currents, and density gradients indicate the existence of a well-organized band of currents that run essentially parallel to the coast. An analytical model is formulated that successfully predicts the strength and location of this coastal boundary current system as a function of wind speed and direction, water depth, and local density gradients. The analytical prediction of the cross-shore current structure agrees well with the field observations in delineating the presence of convergences and divergences that will act to restrict the seaward migration of fine-grained terrigenous particulates and thus preserve the identity of the two contiguous facies. Variations in the model inputs (e.g., rainfall runoff, wind regime) allow estimates of how such systems operated in different geological regimes, and consequently how such facies relations evolved in climatic regimes different from that of the present time. An understanding of the physical processes that control the siliciclastic-carbonate interface on the eastern Nicaragua shelf emphasizes the delicate balance that exists between terrigenous or carbonate dominance over the shelf.

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Middle Ordovician Knox Unconformity, Virginia Appalachians: Transition from Passive to Convergent Margin

The Knox unconformity, central and southern Appalachians, is one of the major targets for petroleum exploration in the Appalachians, as well as being closely associated with base metal mineralization. It developed on Lower to Middle Ordovician Knox/Beekmantown carbonates, and marks transition from passive margin carbonate deposition to deposition in a foreland basin (convergent margin), possibly during global sea level lowering.

Erosional relief on the unconformity is over 140 m (460 ft) in southwest Virginia, decreasing to 20 m (66 ft) or less in northern Virginia. Decrease in relief is accompanied by rapid depositional thickening of Lower Ordovician and earliest Middle Ordovician units into the Pennsylvania depocenter. Paleokarst features include topographic highs (tens of meters relief), breccia, and mud-filled sinkholes and caves that extend to 65 m (215 ft) below the unconformity, and sub-unconformity intraformational dolomite breccias that formed after dissolution of limestone interbeds. Coarse detritus on the unconformity surface formed thin to thick veneers of regolith that were locally reworked by fluvial and marine processes. Dolomite detritus also was deposited in alluvial fan and playa mud flats in lows on the unconformity surface. Under the luminoscope, the detrital dolomite is evidenced by corroded nonluminescent detrital cores overgrown by luminescent dolomite. The unconformity influenced the regional distribution, composition, and thickness of some post-unconformity peritidal carbonates and may have localized some Middle Ordovician downslope buildups. The unconformity also localized deposition of Pb-Zn ores, which commonly are associated with unconformity related intraformational breccias that remained open during deeper burial diagenesis.

Development of regional unconformities on shelf sequences of passive margins immediately beneath foreland basin sequences is common in other orogens, reflecting gentle warping of the shelf prior to foundering and burial beneath synorogenic clastics. Such unconformities may localize hydrocarbons and base metal deposits (Pb-Zn) by developing permeable zones adjacent to the unconformity.

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Facies Cycles and Related Main Depositional Environments in Ancient Turbidite Systems

Ancient turbidite depositional systems—not necessarily equivalent to deep-sea fans—can be defined as systems where channel-fill sediments are replaced in a downcurrent direction by nonchannelized sandstone lobes. Facies types and facies sequences that characterize channels and lobes have become sufficiently understood within the last 10 years to permit their relatively east recognition in both field and core analyses.

Channel-fill sequences may differ considerably from one system to another. However, two main types of channel-fill sequences, which may be intergradational, can be recognized in most ancient systems. The first type represents channel-levee complexes, and is made up of highly lenticular bodies of coarse-grained sediments originally deposited in channel-axis zones, and of thin-bedded mudstones and fine-grained sandstones produced by overbank processes both within the channels and in adjacent interchannel regions. The second type consists essentially of broadly lenticular bodies of thick-bedded, graded sandstones that are commonly characterized by an abundance of rip-up shale clasts and scoured surfaces. Most individual sandstone beds typically thin toward and onlap onto channel walls. Both types of channel-fill deposits develop facies sequences with an overall thinning- and fining-upward character. In addition, each sequence is typically bounded by a basal erosional surface.

