coarser-grained substrates. Regional trends in the distributional patterns of these taxa may aid in locating additional phosphate deposits.

SOEDER, D. J., Inst. Gas Technology, Chicago, IL

Reservoir Properties and Pore Structure of Tight Gas Sands

Thin section and SEM observations indicate that tight gas sands may be grouped into four broad categories based on pore geometry. These consist of (1) primary interparticle porosity; (2) primary interparticle porosity filled with authigenic minerals; (3) primary porosity reduced to narrow cracks with secondary honeycombed grains; and (4) intercrystalline porosity within a fine grained, elongate matrix. Type 1 porosity is common in conventional sands, types 2 and 3 are prevalent in tight sands, and type 4 is a rare class found in extremely tight rocks.

Reservoir property data on 51 sandstone core samples from the Mesaverde, Spirit River, and Frontier Formations led to an attempt to correlate reservoir parameters with pore geometry. The reservoir properties measured on these rocks under net confining stress include dry permeability, relative permeability, porosity to gas, and pore volume compressibility.

Results of the core analysis were combined with petrographic information to provide the following observations.

(1) Pore volume compressibility correlates well with pore geometry. Rocks containing types 1 and 2 pore structures are relatively incompressible owing to a rigid support framework of quartz sand grains in intimate contact. Clay linings on quartz overgrowths and weakly structured solution pores in the type 3 geometry cause moderate compressibility. Type 4 geometry, which occurs in matrix-supported rocks with rare quartz-grain contacts, is generally the most compressible of the 4 classes.

(2) Permeability correlates in general with the pore classes. Type 1 geometry is the most permeable and type 4 is generally the tightest.

(3) Porosity to gas did not correlate very well with pore geometry except on a sample-by-sample basis.

Development of a specific type of pore geometry in a tight sand is controlled by the original grain size and composition, depositional environment, and diagenetic history. It is usually difficult to isolate the effects of one factor from the others. The Mesaverde samples, however, were deposited from a single source into a variety of depositional environments, and underwent approximately uniform diagenesis. In this case, with the composition and diagenesis held constant, notable differences were seen in the pore geometry and reservoir properties that correlated quite well with depositional environment.

SOMMER, S. E., and D. E. WOESSNER, Mobil Research & Development Corp., Dallas, TX

Application of Solids MAS Nuclear Magnetic Resonance to Study of Diagenetic Processes

Magic angle spinning–nuclear magnetic resonance spectroscopy (MAS-NMR) provides the opportunity to probe composition of and ordering in minerals involved in the formation and alteration of sediments. MAS-NMR has the capability to detect a large number of elements, including aluminum, silicon, boron, oxygen, and magnesium. The chemical state, structural location, and with cross polarization, hydration character and surface proximity can also be determined using this method. Although MAS-NMR is relatively new and quantitative methodology is still being developed, a variety of geologic processes have been clarified through its application. Use of ^{27}Al NMR allows detailed determination of the smectite-illite transformation by monitoring the movements of aluminum into tetrahedral positions and resultant cation ordering. Because ^{27}Al is detectable to low ppm levels, clay mineral components can be determined well below XRD detection levels. The ^{29}Si and ^{27}Al MAS-NMR have sufficient resolution to discriminate between minerals in a natural assemblage but not with the resolution of XRD. Quadrupolar nuclei such as ^{27}Al have relatively poor spectral resolution as compared to nonquadrupolar nuclei such as ^{29}Si. However, modern high field instrumentation can discriminate between most aluminum-containing minerals including aluminum oxides, hydroxides, oxyhydroxides, clays, and feldspars, as well as trace aluminum levels in quartz, cristobalite, and tridymite. The combination of ^{27}Al and ^{29}Si NMR (and availability of other nuclei) provide a powerful aid to the resolution of exploration and production problems including determination of minor to trace amorphous components, hydration state of elements in cherts and clays, and formation damage.

SONNENBERG, STEPHEN A., Bass Enterprises, Denver, CO

Sorrento Field—Morrow Discovery in Southeast Colorado

Pennsylvanian Morrow sandstones are oil and gas productive throughout a large area in southeast Colorado. The Sorrento field is a recent Morrow discovery with recoverable reserves estimated at more than 10 million bbl of oil in an area of 3,200 acres (1,280 ha.) at depths of 5,400 to 5,600 ft (1,646 to 1,707 m). Minor production also occurs from the Mississippian Spergen, Mississippian Saint Louis, and Pennsylvanian Marmaton.

Productive Morrow sandstones are interpreted on the basis of subsurface mapping as fluvial valley-fill deposits, mainly channel sandstone. These deposits are encased in marine shale and range in thickness from 5 to 55 ft (1.5 to 16.7 m). Net pay ranges from 5 to 30 ft (1.5 to 9.1 m). Porosities average 19% and permeabilities range from 1 to 4,000 md.

Analyses of Morrow stratigraphic intervals indicates that paleostructure influenced Morrow depositional patterns. Morrow channel sandstones accumulated in paleostructural low areas created by movement on basement fault blocks. Structural nosing is present in the same location and trend as the Morrow channels, indicating structural inversion. The field is regarded as a combination structural-stratigraphic trap.

