detailed x-ray radiography (for sediment structure) and x-ray diffraction (for clay mineralogy) analyses evaluated in conjunction with their geotechnical properties (shear strength, Atterberg limits, etc). Sediments from each major part of the mudflow system (gully heads, chutes, and mudflow lobes) share a set of common sedimentary structures. The most complicated deposits are the wide-spread and rapidly deposited mudflow lobes. They are composed of overlapping wedges of highly remolded, low-shear-strength deposits, separated by thin, interlobe units of acoustically reflective and slowly accumulated hemipelagic sediment. Gas-related features, convolute structures, inclined bedding, evidence of flowage, and indications of thorough mixing are found in mudflow lobe deposits. Clay mineral assemblages are typical of rapidly deposited pro-delta clays (smectite:kaolinite:illite $\approx$4:4:1). In contrast, thin interlobe units and distal shelf sediments contain evidence of biogenic activity (micro-organism tests, burrows, and shell fragments) and diagenetic products. Interlobe and distal shelf deposits have clay mineral suites characterized by an increase in kaolinite and illite at the expense of smectite, which allows for distinction of individual flows and the general mudflow base.

ROBBIN, DANIEL M., U.S. Geol. Survey, Miami Beach, FL

A New Holocene Sea Level Curve for Upper Florida Keys and Florida Reef Tract

A new Holocene sea level curve for the upper Florida Keys and Florida reef tract has been constructed by integrating existing and new data from ^{14}C age analyses. New data are derived from 21 mangrove peat samples from 5 locations and 3 laminated $CaCO_3$ soilstone crust (caliche) samples from 3 locations. The new sea level curve is based on ^{14}C ages ranging from 360 $\pm$ 60 y.B.P. to 14,000 $\pm$ 160 y.B.P., and indicates a fluctuating sea level rise of approximately 0.3 mm/yr (from 14,000 to 7,000 y.B.P., sea level rose from 9.2 to 7.0 m, 30.2 to 23 ft, below MSL), approximately 1.2 mm/yr (from 7,000 to 2,000 y.B.P., sea level rose from 7.0 to 0.75 m, 23 to 2.5 ft, below MSL), and approximately 0.3 mm/yr (from 2,000 y.B.P. to present, sea level rose from 0.75 m, 2.5 ft, below MSL to present MSL).

No evidence was found in this area that, during the last 14,000 yr, any highstand was greater than the present sea level. The rate of rising sea level, however, has varied. Sea level stand in this area at 14,000 y.B.P. is much shallower than indicated on other published curves for the east coast of the United States.

ROBERTSON, JAMES D., ARCO Oil & Gas Co., Dallas, TX, and WILLIAM C. PRITCHETT, ARCO Exploration Co., Dallas, TX

Bright Spot Validation Using Comparative *P*-Wave and *S*-Wave Seismic Sections

Coincident *P*-wave and *S*-wave CDP lines were shot across the Willow Slough and Putah Sink fields, Yolo County, California, by the 1977-78 Conoco *P*-Wave/Shear-Wave Group Shoot. The fields produce gas from pay sands in the Cretaceous Starkey and Winters formations. Several of the thicker pay sands correlate with amplitude anomalies on the *P*-wave sections, and these amplitude anomalies are true seismic "bright spots." The equivalent events on the *S*-wave sections are much lower in relative amplitude when the overall gains of the *P* and *S* sections are balanced. The difference in the *P* and *S* responses is consistent with laboratory experiments which show that introducing gas into the pore space of a liquid-saturated rock dramatically lowers *P* velocity but minimally affects *S* velocity. The experimental lines demonstrate that comparison between the amplitudes of *P* and *S* is a diagnostic technique that can be sued to distinguish gas-liquid contacts from lithologic interfaces. An *S*-wave section validates a *P*-wave bright spot attributed to gas saturation when there is no anomalous amplitude at the equivalent *S*-wave event.

RODGERS, DONALD A., Applied Tectonics, Inc., Houston, TX

Exploration Consequences of Divergent Strike-Slip Motion on Mexia Fault Zone of Central Texas

The several proposed models for the evolution of the Gulf of Mexico suggest different types of movement on the Mexia fault zone. One recent model suggests that the Yucatan Peninsula, in the Gulf at the beginning of the Jurassic, moved southwest to its present position during the Jurassic. This requires major right-lateral strike-slip movement with minor divergence in the vicinity of the Mexia fault zone. This fault zone trends north-south, consists of en echelon horsts and grabens striking about 30° east of the zone's trend, and was active from the Jurassic through the Eocene. The presence of the grabens, their orientation and en echelon arrangement, and the age of movement are all consistent with divergent strike-slip movement.

Hydrocarbons are generally produced from the basin side of the fault zone but have also been produced from fault traps within the grabens. Theoretical models, physical models, and field examples of strike-slip faults suggest the presence of en echelon anticlinal traps along the fault zone, and development of smaller antiformal structures where the en echelon grabens overlap. Such structures have not been described along the Mexia fault and may be important new structural plays, particularly for oil in the Smackover.