Lobe sequences are characteristically expressed by an alternation of thick-bedded nonchannelized sandstone bodies, commonly between 3 and 15 m (10 and 50 ft) thick, and thinner bedded and finer grained deposits. Also in this case, facies types and facies associations may vary considerably from one system to another. The loci of maximum sand deposition of the lobe environment can either prograde basinward, particularly in small sand-rich systems, or shift laterally with time in systems which develop essentially through vertical aggradation processes. In both places, the resulting facies sequences do not show significant erosional boundaries and can be generally described as thickening upward. Minor thickening-upward sequences, commonly consisting of a limited number of sandstone beds, are virtually ubiquitous within lobe sandstone units and are thought to represent compensation features produced by the progressive smoothing out of the depositional relief during the process of lobe upbuilding.

The transition between channels and lobes is still very poorly understood in both modern and ancient turbidite depositional systems. However, evidence provided by ancient sequences suggests that, at least in some systems, the transition is characterized by an abundance of coarse-grained, cross-stratified, and megaripple-shaped sandstone beds that represent either the bypassing zone of turbidity currents still moving basinward or the most proximal depositional product of the same currents before they develop complete Bouma sequences.

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Paleogene Oxygen Isotope Record for DSDP Sites 511 and 512, Sub-Antarctic South Atlantic Ocean: Paleotemperatures, Paleoceanographic Changes, and Eocene/Oligocene Boundary Event

An Eocene-Oligocene oxygen and carbon isotope history based on planktonic and benthic foraminifers from Deep Sea

Drilling Project Leg 71 cores has been constructed for the Maurice Ewing Bank of the eastern Falkland Plateau, southwestern Atlantic Ocean. Specifically, the cores cover portions of the middle Eocene, upper Eocene, and lower Oligocene. Surface water isotopic temperatures postulated for the middle Eocene at Site 512 fluctuated within about four degrees but generally averaged about 9°C (48°F). Bottom isotopic temperatures at Site 512 (water depth = 1,846 m, 6,056 ft) were generally a degree lower than surface water temperatures.

Surface water isotopic temperatures at Site 511 initially averaged about 11°C (52°F) during the late Eocene, but dropped to an average of 7°C (44.5°F) in the early Oligocene. Bottom isotopic temperatures at Site 511 (water depth = 2,589 m, 8,494 ft) generally record temperatures between 12.5°C (54.5°F) and 8°C (46.5°F), similar to the range in the surface water temperatures. During the early Oligocene, bottom isotopic temperatures dropped sharply and averaged about 2°C (35.5°F), very close to present-day values. Surface water isotopic temperature values also decreased to an average of about 7°C (44.5°F), leading to a significant divergence between surface and bottom water isotopic temperatures during the early Oligocene. Comparisons among Southern Ocean DSDP Sites 511, 512, and 277, and between these and other DSDP sites from central and northern latitudes (Sites 44, 167, 171, 292, 357, 398, 119, and 401) show that much of the Eocene was characterized by relatively warm temperatures until sometime in either the middle Eocene, late Eocene, or early Oligocene. At each site, conspicuous ^{18}O enrichments occur in both the benthic and planktonic foraminifers over a relatively short period of time. Although a general trend toward a climatic deterioration is evident, the density of data points among the various studies is still too sparse to determine either a synchroneity or a time transgression between the major isotopic events.

A close correlation could be made between the Site 511 oxygen isotope temperature curve and paleoclimatic trends derived independently from radiolarian studies. The sharp temperature drop and the divergence between bottom and surface water temperatures during the early Oligocene apparently reflect a major expansion of the Antarctic water mass. The migration of the boundary between the sub-Antarctic and Antarctic water masses over the site at this time would account in part for the sharp temperature changes. Sharp changes of this nature would not necessarily be noted in other geographic areas, particularly those to the north which have different oceanographic regimes.