Knowledge of paleostructural control on reservoir facies provides a new idea for exploration for Morrow reservoirs in southeast Colorado.

SPENCER, CHARLES W., U.S. Geol. Survey, Lakewood, CO

Recent Resource Assessments of Tight Gas Reservoirs

Two fairly recent estimates of natural gas recoverable from tight gas reservoirs in the U.S. have been made. One was prepared in 1978, by Lewin and Associates for DOE (U.S. Department of Energy) and the second was made by the NPC (National Petroleum Council) in 1980. Lewin estimated about 200 tcf is recoverable from the 14 most favorable regions in the U.S. The NPC estimated that about 500 tcf is recoverable from the entire onshore U.S.

These studies involved a careful analysis of available data; however, both studies excluded large areas and great thicknesses of rock strata from their resource data base. The reasons for these exclusions were mostly lack of good well control and not absence of gas potential. Therefore, both assessments were conservative and the potential recoverable resource is probably much larger than even the 500 tcf estimated by the NPC.

Unfortunately present-day technology is not able to consistently identify, stimulate, and produce large volumes of gas from lenticular and (or) deep tight reservoirs. The NPC recognized these problems and listed many research topics and programs, in their report, that should be undertaken to increase the amount of recoverable gas.

A few of the more important informational needs are: (1) better methods to predict geometry of reservoirs, (2) improvement of log interpretation, (3) better prediction of natural fracture systems, (4) control of, and prediction of, hydraulic fracture height, length, and orientation, (5) elimination of formation damage, and (6) development of innovative reservoir stimulation methods. DOE has supported a number of research efforts directed toward solving many of these problems.

SPERLING, TEDD F., Sperling Geophysics Corp., Lansing, MI

Microcomputers and the Geoscientist

The microcomputer represents a technology that heretofore has not been afforded the professional. To the user, this technology renders a powerful advantage with respect to ease of data access and manipulation; increased security and user control; increased efficiency in processing and conveying information to management and clients; and most important, better informed and more accurate decision-making processes.

At this time, the primary oil and gas applications for the micro fall into 4 basic categories: (1) data base management such as well and reservoir data, client files, lease management, financial records, taxes, and accounting; (2) word processing for letter correspondence, contracts, leases, and invoices; (3) professional and scientific applications in contouring, mapping, well posting, geologic and geophysical modeling, reservoir analysis, spreadsheet evaluations, and investment analysis; and (4) custom programming, that is, the program that provides a specific edge on the competition. Each category has its advantages and limitations, depending on the type of micro and the quality of the software. Additional categories will surface as the micro is accepted within the profession.

The microcomputer will undoubtedly become an integral part of our profession. The professional and personal adjustment to the micro will most certainly be bittersweet. As with all innovations, there are dangers of misconceptions and subsequent misuse of the micro. These dangers are not always apparent, and can deter its useful application. It is important to identify and understand the microcomputer, its uses, its strong points, and its limitations.

SPIRAKIS, CHARLES S., and CHARLES T. PIERSON, U.S. Geol. Survey, Denver, CO

Chemical Characteristics of Some Major Uranium Deposits in Western USA

Multi-element chemical analyses of several thousand samples were retrieved from the U.S. Geological Survey's computerized Rock Analysis Storage System and used to estimate the average abundances of various elements in each of several types of uranium deposits, in altered rocks associated with some of these deposits, and in unmineralized parts of the various host rocks. Deposits for which results are presented include the tabular deposits in the Morrison Formation, Ambrosia Lake district, New Mexico; secondary deposits in the Ambrosia Lake district; tabular deposits in the Morrison Formation of the Henry Mountains, Utah; tabular deposits in the Chinle Formation in Utah and Colorado; roll-type deposits in Tertiary rocks from the Texas Gulf district; roll-type deposits in the Tertiary basins of Wyoming; tabular deposits in the Entrada Sandstone in Colorado; and a vein-type deposit in crystalline rocks of the Front Range of Colorado. Statistical treatment of the data identified elements that were notably more or less abundant in the deposits and altered rocks than in the unmineralized parts of the host rocks. Comparisons of the mean abundances of elements in the deposits show that the chemical composition of roll-type deposits varies greatly even among deposits in the same district. By contrast, the chemical characteristics of tabular deposits display little variation; the Ambrosia Lake tabular deposits and those of the Henry Mountains district are particularly similar. The data place some constraints on the geochemical aspects of genetic models and suggest certain elements as potential prospecting guides.

SPRAGUE, A. R. G., Univ. Texas at Dallas, Richardson, TX

A Channelized, Sand-Rich, Deep-Sea Fan Deposit, Lower Atoka Formation (Pennsylvanian), Ouachita Mountains, Oklahoma and Arkansas

The lower member of the Pennsylvanian Atoka Formation exposed in the Ouachita Mountains of Oklahoma and Arkansas is part of a thick (more than 10,000 m or 32,800 ft) turbidite sequence deposited in a remnant ocean basin (the Ouachita geosyncline) during the Carboniferous. Paleocurrent data indicate a predominantly longitudinal sediment dispersal pattern westward down the basin axis.

