restricted to the Ponta Grossa Formation, a potential source rock unit.

The subsurface distribution, the character and the stratigraphic limits of this formation are not precisely known yet.

Paleontological studies of the macrofauna from this formation indicated an Early Devonian age. Previous palynological analysis has been exclusively based on chitinozoans, spores, and the acritarchs of the leiofusidae group and the *Maranhites* genera.

Other microplankton have not been considered.

This paper intends to fill this lack in the palynological record of the Devonian for the Parana basin.

For this paper a wide range of surface samples and core samples from eight wells drilled by PAULIPETRO (a CESP-IPT joint venture) have been studied.

Microplankton from the Devonian of the Parana basin never before described are presented here, together with their biostratigraphical and paleoecological implications. Intrabasinal and interbasinal correlations are also made.

From a total of 60 species identified until now, twenty forms having well-defined stratigraphic ranges and broad (intercontinental) geographic representation are described herein. This assemblage is marked by the presence and diversity of the Subgroups Polygonomorphitae and Pteromorphitae. The Subgroup Acanthomorphitae is also well represented.

The Emsian-Frasnian age previously established for the Ponta Grossa Formation through other palynological studies is further confirmed by the paleomicroplankton evidence. Moreover, the chronostratigraphic limits of these sediments may now be refined even further. Thus, despite the presence of long-ranging forms, other species, such as *Triangulina alargada*, which is restricted to the Emsian in the "La Vid" Formation in northern Spain, allow a better chronostratigraphic subdivision of the Ponta Grossa Formation.

The microplankton assemblage is very similar to others known from the Maranhão basin, Brazil; the province of Leon, Spain; and Ghana, Africa.

The abundance of forms of *Tasmanites* together with a large quantity and diversity of microplankton provides the basis for the paleoecologic interpretations.

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Effects of Depositional and Diagenetic History Upon the Reservoir Properties of Parkman Sandstone, Powder River Basin, Wyoming

The depositional system within which the Upper Cretaceous "Parkman Formation" (= Parkman Sandstone Member of the Mesaverde Formation) of the Wyoming part of the Powder River basin was formed, was delineated using a combination of outcrop data, subsurface core data, and geophysical well logs. The post-depositional history of these rocks was determined, semiquantitative compositional analyses of authigenic components were made, and paragenetic sequences were established with the aid of scanning electron and transmission electron microscopy.

The Parkman Formation in the study area is composed of a progradational deltaic complex of interstratified sandstone, siltstone, and shale that overlies the extensive marine shelf deposits of the Steele Shale. Four distinct units within the Parkman have been delineated: (1) interbedded shale, siltstone, and very fine grained, well-sorted sandstone, which were deposited in prodeltaic environments; (2) coarsening-upward sequences of sandstone with lenticular siltstone beds and some shale interbeds, which were deposited in distributary mouth-delta front environments; (3) fine-grained, moderately sorted, horizontal to cross-bedded sandstones deposited in beach environments; and (4) dark lignitic shales, carbonaceous siltstones, and fining-upward sandstone sequences deposited in floodplain, swamp, and distributary channel environments.

The timing and intensities of diagenetic alterations have profound effects upon reservoir properties of the Parkman Sandstone in the Wyoming part of the Powder River basin. In the subsurface samples, major authigenic minerals observed in the Parkman Sandstone are clay minerals (chlorite, illite, montmorillonite, kaolinite), quartz, feldspar, calcite, dolomite, and iron-oxides, whereas in the surface samples there was no authigenic chlorite and only rare quartz overgrowths, but rather more kaolinite, calcite, and iron-oxide.

The generalized diagenetic sequence can be summarized as follows: (1) ductile grain deformation and original porosity reduction due to settling and mechanical compaction; (2) authigenic chlorite formation as grain coatings or pore linings; (3) authigenic quartz overgrowths from dissolution of silica grains, and clay diagenesis, as well as pressure solution; (4) authigenic feldspar overgrowths; (5) minor authigenic mineral deformation due to continued mechanical compaction; (6) authigenic feldspar alterations to clay minerals; (7) calcite cementation; (8) dolomitization; (9) calcite replacement of siliciclastic grains; and (10) iron-oxide development.

