shale interbeds (4) dolomite, light colored, often algal (5) dolomite, dark and cherty.

Cores of widely scattered geographic, depth, and environmental locales are presented and compared, e.g., Southern Montana (Fig. 5), the deep mid-Basin play (Figs. 6 and 7), the Reno Area (Fig. 8), and the Southeastern Powder River Basin and West Flank (Fig. 9).

The Minnelusa sandstones of Permian-Pennsylvanian age are believed to be south-east trending longitudinal wind blown dunes that are migrating into a tidal flat basin with concomitant rise of sea level on an almost cyclical basis. Deepening water in each pulse of the transgression reworked and smoothed out the original sandstone mound.

After uplift in the northeastern part of the Powder River Basin after Wolfcamp (?) time subaerial erosion patterns were developed in southeasterly trends. As the drainage incised itself northward the Opeche estuarine "fill in" sealed the ancient valleys. These linear red shale valleys are vaguely related to the original Minnelusa sandstone buildups by a possible compaction and swale process, i.e., erosion generally occurred in the more densely compacted dolomite facies.

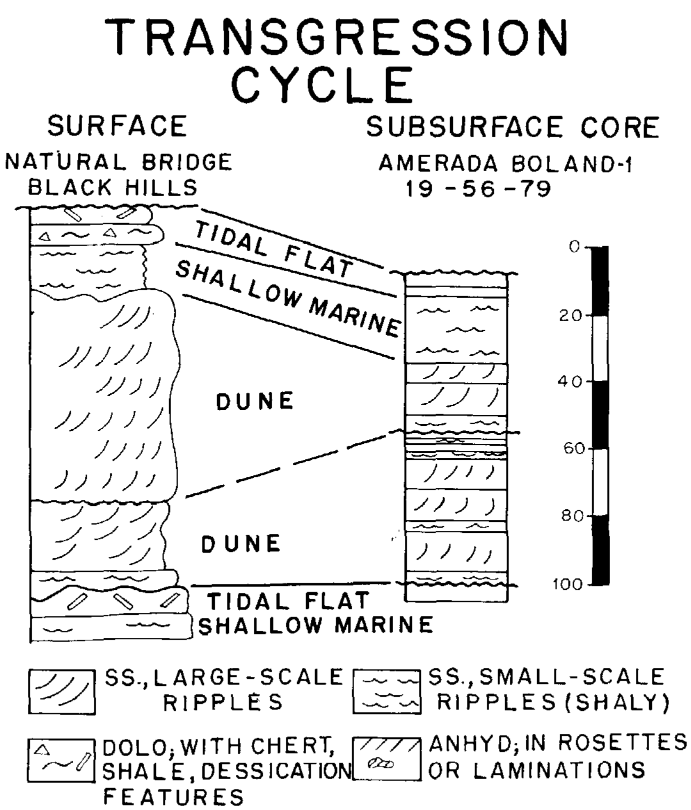


FIGURE 1

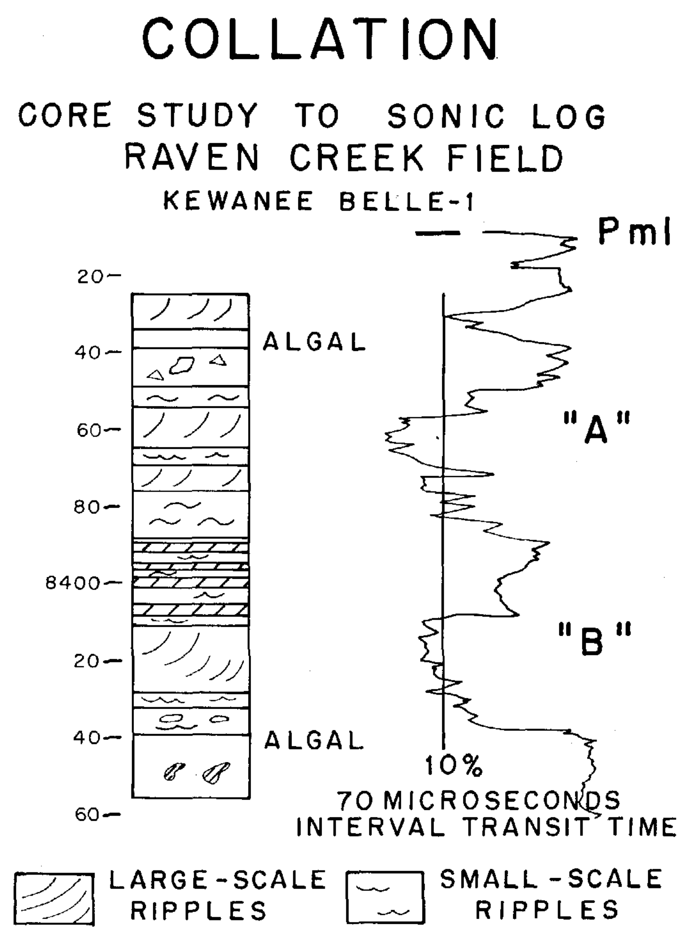
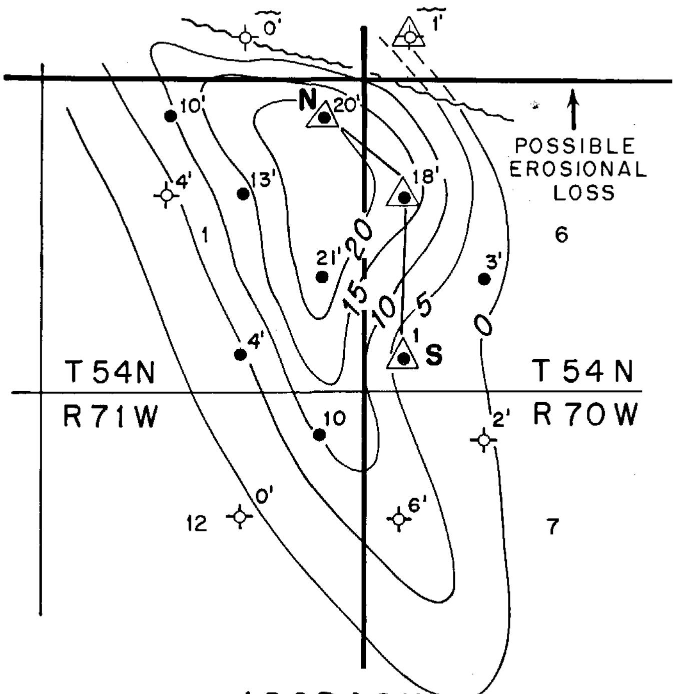