Post-Jurassic movement on the fault zone enhanced the structural relief of the grabens and probably was related to the mobilization of the Louann salts. Traps in the Cretaceous which produce most of the hydrocarbons are due to this later movement.

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Cyclicity Concept in a Deltaic to Shallow-Marine Environment of Deposition Concerning an Oil-Sand Setting

The need to accurately define sand trend and quality in a deltaic to shallow-marine environment of deposition where facies changes take place over a short distance is widely recognized. In an oil-sand environment, such as the Cerro Negro area of the Orinoco Petroliferous Belt, this need is more evident because enhanced recovery projects are necessary. Facies variability and correlation problems in such a setting have led many workers to apply indiscriminately the cyclicity concept as an exploration/exploitation tool. According to this concept, a cycle begins with a transgressive sand and ends with a marsh facies represented by a coal bed. Subdivision of the rock column into cycles allow delineation of sand geometry.

Recent works have demonstrated that rooted coal beds can be formed in different coastal environments, ranging from the upper delta plain to the back-barrier lagoon facies. Therefore, it is obvious that the association of these facies will differ from one another and from the standard cycle concept.

In the Cerro Negro area, the process-controlled genetic unit concept was of great help in defining sand geometry and quality. The rock column of cored wells can be subdivided according to the presence of physical and biological parameters into 4 units, differentiated by the occurrence of rooted coal, limestone, sand, shale, *Ophiomorpha*-type burrows (*Fositextura figurativa*), bioturbation structures (*Fositextura deformativa*), and shell fragments.

ROLLINS, FRANCIS O., CHRISTINE A. POWELL, and JOHN M. DENNISON, Univ. North Carolina, Chapel Hill, NC

Flexural Modeling of Devonian Catskill Delta in Eastern United States and Formation of Taghanic Unconformity

The Devonian Catskill delta is an exogeosynclinal clastic wedge in the Appalachian basin. Subsidence caused by this load is modeled as flexure of a perfectly elastic crust. Subsidence can be measured accurately in eastern New York and Pennsylvania because of excellent well and outcrop control and the ability to recognize shoreline position.

Calculated flexural response to the load of the Erian Series sediments predicts subsidence smaller than observed values, especially in the eastern portion of the delta. It is necessary to postulate an additional tectonic component of subsidence. Additional subsidence is modeled as a cosine curve decaying exponentially with distance from a point deflection of the crust. This model, plus the flexure caused by sediment load, produces subsidence consistent with observations.

The flexural response of the crust offers an explanation for an unconformity in black shales that developed during the Taghanic age on the west side of the Appalachian basin, with at least 50 m (165 ft) of expected strata missing. This unconformity expands westward and southwestward from the maximum sediment load. The unconformity is unusual because it formed during a sea level rise (Taghanic onlap) which apparently affected all of North America. Flexural modeling predicts upwarp in central and western New York, western Pennsylvania, and eastern Ohio, and offers a plausible explanation for this unconformity.

The tectonic component of the subsidence curve, coupled with the geologic constraints, offers an opportunity to model the location of the Acadian Mountains to the east, which have since been eroded to their roots.

ROLLINS, THOMAS W., Continental Resources Co., Houston, TX

Future Energy Invulnerability

The forces of supply and demand in a free-market economy will result in increased supplies and lower consumer prices for energy resources in the United States. This paper examines this thesis in light of post-World War II trends in oil and gas resources. A review of these trends shows the relationships between market price and the supply of oil and gas, and verifies the importance of profits in the economic cycle of energy development.

One of the main points considered in this analysis is the effect of government regulation on the oil and gas markets. Government price ceilings and incentive prices have encouraged both excess consumption and inefficient production of oil and gas resources. As the nation's oil and gas markets come out from under the labyrinth of government controls, one of the keys to success for those in the oil and gas business will be the ability to use innovative marketing techniques in nonregulated markets.

The abundance of domestic reserves of oil and gas remaining to be discovered in the United States is ample to carry our nation into the next century without excessive dependence on unstable foreign sources of supply. Free-market forces and successful "team effort" exploration will not only allow the efficient development of those reserves, but will also bring forth supplies of substitutes for oil and gas, such as coal, nuclear, thermal, wind, and synthetic fuels, as prices and costs warrant.

ROSE, PETER R., Telegraph Exploration, Telegraph, TX, and J. R. EVERETT and I. S. MERIN*, Earth Satellite Corp., Washington, D.C.

Potential Basin-Centered Gas Accumulation—Raton Basin, Colorado

The Raton basin of south-central Colorado is a small basin of Laramide age that is analogous structurally to other Rocky Mountain basins that contain commercial basin-centered gas deposits in tight Cretaceous sandstones. Moreover, the mineralogy, depositional setting, and stratigraphic succession of Cretaceous rocks in the Raton basin generally are comparable to gas-productive basins in the Rocky Mountain region where similar thick, gas-prone, thermally mature source rocks are present. Oil, condensate, and abundant natural gas shows occur in Cretaceous and Tertiary beds throughout the Raton basin, but substantial petroleum production has not yet been established. Certain geologic features may have influenced gas accumulation, such as ground-water movement, fracturing, igneous intrusions, CO_2 generation, mildly elevated heat flow, sandstone mineralogy, and diagenesis. Drilling density is low, particularly in the deeper parts of the basin. Prospects of developing a basin-centered gas deposit here appear favorable.