All of the authigenic minerals in the Parkman Sandstone, where they are abundant, reduce the effective primary porosity and permeability of potential reservoir sandstones prior to petroleum generation, migration, and accumulation. In the subsurface samples where authigenic chlorite occurs, the pore space was reduced by 5 to 10 μ. However, where chlorite is thin or absent, quartz overgrowths tend to grow larger to a maximum crystal diameter of 30 to 40 μ, filling most of the pore space. Therefore chlorite coatings actually prevent the porosity from being completely destroyed with quartz overgrowths. In surface samples, chlorite coatings have not been observed, but late-stage calcite cement replaced most of the siliciclastics and, along with iron-oxide cements, further reduced porosity and permeability.

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Experimental Low-Altitude Aeromagnetic Reconnaissance for Petroleum in Arctic National Wildlife Refuge, Alaska, Using Horizontal Gradients—A Progress Report

Variations in the earth's magnetic field arising from areally restricted increased amounts of shallow-buried magnetite over hydrocarbon deposits have been mapped in the Arctic National Wildlife Refuge and elsewhere is northern Alaska. The anomalies have been delineated with a low-flying (90 m; 295 ft) magnetic horizontal gradiometer mounted on a fixed-wing airplane. Limited data from stable carbon isotope and remanent magnetism measurements of rock cores from the Cape Simpson region strongly suggest that the magnetic anomalies result from the chemical reduction of iron oxides in the presence of seeping hydrocarbons. Relatively large magnetic contrast between typical sedimentary rocks and those locally enriched with this epigenetic magnetite results in distinctive high wave-number and low-amplitude total field anomalies. Magnetometers extended from each wingtip and in a tail stinger permit calculation of the resultant horizontal gradient vector relative to the flight path. This calculation provides data for the unmeasured area between adjacent flight lines spaced at 1.5 km (.9 mi), thereby allowing

generation of accurate computer-enhanced images or maps. Problems related to diurnal variations and solar storms at high magnetic latitude are largely overcome because changes in the total magnetic field do not significantly affect the magnetic gradient. Analysis of an experimental survey, covering 4,418 line km (2,745 line mi), suggests that the Marsh Creek anticline in the Arctic National Wildlife Refuge is prospective for oil and/or gas. Additional magnetic anomalies were also identified. Although the effect of permafrost on epigenetic processes has not been investigated, the data suggest that special purpose aeromagnetic surveying may be a useful and relatively inexpensive way to explore for oil and gas in this hostile environment.

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Applied Biostratigraphy in Paleozoic Exploration

Integration of data from the palynological analysis of acritarchs and chitinozoa, together with conodont data, provides biostratigraphic results in all environments from wide carbonate platform, inner and outer shelf, basin margin, to deep basin sediments.

This integrated data is of great value in Paleozoic exploration biostratigraphy, in particular where miospore and calcareous microfossil data are inadequate. The acritarch data are of prime importance as the numerous, diverse assemblages provide a refined biostratigraphy of shelf and basin margin sediments worldwide; the chitinozoa are of particular value in deep basin areas, whereas the conodonts are of value in carbonate platform areas.

Identification of basin margins and basin subsidence can be gained by the preservation and known environmental distribution of selected acritarchs and chitinozoa. Sediment source areas can be identified using recycled palynomorphs. Thermal maturation based on vitrinite reflectance cannot be applied to pre-Silurian rocks; in the Paleozoic visual kerogen analysis including acritarch and chitinozoa colors, together with conodont coloration and organic pyrolysis provides the data on organic thermal maturation and source rock oil and gas potential.