FIGURE 2



ISOPACH
CAMP CREEK FIELD
SANDSTONE >10% POROSITY
CI = 5'
FIGURE 3

CROSS SECTION N-S
CAMP CREEK FIELD
PROFILE
OF
MINNELUSA FACIES VARIATIONS

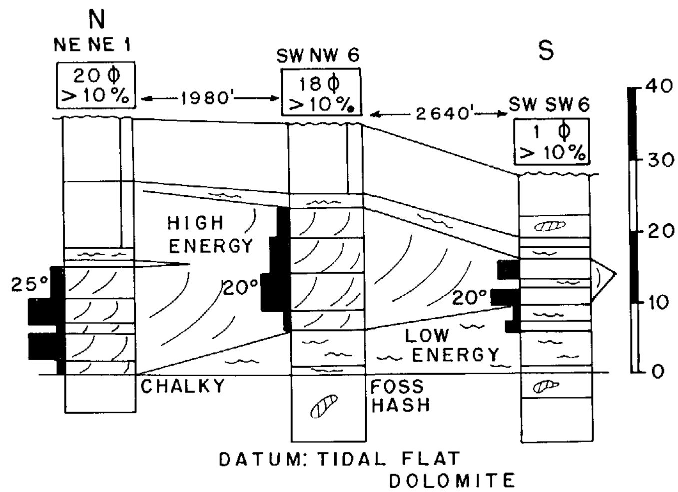


FIGURE 4

SOUTHERN MONTANA

