be designed to minimize problems caused by diagenetic components. Well production can even be increased when proper procedures are designed using information on potential formation damaging diagenetic minerals that are present within pore systems of Woodbine reservoir rocks.

VAHRENKAMP, VOLKER C., DONALD F. ESCHMAN, and BRUCE H. WILKINSON, Univ. Michigan, Ann Arbor, MI

Supraglacial Diamictons at Continental Ice Margins: Pleistocene Alluvial Fan-Flow Till Deposition in Southeastern Michigan

Glacial sediments more than 50 m (165 ft) thick were laid down over southeastern Michigan during retreat of the late Wisconsinan continental ice sheet. As a result, the topography of the region is now dominated by recessional moraines composed of thick sequences of outwash sand and gravel, which are in turn capped by up to 7 m (23 ft) of glacial diamicton. Sedimentary structures exposed in many gravel pits in the Fort Wayne moraine suggest that outwash sequences were deposited as proglacial alluvial fan systems which were partially overridden during short periods of ice readvance. Several features, including abruptly truncated trough cross-bedding in gravels and truncated large clasts of previously ice-cemented sand at outwash-till contacts, require shearing at outwash surfaces either prior to or during till emplacement. Such outwash till contacts suggest that some of the diamicton was deposited in subglacial settings as lodgement till. Other exposures, however, exhibit gradational outwash till contacts, fluidized mixtures of thin outwash and till layers, and till draped over large sand clasts. Such features require that much of the diamicton was emplaced without truncation at the outwash surface, and suggest that deposition occurred in supraglacial settings as flow till.

The distribution of lodgement till and flow till in this region indicates that lodgement tills predominate on proximal (iceward) portions of moraine slopes and that flow tills predominate on distal slopes. This distribution suggests that during outwash till deposition, the front of the continental ice sheet had readvanced only to the moraine crest, and that a single depositional episode gave rise to the entire outwash till sequence.

Similar features are typical of other moraines in the region and suggest that, in general, the crests of gravel-cored Pleistocene moraines coincide with the maximum limits of ice readvance and delineate areas of lodgement till deposition on proximal slopes and areas of flow till deposition on distal slopes.

VAN ALSTINE, DAVID R., Sierra Geophysics, Redmond, WA, DOUGLAS C. BLEAKLY, CER Corp., Las Vegas, NV, and STEPHEN L. GILLETT, Sierra Geophysics, Redmond, WA

Paleomagnetic Applications in Hydrocarbon Exploration and Drilling Operations

A new generation of high-sensitivity cryogenic magnetometers permits paleomagnetic applications in weakly magnetized sedimentary rocks. One of the most useful paleomagnetic applications is drill-core orientation, which is important for determining fracture orientations, for stress analysis, and for determining sediment transport directions. A 2-year study involving ~600 core plug samples from five wells in three Rocky Mountain basins yielded paleomagnetic orientations that agree with those obtained using the conventional photographic "multishot" technique. The strongest paleomagnetic signal in these rocks points toward the late Cenozoic paleomagnetic pole and probably represents a secondary magnetization imposed by thermal effects associated with the late Cenozoic uplift and tectonism in this region.

Weaker paleomagnetic signals, reflecting earlier thermal, diagenetic, or depositional magnetizations are also commonly preserved in sedimentary rocks and can also be used to orient core. For example, lower Paleozoic rocks of the southern Great Basin contain three secondary magnetizations acquired during the Late Permian (time of deepest burial), the Late Cretaceous (Sevier orogeny), and the Late Cenozoic (recent weathering). Although many different magnetizations commonly reside in the same rock sample, these magnetizations can be routinely separated by subjecting the samples to partial demagnetization, using alternating-field, thermal, or chemical "cleaning" techniques. The components of magnetization are destroyed at vastly different rates depending on whether they reside, for example, in trace amounts of magnetite, hematite, or goethite.

In paleomagnetic core orienting, the most precise orientations are obtained from fine-grained rocks, and the method requires some prior knowledge of the region to establish the reference magnetization direction. However, paleomagnetic core orienting requires no special downhole equipment and can selectively orient only those intervals of core that are of interest after visual inspection. The paleomagnetic core orienting technique has been successfully tested against the multishot technique in several regions of the United States and internationally.

Other paleomagnetic applications can be derived from the same plugs used for orienting drill core. Some of these applications use the "primary" magnetization acquired penecontemporaneously with deposition. For example, establishing the geomagnetic polarity reversal pattern in a sedimentary sequence elucidates the sedimentation rate (by thickening or thinning of the polarity stratigraphy) and the duration of hiatuses in deposition (by absence of segments of the reversal history). The reversal stratigraphy also provides timelines that are independent of the biostratigraphy and lithostratigraphy and that are useful in correlating beds from well to well. Other paleomagnetic applications use one or more secondary magnetizations reflecting later diagenetic and thermal events. These secondary magnetizations can have important implications regarding both permeability and thermal maturity. Finally, changes in rock magnetic properties, such as bulk magnetic susceptibility, can be used to detect mineralogic alteration associated with hydrocarbon migration.

VAVRA, CHARLES L., ARCO Oil and Gas Co., Plano, TX

Mineral Reactions and Controls on Zeolite Facies Alteration in Sandstone of Central Transantarctic Mountains, Antarctica

Volcanic sandstones of the Fremouw and Falla formations, like many volcanic sandstones in productive and nonproductive circum-Pacific basins, contain abundant zeolite-facies authigenic minerals. Mineral and chemical patterns in Fremouw and Falla sandstone suggest that porosity and authigenic mineralogy were controlled by parent material composition, fluid chemistry, permeability, and temperature. Mineral patterns suggest simple rock-fluid reactions in which unstable volcanic rock fragments and plagioclase grains were altered to clay, heulandite, albite, laumontite, and/or prehnite. Chemical patterns suggest that significant mass transfer of Na^{+}, Ca^{+2}, and Si^{+4} occurred in the sandstone during alteration, whereas Al^{+3} mobility was restricted to migration from reaction sites to nearby pore space where Al^{+3} was incorporated into clay and/or zeolite cements. These cements typically reduced primary porosity to a few percent; however, some secondary porosity was created by the dissolution of detrital plagioclase grains. An examination of albitization and laumontization reactions involving detrital plagioclase suggests that porosity loss resulting from these reactions is directly proportional to the anorthite content of the grains undergoing alteration. Chemical and mineral patterns also suggest that clay mineral diagenesis in mudstone units supplied at least some of the ions required by reactions in neighboring sandstone.