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Regional Cathodoluminescent Cement Zonation Related to Upland-Sourced Paleoaquifers: Devonian Helderberg Carbonates and Clastics, Central Appalachians

Cathodoluminescent zonation in shallow burial calcite cements of the Keyser and New Creek Limestones (lower Helderberg Group, Upper Silurian–Lower Devonian) in Virginia, West Virginia, and Maryland can be mapped regionally. Regional distribution of cement zones coincides with the distribution of easterly derived sandstone tongues within the carbonate sequence. In southwestern Virginia, calcite cements in limestones subjacent and laterally equivalent to the Clifton Forge and Healing Springs Sandstones show cathodoluminescent zonation of nonluminescent (earliest cement) to bright to dull or subzoned dull (last shallow burial cement). Noneluminescent cements are Mn^{2+} and Fe^{2+} poor and precipitated from oxidizing meteoric pore fluids; bright cement (Mn^{2+}-rich) reflects more reducing pore fluids; dull cement (Fe^{2+}-rich) precipitated from most reducing shallow to deeper burial pore fluids. Nonluminescent-bright-dull zonation grades abruptly into correlative subzoned dull cement downdip from sandstone tongues. Further downdip, subzoned dull cement grades into dull (nonzoned) cement. Limestone adjacent to the Elbow Ridge Sandstone (West Virginia and Maryland) lacks nonluminescent and bright cement but has subzoned dull cement that grades into dull cement westward. Clear rim cement on scattered pelmatozoan grains in the Clifton Forge, Healing Springs, and Elbow Ridge Sandstones have complexly zoned nonluminescent and bright cements. Quartz grains have pressure-solved contacts and are cemented by dully luminescent, deep burial cement. Predominance of deep burial Fe-rich cement in sandstone indicates that they remained "open" during shallow burial diagenesis and that sandstone tongues acted as conduits for oxidizing meteoric ground waters recharged from tectonic highlands. Downdip from sandstone tongues, subzoned dull and nonzoned dull cements precipitated from reducing meteoric ground waters distant from subareal recharge areas. Precipitation of shallow burial zoned cements ceased when recharge areas were buried by thick Devonian clastics (Ridgeley Sandstone, Huntersville Chert, Millboro Shale) or when burial removed the sediments from the effects of upland sourced meteoric ground waters. Final porosity occlusion in the limestone is by deep burial, clear, Fe-rich calcite cement (dull luminescence), Fe-rich "saddle dolomite," silica cement, and rare fluorite. This study emphasizes the importance of (1) tectonic uplands as recharge areas for aquifers involved in cementation; (2) potential of interlayered sandstones in carbonate sequences to act as permeable conduits for meteoric ground waters because they are less susceptible to calcite cementation than associated lime grainstones; and (3) documenting regional cathodoluminescent zonation of porosity-occluding shallow burial calcite cements in potential reservoir facies prior to hydrocarbon migration.

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A Petrologic Examination of Some Resedimented, Coarse-Grained, Clastic Intervals in Ouachita Mountains, Arkansas

Several resedimented, coarse-grained clastic intervals exist in the strata of the Ouachita Mountains. A petrologic examination of selected units in the basal Stanley Shale, the Arkansas Novaculite, and the Missouri Mountain Shale yields information pertaining to provenance, transportation, and deposition.

Twenty-five coarse-grained units sampled are categorized as massive sandstone, pebbly sandstone, clast-supported conglomerate, and matrix-supported conglomerate. Samples exhibit grading, imbrication, and stratification indicative of mass flow and fluidal flow-transport processes. Sedimentary rock fragments are the predominant clasts, with chert being the primary constituent. Other major constituents are detrital quartz, rip-up clasts, and shale fragments, of which the latter show signs of soft-sediment deformation. A metasedimentary source area is inferred. Paleoflow direction, estimated to be to the south and southwest, was ascertained by orientation of imbricated clasts and channel cuts.

A vertical sequence change from a matrix-supported conglomerate to a bimodal, clast-supported conglomerate, both of which exhibit channeling, to a massive sandstone occurs at one locality. This fining-upward sequence is due to a change in source area, which may be the result of tectonism and/or glacio-eustatic sea-level fluctuations.

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Foraminifera as Paleobathymetric Indicators

Benthic foraminifera are one of the principal means of inter-