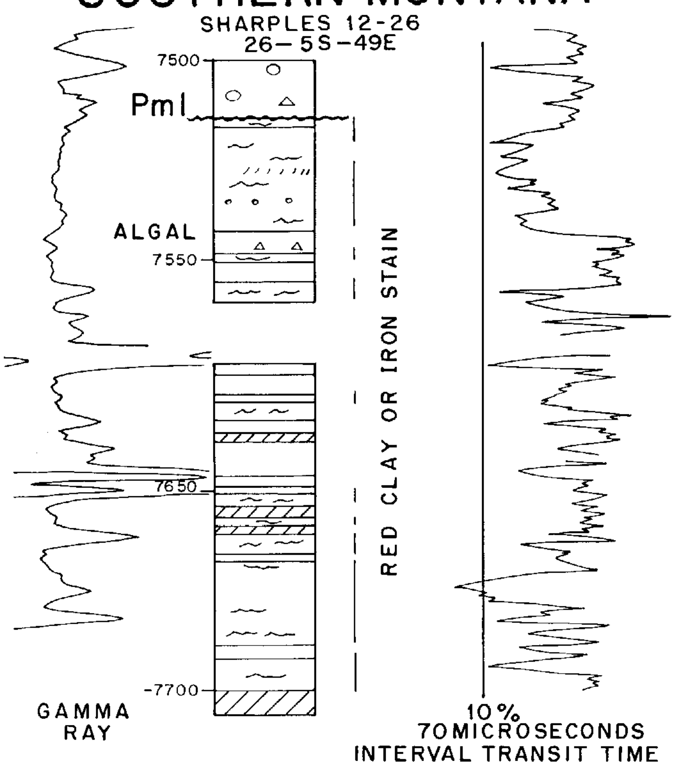


FIGURE 5

DEEP MID-PLAY

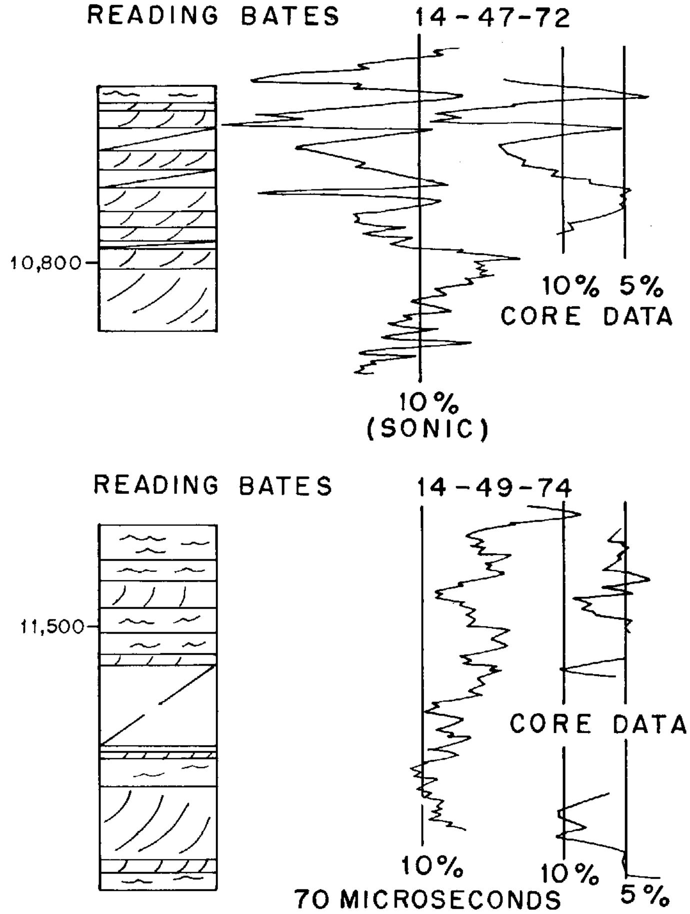


FIGURE 6

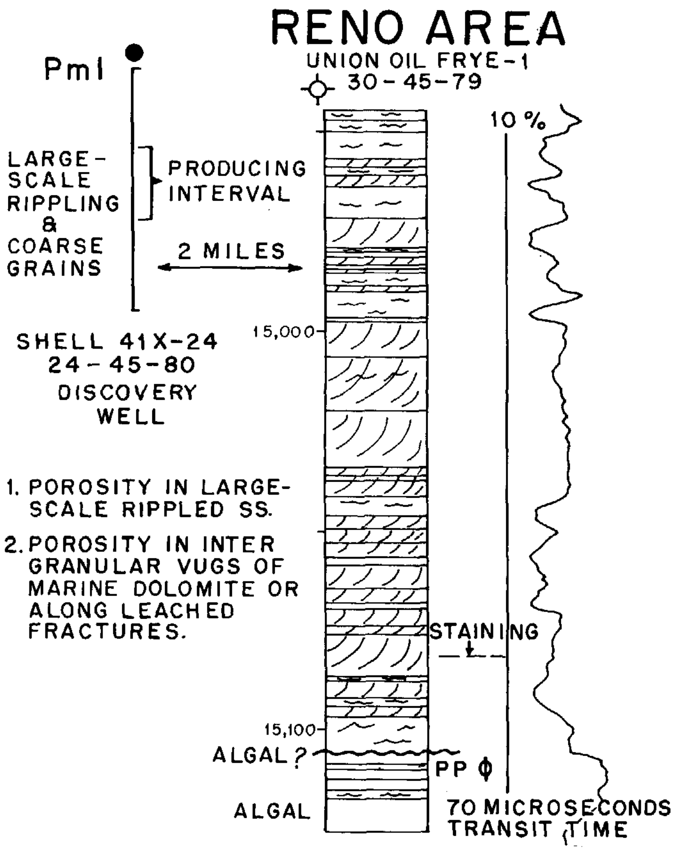


FIGURE 8

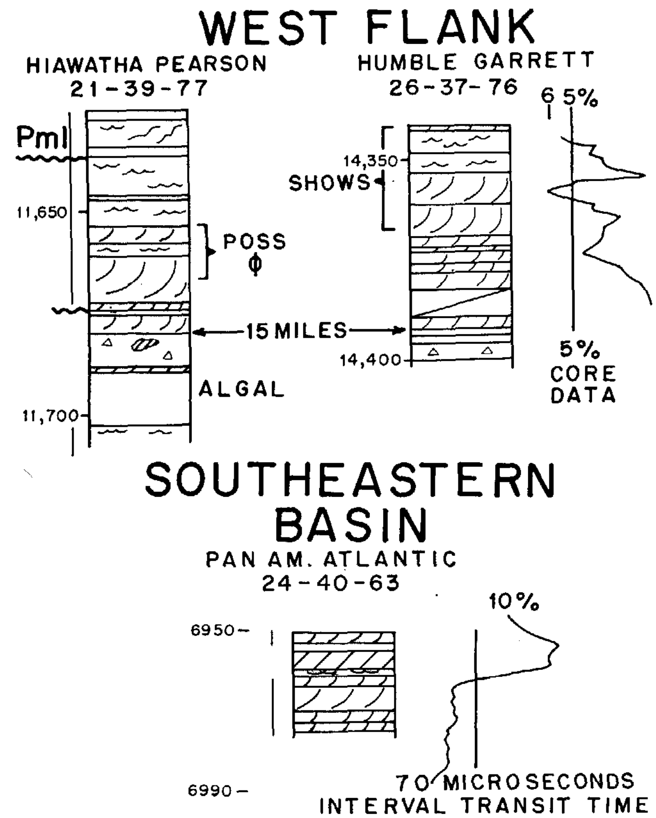


FIGURE 9