crop samples: 1.50 to 7.95% (4.29 median) for phosphatic shales, 0.67 to 5.11% (2.64 median) for phosphorites, and 0.40 to 3.17% (1.25 median) for micrites. Hydrocarbon analyses range from 50 to 300 ppm in areas where conodont CAI values range from 1.5 to 4.

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Use of Devonian Conodonts in Petroleum Exploration, Western United States

Forty-eight Devonian conodont zones are now recognized worldwide: 11 zones in the Lower Devonian, 10 zones in the Middle Devonian, and 27 zones in the Upper Devonian. Only five of these zones have not yet been recognized in the western United States. Conodonts, which range from Cambrian to Triassic, attained their maximum faunal diversity and abundance during the Late Devonian, when each conodont zone lasted about 0.5 m.y. Because each zone represents such a short interval of geologic time, conodonts provide an indispensable tool for petroleum exploration in the Rocky Mountain, Overthrust belt, and Great Basin regions.

Conodont color-alteration index (CAI) values have been used successfully to predict cool areas of potential production in otherwise thermally overcooked regions. Their use has also been demonstrated as follows.

1. Conodonts, by providing virtual time planes, suggest the complex relations between source beds in the Pilot basin and reservoir rocks in the enclosing carbonate platform.
2. Conodonts have been used to determine rates of sedimentation of source rocks and other synorogenic sediments of the Antler orogeny. These rates range from 1 to 400 m/m.y. They also demonstrate that deposition was episodic and that there were times and areas of nondeposition within marine basins.
3. Conodonts precisely date Antler orogenic events, which governed eustacy and caused marine transgressions and regressions on the craton. For example, the emplacement of the Roberts Mountains thrust took approximately 8 m.y.
4. Conodonts are used for biofacies analysis and for paleotectonic reconstructions. For example, within the Late Devonian *Polygnathus styriacus* Zone, eight different conodont biofacies, with almost mutually exclusive faunas, have been used to reconstruct five paleotectonic settings ranging from peritidal to offshore pelagic.

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Organic Model for Roll-Front Uranium Deposits

The almost universal association of uranium with humic-type organic matter in sedimentary deposits has long been recognized. This close relation is often overlooked in some sandstone uranium deposits owing to the difficulty in recognizing the unstructured organic material, the lack of analyses for organic carbon, or the labile nature of the immature humic substance. A colloidal suspension of humic acids derived from decaying vegetal matter can be made to flocculate by a drop in pH, by local changes in cation concentration, or by adsorption on clays. Evidence shows that the roll-type deposits are essentially "organic rolls" in which the humic acids were precipitated primarily by the drop in pH associated with the redox interface. Once precipitated the humic substances are particularly efficient in the collection of metals from very dilute solutions such as natural waters.

In actively migrating oxidation fronts, the humic matter and some of the uranium appears to be remobilized and concentrated downdip from the "radiometric front." This may explain the poor correlation between organic matter and uranium in some of the Texas deposits. The humic substances, however, are believed to be an essential prerequisite for the original accumulation of the uranium in the roll fronts.

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Geologic-Seismic Exploration Model for Reworked Deltaic Sandstones—Excellent Subsurface Reservoir

Reworked deltaic sands are produced by the reworking of abandoned deltaic lobes. Criteria and models are developed for the recognition of reworked deltaic sand bodies on subsurface log and seismic data. A geologic-seismic model and a subsurface prospect example is presented.

A reworked deltaic sand sequence is composed of four depositional components. From base to top these are, prodelta shale, distributary mouth bar sandstone, reworked deltaic sandstone, and transgressive marine shale. The basal prodelta shales possess lower velocities and commonly lower density and resistivity, and are generally very thick—greater than 300 ft (91 m) and commonly 3,000 ft (914 m) or more. The thickness of overlying distributary mouth bar sands generally ranges between 200 and 400 ft (61 and 122 m) and they are depopod-shaped—2 to 4 mi (3.2 to 6.4 km) along depositional dip and 2 to 6 mi (3.2 to 9.6 km) along depositional strike. Mouth bar sands display moderate to poor sorting in contrast to the overlying reworked deltaic sands which are well sorted, possess excellent porosity and permeability, and make better reservoirs. Reworked sands are elongated along depositional strike—5 to 15 mi (8 to 24 km) long and 0.25 to 0.5 mi (0.4 to 0.8 km) wide. Their thickness ranges between 20 and 60 ft (6 and 18 m). Marine shales overlying the reworked deltaic sands possess higher velocities and exhibit higher resistivity on electric logs. They are calcareous, contain abundant oyster fragments, and reflect deposition initially in shallow brackish waters and later in deep open-marine waters.

The contrasting lithologies, velocity differences, and the geometries of various depositional units of reworked detrital sand sequences provide excellent clues for their recognition on log and seismic data.