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Trace Fossils in Siluro-Devonian Tidal Flat to Distal Basin Slope Carbonates of Arctic Canada

Upper Silurian and Lower Devonian carbonates of Somerset, Griffith, Cornwallis, and Devon Islands (Arctic Canada) were deposited under conditions which ranged from tidal flat in the south to basin slope in the north. Trace fossils occur commonly in this succession. *Planolites, Palaeophycos, Chondrites*, and *Skolithos* are ubiquitous throughout the sequence. Seven commonly occurring ichnogenera exhibit restricted environmental conditions: *Polarichnus* is confined to tidal flat deposits, *Zoophycos* and *Pilichnia* are most common in deep subtidal shelf and upper basin slope deposits, and *Phycodes, Lockeia, Taenidium*, and *Cruziana* occur predominantly in basin slope deposits. Seven other ichnogenera, *Arenicolites, Arthraria, Cochlichnus*, cf. *Furculosus, Helicodromites, Teichichnus*, and cf. *Thalassinoides*, occur only very rarely.

Trace fossil assemblages of the tidal flat and subtidal shelf carbonates are broadly similar to the *Skolithos* and *Cruziana* ichnofacies reported from environmentally equivalent siliciclastic deposits. Similarly, the assemblage of the deep subtidal-upper basin slope carbonates resembles the environmentally equivalent *Zoophycos* ichnofacies. In contrast, the assemblage of the basin slope carbonates comprises abundant resting and feeding traces (*Cruziana* ichnofacies) whereas assemblages of siliciclastic slope deposits are dominated by complex grazing traces and graphoglyptids (*Nereites* ichnofacies). The relative scarcity of arthropod traces throughout this carbonate sequence probably reflects diagenetic alternation of bedding surfaces.

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Radiolarian Succession of Latest Carboniferous through Permian, Urals and West Texas

A succession of characteristic radiolarian assemblages has been recognized through the Late Carboniferous and stratotypic Permian of the Urals and west Texas. The majority of the component taxa are yet undescribed. The oldest well-preserved assemblage from the regions appears in the lower Gzhelian Stage of the Urals and consists of more than 30 species belonging to 12 genera. Typical are large *Albaillella*, curled *Haplodiacanthus*, abundant spongy, cross-axon forms with an open central area, and *Polyentactinia* of octahedral form. The top of the Gzhelian Stage contains 54 species assigned to 18 genera. A new genus of the Corythoecidae, species of a highly plastic, closed spongy, cross-axon form, an unsegmented *Albaillella* with massive basal spines, *Camptoalatus, Popofskyellum*, and various triradiate, cross-axon forms are characteristic.

The lower horizons of the Asselian Stage are distinguished by the appearance of *Latenofistula crucex*, a unique, large-pored *Entactinosphaera*, and spherical and elliptical forms with multiple concentric shells. Thus, radiolarian assemblages gradually change at the Carboniferous-Permian boundary. The Sarabil Suite of the Sakmarian Stage is distinguished by *Haplodiacanthus perforatus* (Kozur), *Albaillella permica* (Kozur), and large *Helioentactinia*. In the upper part of the Sakmarian Stage appears as assemblage of *Camptoalatus monopterygius* Nazarov and Rudenko, *Raphidociclicus hiulcus* Nazarov and Rudenko, and a new species of *Ruzhencevispongus*. The base of the Artinian Stage is characterized by the appearance of a new, multishelled, spongy polycystine genus possessing a three-rayed internal framework, *Tormentum*? *pavlovi* (Kozur), and a large, triradiate form with two strongly curving legs. The lower and middle parts of the Aktastinian Substage (Artinian Stage) are distinguished by an undescribed, small, discoidal, five-rayed radiolarian and by *Entactinosphaera* sp. The top of the Artinian Stage is typified by *Haplodiacanthus anfractus, Raphidociclicus gemellus*, and *Ruzhencevispongus uralicus* Kozur, and marks the first appearance of *Follicucullus* Ormiston and Babcock in the Urals. This is clearly an older horizon than that of the type species, *Follicucullus ventricosus*, known from the Guadalupian of west Texas. Direct comparison of radiolarian faunas indicates a correlation of the Bone Spring Limestone (Leonardian) of west Texas with the upper Sakmarian and/or Artinian Stages of the Urals.

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