ROYBAL, GRETCHEN H., and FRANK CAMPBELL, New Mexico Bur. Mines and Mineral Resources, Socorro, NM

Coal Geology of Salt Lake Coal Field, West-Central New Mexico

Recent detailed mapping and drilling has defined the Cretaceous coal-bearing sequence in the little-known Salt Lake field in the west-central part of New Mexico. Structurally, the Salt Lake field is simple with only a few northeast-trending faults and small-scale flexures related to the Tertiary volcanism throughout the field. The regional dip in this field is 3°-5° to the southeast. The majority of the coals in the Salt Lake field are in the Moreno Hill Formation with a few thin coals in the underlying Dakota Sandstone.

The 3 members of the Moreno Hill Formation contain 4 coal zones. The upper member has one and the lower Moreno Hill contains 3 coal zones. These 4 coal zones vary in thickness, quality, and location within the Salt Lake field. The 4 zones contain resources in excess of 400 million tons of bituminous coal. Research has shown that the variations which occur within a zone and between zones are indicative of changing depositional environments. The better quality coals within the Moreno Hill Formation are directly related to particular sedimentation sequences.

ROYDEN, LEIGH, Harvard Univ., Cambridge, MA

Thin-Skinned Extension of Vienna Basin

The Vienna basin is an area of middle Miocene (Karpatian-Badenian, 17.5-13.0 Ma) extension and contains up to 6 km (20,000 ft) of Miocene to Quaternary sedimentary rocks. This basin is partly superimposed on the north-vergent flysch belt of the outer West Carpathians and partly on more internal Carpathian nappes. The obvious rhombohedral shape of the Vienna basin, the left-stepping pattern of en echelon faults within the basin, and the southward migration of basin extension through time strongly suggest that this basin is a pull-apart feature formed during middle Miocene sinistral strike-slip faulting along a northeast-trending fault (or fault system). This interpretation is supported by geologic mapping in the Carpathians indicating several tens of kilometers of Tertiary sinistral displacement along a fault that trends northeast from the Vienna basin.

This fault appears to have functioned mainly as a middle Miocene tear fault within the Carpathian nappes, separating the areas of active north-vergent thrusting east of the Vienna basin from areas west of the basin where thrusting had already been completed. Reflection seismic lines show that the autochthonous European plate basement continues beneath the allochthonous Carpathian nappes and beneath the Vienna basin, and that the European plate is not significantly disrupted by the normal faults that bound the basin. Thus both the normal faults that bound the basin and the associated strike-slip faults appear to merge into a gently southeast-dipping detachment horizon at depth. In this way extension of the Vienna basin appears to have been restricted mainly to shallow crustal levels above that detachment horizon (i.e., restricted mainly to the allochthonous nappes of the Carpathians). Detailed analyses of subsidence and heat-flow data indicate that little or no heating of the lithosphere occurred during extension of the Vienna basin, and support the interpretation that extension was confined to shallow crustal levels.

ROYLANCE, MICHAEL H., Marathon Oil Co., Casper, WY

Significance of Botryoidal Aragonite in Early Diagenetic History of Phylloid Algal Mounds in Bug and Papoose Canyon Fields, Southeastern Utah and Southwestern Colorado

Abundant altered botryoidal aragonite cement is recognized both in core slabs and thin sections from phylloid algal-mound facies in the Desert Creek interval of the Paradox Formation in the Papoose Canyon–Bug field area. This subsequently dolomitized cement occurs as individual to coalescing botryoids, which appear in cross section as rounded featheredge fans composed of radiating crystals. Botryoids locally comprise up to 90% of any given section of core. The botryoids are similar in appearance to Holocene botryoidal aragonite cement. However, it is deduced that, unlike modern counterparts, these botryoids grew both on the sea floor as well as within open cavities within the mound framework.

The diagenetic history of the mounds in the Papoose Canyon–Bug field area was initiated with precipitation of botryoidal aragonite cement penecontemporaneously with deposition of phylloid algal plates, creating rigid anastomosing frameworks containing abundant primary porosity. When compacted, these mounds were brecciated, thus opening up more porosity. Some of the porosity was subsequently infilled by internal sediment and calcite and gypsum cements. Finally, these mounds were extensively dolomitized, and some secondary porosity was created by leaching.

The fundamental significance of botryoidal aragonite at Papoose Canyon and Bug fields is that it helped to create and preserve very porous and permeable phylloid algal mounds by contributing to the formation of a rigid framework containing primary porosity, and by cementing the mounds early so that they became brecciated upon compaction. The preserved pores were ultimately filled with oil.