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Heat-Flow and Heat-Production Studies in North Dakota

Thirty-one new heat-flow determinations made in both oil and water wells in North Dakota range from 0.6 to 1.9 HFU.

Heat-production data from basement rocks used with nearby heat-flow values indicate that only two of six sites may be considered to be similar to Basin and Range values for heat flow. One site occurs in southwestern North Dakota in a region west of 103°W where no heat-flow value is less than 1.5 HFU. The other site in north-central North Dakota is problematic, but an eastern United States interpretation is favored. The remaining four sites are interpreted as eastern U.S. values.

A transition in heat-flow character from eastern United States values to Basin and Range values occurs west of 103°W long. in southwestern North Dakota. The narrow width (28 km) of the transition zone between heat-flow provinces implies a shallow depth to partly molten lower crust or upper mantle.

The heat-flow results coincide with a zone of anomalous electrical conductivity. When used with experimental petrologic data for peridotite in the presence of excess water, temperature calculations suggest that a partial melt zone begins approximately at 45 to 55 km, which coincides with crustal thicknesses from seismic refraction data for southwestern North Dakota.

For southwestern North Dakota, uplift of the badlands appears to be a result of partial melting.

If the high heat-flow region extends northward into northwestern North Dakota, the generation of petroleum was controlled by the zone of high heat flow. This interpretation implies that source rocks are depleted in their mobile petroleum components within the region of high heat flow.

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Biostratigraphic Problems Generated by Deep Sea Coring—Biosystematic Analysis, Evolutionary Species, and Non-Validity of Lineage Zones

Recent availability of stratigraphically continuous and hiatus-free sequences of pelagic sediment in deep sea cores have encouraged biostratigraphers to interpret lineages of oceanic microfossils from a viewpoint of gradual phyletic evolution. A few taxa do show anagenetic evolution, but the excellent stratigraphic record obtained from deep sea coring reveals that the overwhelming majority of species show only cladogenetic evolution with no gradual speciation. Biostratigraphers nevertheless persist in recognizing ancestral-descendant relations whenever possible, and arbitrary limits must therefore be applied when an evolving lineage is divided. This typological practice may be good biostratigraphy, but it is poor biosystematics.

Phyletic biohorizons and lineage zones are explicitly defined and recognized by evolutionary criteria. For interpretation, these horizons and zones must rely on notions of phyletic gradualism and ancestor-descendant relations. These notions must rely on an evolutionary theory to allow their inference. However, biostratigraphy should not rely on evolutionary theory since biostratigraphy is the means by which we correlate strata to test evolutionary hypotheses about patterns of fossil phylogeny.

For good biostratigraphic practice, evolutionary species should be recognized as single lineages without arbitrary and typological subdivision. Biosystematic analysis should begin with a cladogenetic analysis which infers taxon relations from characters exhibiting shared derived similarities. Classification should immediately follow to preserve the monophyletic relations of the clades. This system results in universal and timeless taxonomic hypotheses which are potentially falsifiable and thus scientifically testable. A biozonation based on such taxa is independent of evolutionary theory. Untestable assumptions and ad hoc hypotheses of ancestral-descendant relations and gradual speciation, such as must be used to recognize phyletic biohorizons and lineage zones, are unnecessary.

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Seismic Stratigraphy of Atlantic Margin in Vicinity of Chevron COST B-3 Well

Correlation of key seismic reflectors with the lithologic, biostratigraphic, and paleobathymetric logs of the Chevron COST B-3 well shows that this part of the Atlantic continental slope changed from a platform-fringed shelf in the Middle to Late Jurassic and Early Cretaceous to a deep-water slope in the Late Cretaceous and early Tertiary. Closely matching paleobathymetric and eustatic sea-level cycles indicate that sea-level fluctuations strongly regulated deposition by cyclically shifting the loci of deposition among the shelf, slope, and rise. At the same time, the alternate loading and unloading of the shelf may have accentuated the relative change in sea-level by producing corresponding cycles of isostatic subsidence and rebound.

Some major seismic reflectors beneath the shelf appear to coincide with erosional disconformities formed during early Oligocene, early Paleogene, early Turonian, and early Barremian. Reflectors of Late Cretaceous through early Tertiary age are continuous from the present shelf to beneath the present rise; their continuity, seismic character, and structural geometry support the idea that the margin was broadly constructional during this interval and that the shelf break was poorly defined. Beneath the rise, reflectors are mainly conformable; their character suggests onlapping fill and slope-front fill facies. Broad downslope channels were cut during the middle Tertiary and late Quaternary presumably in response to major drops in sea level.

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Continental Stretching—Explanation of Post-Mid-Cretaceous Subsidence of Central North Sea Basin

The North Sea is a major continental basin filled with sediments ranging in age from early Paleozoic to recent. It has been active several times in the past. Since the last