Nine lithofacies are recognized: massive, amalgamated sandstones (A1), graded, matrix-supported sandy mudstones (A2), six different types of classic turbidites (C1, C2, C3, D1, D2, and D3), and chaotic deposits (F) including debris flows. These occur in two principal lithofacies associations, both representing deposition in an areally extensive, sand-rich, channelized deep-sea fan environment. Lithofacies association 1 consists of packages of lithofacies A1 (and to a lesser extent A2 and C3) 1-30 m (3-98 ft) thick, interbedded with intervals comprised of lithofacies A2, C1, C2, C3, D1, D2, and D3, in which the sandstone:shale ratio is generally high (amalgamated to 1:5). Thickening- and thinning-upward sequences are arranged symmetrically about the lithofacies A1 packages, producing stacked symmetrical sequences 1 to 20 m thick. Lithofacies association 2 consists of lithofacies C3, D1, D3, and minor amount of D2, arranged in symmetrical as well as individual thickening- and thinning-upward sequences 1-40 m (3-130 ft) thick. The sandstone:shale ratio is highly variable (amalgamated to 1:50). Although thickness trends in this lithofacies association can be highly complex, thinning-upward sequences (10-40 m or 33-130 ft thick) are prominent. Slumped chaotic deposits (lithofacies F) are intercalated throughout both lithofacies associations. Common crevasse splays that develop into new channel segments, and filling of distributary channels are the inferred processes involved in the development of the two lithofacies associations.

The absence of deposits of major depositional lobes and the extensive development (both vertically and laterally) of a channelized (distributary channel) fan environment suggest that current submarine-fan models are not generally applicable to this deposit.

STANLEY, WILLIAM D., U.S. Geol. Survey, Denver, CO, and ROBERTO ANTONIO SAAD and WALTER OHOFUGI, Inst. Pesquisas Technologicas, Sao Paulo, Brazil

Using Magnetotellurics in Regional Hydrocarbon Exploration of Parana Basin, Brazil

The magnetotelluric (MT) geophysical method has been used effectively as a hydrocarbon exploration tool in the intracratonic Parana basin of South America. The Parana basin, an area of about 1,200,000 km^2 (463,322 mi^2), extends over portions of Brazil, Paraguay, Uruguay, Argentina, and Bolivia. It has been only sparsely explored by drilling, and only a few of the 100 or so complete wells have penetrated basement rocks. The basin is covered by the world's most extensive flood basalt complex, making geophysical exploration of the underlying Paleozoic sediments extremely difficult, although modern seismic techniques have begun to achieve good results. The thick surface basalts and buried diabase sills pose no problem for the MT method, because the natural electromagnetic fields utilized as the energy source pass easily through the basalt and underlying sediments to provide scattered signals containing critical information on thicknesses and resistivities of the geologic units.

The MT method has been utilized in a multidisciplinary exploration program recently completed in the Parana basin by the State of Sao Paulo. In the deeper portions of the Parana basin, MT interpretations show that basalts have thicknesses of up to 2 km (6,500 ft) and that basement may be as much as 6 km (19,700 ft) below the surface. In most of the basin, the basalts are covered by thin units of Upper Cretaceous to Holocene continental sediments and are underlain by 2-4 km (6,500-13,000 ft) of prospective Paleozoic sediments. In addition, interpretation of the MT sounding data with layered and fault-dike models outlines a linear uplift known as the Ponta Grossa arch.

Permian Irati sediments are an important source unit classified as mostly in the "oil window." Good electrical contrasts occur between the Permian sediments and older units, so that MT measurements can indicate the regional thickness of the Permian and younger sediments for use in interpretation of migration patterns and possible traps. In addition to providing this stratigraphic information, MT and aeromagnetic surveys have delineated the influence of the Sao Francisco craton in truncating uplift and tensional features of the Ponta Grossa arch.

STEIDTMANN, JAMES R., Univ. Wyoming, Laramie, WY, and LARRY T. MIDDLETON, Northern Arizona Univ., Flagstaff, AZ

Laramide Sedimentation and Tectonic Development Along Southern Margin of Wind River Range, Wyoming

Surface observations along the southern margin of the Wind River Range indicate that motion on the Wind River and Continental faults controlled depositional patterns and lithologic character of early Eocene syntectonic sediments. The stratigraphic sequence consists of alluvial plain, lake margin, deltaic, and alluvial fan units. Subsequent movement on the Wind River fault warped this sequence into a monocline 2 mi (3.2 km) long. This structure dies out to the northwest and southeast along the Wind River fault and is overlain by undeformed middle Eocene sediments. Clast composition and paleocurrent studies of post-early Eocene conglomerates indicate that there were additional sources for coarse clastics formed by subsequent uplift in the Precambrian core of the range.

Tectonic implications of these interpretations are: (1) early motion on the Wind River fault controlled the margin of Eocene Lake Gosiute and generated a distal sediment source to the east; (2) last motion on the Wind River–Continental fault system was episodic and principally over by the end of early Eocene; (3) the Continental fault, now a post-Miocene col-