els of listric-normal faulting occur in the Boulder-Greeley area. These tectonic sensitive intervals are present in the following Cretaceous formations: Laramie-Fox Hills-upper Pierre, middle Pierre Hygiene zone, and the Niobrara-Carlile-Greenhorn. Documentation of the listric-normal fault style reveals a Wattenberg high, a horst block or positive feature of the greater Transcontinental arch, was active in the east Boulder-Greeley area during Cretaceous time. Paleotectonic events associated with the Wattenberg high are traced through analysis of the listric-normal fault systems that occur in the area. These styles are important to recognize because of their stratigraphic and structural influence on Cretaceous petroleum reservoir systems in the Denver basin. Similar styles of listric-normal faulting occur in the Cretaceous in many Rocky Mountain foreland basins.

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Use of Seismic Stratigraphy for Minnelusa Exploration, Northeastern Wyoming

The Powder River basin in northeastern Wyoming has long been a productive oil province. Abrupt lithology changes of the Upper Pennsylvanian-Permian Minnelusa Formation have provided a variety of hydrocarbon traps. However, these same abrupt changes have also yielded many surprises to the hopeful explorationist.

The upper Minnelusa is composed mainly of sands, dolomites, and anhydrites, and was deposited in sabkha environment. Unconformably overlying the Minnelusa is the supratidal Opeche shale. Hydrocarbon traps in the upper Minnelusa sands are usually stratigraphic in nature, and are of two common types. In one, a porous sand is trapped by an updip facies change; in the other, thick Opeche deposits in interdunal areas provide an updip seal for the porous sands.

The C-H field area, located in Campbell County, Wyoming, was chosen for initial study. Abrupt updip termination of the thick productive upper Minnelusa sand appeared to provide an ideal situation for a stratigraphic-seismic study. Sonic logs used to construct a geologic cross section showed a significant difference in the sonic response of porous upper Minnelusa sand versus no sand. Synthetic seismograms were then produced from these wells and, when organized in cross-section form, they again showed an obvious difference in response from sand to no sand conditions.

A "pilot" seismic line tying these wells was acquired. From this data, a good correlation between synthetic and actual seismic data was achieved. The updip termination of the productive Minnelusa sand was clearly identifiable on the seismic data.

The drilling phase of our exploratory program yielded mixed results. Some excellent development wells were drilled, one being completed for 625 BOPD. Although we were 70 to 80% successful in predicting the presence or absence of porous upper Minnelusa sand, only 20% of our extension or wildcat wells were productive.

Two major problems were soon discovered: (1) the seismic response from a thick, relatively low velocity Opeche shale is very difficult to distinguish from an upper Minnelusa sand; and (2) thin, porous Minnelusa sands are difficult to identify seismically, thus updip trap limits are not easily defined.

A variety of seismic trace attributes were examined in hopes that subtle amplitude and frequency differences would help distinguish thick Opeche shale from Minnelusa sand. This approach produced very limited success. Better results were achieved on the second problem, that of thin bed resolution. Accentuating the upper portion of the seismic frequency spectrum (40 to 80 Hz) did allow better mapping of thin Minnelusa sands.

In conclusion, through a closely coordinated geologic-geophysical effort, a useful methodology was developed which can be applied to a variety of stratigraphic-seismic exploration projects. The basic steps involved are as follows. First, determine if known lithologic changes can be seen on sonic or density logs. If successful, can the changes on logs be seen on synthetic seismograms? If successful, can the change be seen on a pilot seismic line? Finally, prepare for some complications and failures.

DE VRIES, JANET L., Hotline Energy Reports, Casper, WY

Evaluation of Low-Temperature Geothermal Potential of Cache Valley, Utah

This research is a continuation of the assessment of low-temperature geothermal resources of Cache Valley, Utah, initiated by the Utah Geological and Mineral Survey. The study area is the southern part of a narrow, north-trending graben located in north-central Utah and southern Idaho.

Tools used for evaluating the low-temperature geothermal resources are ground-water temperatures, thermal gradients, silica and Na-K-Ca geothermometers, and mixing models for estimating reservoir temperatures.

Ground-water temperatures range from 9.9 to 50.0°C, with a background temperature of about 13.0°C. The three areas in the study area with anomalous water temperatures are: (1) North Logan, 16.0 to 25.1°C; (2) Benson, 13.5 to 23.0°C; and (3) Trenton, which has evidence for past and present warm spring activity, with temperatures ranging from 22.9 to 50.1°C.

Thermal gradients generally range from 15° to 52°C/km, approximately the same as the average thermal gradient for the Basin and Range province, 35°C/km.

The silica and Na-K-Ca geothermometers, when applied to the ground-water of Cache Valley, Utah, show varying degrees of agreement, with estimated reservoir temperatures averaging 50 to 100°C. When the mixing models are applied to the water in the Trenton area, estimated reservoir temperatures are 30 to 200°C.

The function, $F(T) = \log(Na/K) + B \log(\sqrt{Ca/K})$, is used as an exploration tool to indicate a possible geothermal anomaly when the value is less than 2.00. The Trenton area is a possible geothermal anomaly located using this method.

Warm water in Cache Valley, Utah, appears to be the result of ground-water which has migrated from depth, is warmed by the normal thermal gradient, rises quickly along permeable fault zones, and either mixes with near surface recharge water or is forced to flow horizontally because of a less permeable confining layer. Both of these models mask the higher temperatures at depth.

Considering measured surface temperatures, calculated reservoir temperatures, thermal gradients, and the local geology, most of the Cache Valley, Utah, area is unsuitable for geothermal development. However, the areas of North Logan, Benson, and Trenton have anomalously warm ground water in comparison to the background temperature of 13.0°C for the study area. The warm water has potential for isolated energy development but is not warm enough for major commercial development.

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Regional Structural Synthesis, Wyoming Salient of Western Overthrust Belt

Surface geologic mapping, regional and high-density reflection seismic data and information from approximately 370 wells are combined to describe geometrically that area of the western Overthrust belt between the Snake River Plain and the Uinta uplift. Particular care has been taken to two-dimensionally verify interpretations of multiple thrust sheets by linear restoration. By establishing equivalence of pre-thrust lengths of affected beds, one can gain confidence in interpreted structural geometrics as well as generate data in regard to internal shortening and deformation intensity. Due to irresolvable geometric problems within sections, 47 cross sections were developed at roughly 6-mi (10 km) spacing to help verify changes in displacement or placement of key structural elements. Displacements of 0 to 32 mi (51 km) have been demonstrated, and both structure of faults and subcrop relations of Absaroka and younger thrusts are described. Jurassic to Paleocene (Sevier) thrusts were active across a previously deformed cratonic shelf terrane and interacted with active structural elements such as the Uinta uplift, Gros Ventre Range, and Moxa arch. Thrusts are progressively younger to the east, except for the Darby-Prospect pair in which the Darby system is younger.

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Depositional Environments of Upper Cretaceous Fox Hills Formation, Niobrara and Weston Counties, East-Central Wyoming