tions contain at least seventeen deep channels (10 to 50 feet), which appear to have been both cut and filled by turbidity currents. The association of deep channels and proximal turbidite sedimentation suggests that the environment of deposition of the Shale Grit was a submarine fan, similar in most respects to the fans at the foot of the Monterey and La Jolla canyons. The Grindslow Shales were probably deposited on the slope above the fan.

The sequence from the Mam Tor Sandstones (distal turbidites) via the lower Shale Grit (distal, with subordinate proximal turbidites) into the upper Shale Grit (proximal, with subordinate distal turbidites) suggests advance of a submarine fan into the central Pennine Basin. The advance continued as the Grindslow Shales slope environment covered the fan, and was itself covered by the nearshore or coastal plain Kinderscout Grit.

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Late Paleozoic Deltas in the Central and Eastern United States

Environmental mapping in Pennsylvanian and Mississippian rocks from Oklahoma to Pennsylvania has shown that most lenticular masses of sandstone and shale are parts of deltaic complexes. In Late Mississippian and Pennsylvanian rocks, deltaic expansion commonly follows brief marine transgressions. Widespread marine limestones may terminate against broad arcs of prodeltas composed of evenly laminated gray shales with ironstone nodules. The prodelta deposits become more sandy upward and are succeeded by conformable sheet sands or unconformable lenticular sandstones. Thicknesses of the combined delta and prodelta deposits in eastern and central United States are as much as 150 feet, composed entirely of shale, or sandstone or both.

Source areas for delta sands are north, east, and southeast of the Appalachian basin; northeast and north of the Illinois basin and northern Mid-continent; and south, southeast, and southwest of Oklahoma. The Ozark uplift, Nemaha ridge, and central Kansas uplift were unimportant sources; the Canadian shield, northern Appalachians, Transcontinental arch, and Ouachita and Arbuckle uplifts were principal sources. Deltaic growth from different directions was not contemporary.

Detailed mapping of minor features of these deltas, now in progress, shows intricate patterns of sand and shale and indicates that surface configuration of a delta is an important determinant of distribution and thickness of Pennsylvanian coals. Four deltas have been studied in the Lower Mississippian (Pepper and Dewitt), twelve in the Upper Mississippian (Swann and Potter), and twenty in the Pennsylvanian. Examples of entire deltas and details of portions of deltas are illustrated.

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The Stratigraphy and Sedimentary Petrology of Miocene Turbidites in the San Joaquin Valley

A thick Miocene marine basinal succession, dominantly sandstone, underlies the southern portion of California's San Joaquin Valley. Deposited in paleontologically defined depths of as much as 5,000 to 6,000 feet, the sands are pebbly and gritty to fine grained, largely angular, poorly sorted, often silty and micaceous, quartzose to arkosic and are interbedded with dark carbonaceous shales. Graded bedding is common and in conjunction with depth estimates is taken to imply turbidity current origin for most of the sands.

Early Miocene turbidites spread far southwestward from the Sierra Nevada provenance, but by late Miocene, anticlinal barriers, rising from the sea floor, restricted the turbidites, including the highly productive Stevens sands, to the northeastern side of the basin. These late Miocene sands at first entered from discrete troughs or canyons but later from more widely dispersed sources as shelf sands encroached. Deep basinal transport seems to have been axially northwestward. Locally, thick Stevens synclinal channel sands spread eastward off the rising Temblor Range. Sudden cessation of basinal sand deposition was followed by deposition of chert, shale, and Pliocene neritic sediments.

Detailed subsurface correlations show that Stevens sand bodies include sinuous channel fills bounded by major anticlines, sands flanking and covering lower structures, and lobate and branching apron sands in simple homoclinal areas. Compaction structures are shown to control some accumulations and offer clues for continuing exploration.

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Chemical Composition of Siderite Nodules in the Environmental Classification of Shales

In the search for geochemical indicators for the environmental classification of non-fossiliferous, clastic sedimentary rocks, the chemical composition of 45 syngenetic "siderite nodules" from shales of Pennsylvanian age was investigated. Nodules were assigned to three categories on the basis of closely associated fossils: (1) FW—freshwater (*Estheria*, *Leaia*, *Anthraconauta*, *Carbonicula*), (2) B—brackish, restricted marine or nearshore marine (*Lingula*, *Orbiculoidea*, *Dunbarella*, *Aviculopecten*), and (3) M—marine (*Chonetes*, *Mesolobus*, etc.). Of 11 elements determined, Si, Al, Mg, Ca, Ba, and V are useful as environmental discriminators. Means (and standard deviations) of these elements by category are as follows:

	% SiO_2	% Al_2O_3	% MgO	% CaO	% Ba	% V
FW	30.75	13.42	2.22	2.55	.0360	.0094
	(12.8)	(7.25)	(.674)	(2.17)	(.0118)	(.0039)
B	13.67	5.77	2.47	2.97	.0180	.0110
	(7.44)	(3.95)	(1.32)	(.824)	(.0110)	(.0042)
M	11.56	4.84	3.58	5.81	.0140	.0140
	(3.25)	(1.12)	(1.02)	(1.66)	(.0033)	(.0043)

A three-group, six-variable discriminant permits complete separation of individual FW and M samples, but is less successful in distinguishing the brackish and restricted marine shales as a separate category. Siderites forming during sedimentation may prove especially useful for environmental discrimination where variations in the detrital to authigenic clay mineral ratio diminish the value of trace element indicators in the argillaceous fraction of the rock.

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$O^{18}-O^{16}$ Ratios of Evaporitic Dolomite From the

Mississippian Charles Formation and Their Significance to the Dolomite Problem

Samples of grey-buff, hard and brittle, cryptocrystalline evaporitic dolomite from the Charles Formation of southern Saskatchewan have an average δO^{18} value of +0.64 per mil relative to the PDB standard. Compared to normal marine calcite limestones of the same age ($\delta O^{18} = -6.21$, standard deviation$=0.89\%$), the dolomite is depleted in O^{16} to the extent of 6.85 per mil. This result does not preclude a primary chemical origin for the dolomite as do the isotopic data of Degens and Epstein (Geochim. Cosmochim. Acta, *28*, 23, 1964).

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Late Cretaceous Deltas, Rocky Mountain Region

During the Late Cretaceous, a basin of deposition covered the western interior of the North American continent, extending from the present Gulf of Mexico to the Arctic. Large quantities of detrital sediment were transported from a source area along the western margin of the basin and deposited in coastal plain, shoreline, and marine environments. Rivers carrying the sediment load formed three large delta complexes: one in central Montana; a second in central Wyoming; and, a third in northern Colorado and southwest Wyoming. These three deltaic centers formed dispersal points from which sediment was carried and distributed within the basin by marine processes. Of the three delta complexes, the northern Colorado-southwest Wyoming delta contains the greatest volume of sediment, representing 2 to 3 times the volume of each delta to the north.

Deltas are defined by establishing time-stratigraphic units in the marine shale formations, either by faunal or physical criteria, and by tracing these units into the shoreline sandstone and coastal plain deposits. Lithofacies maps, isopachous maps, and restored sections are prepared for each time-stratigraphic unit. The recognition of a delta is based on two or more of the following criteria: 1) an arcuate lithofacies pattern of coastal plain strata (nonmarine) protruding into the marine basin; 2) for a designated time-stratigraphic unit, thickest deposits in the general shoreline zone (area of topset and foreset strata) associated with this lithofacies pattern; 3) a complex intertonguing of marine (foreset and bottomset) and nonmarine (topset) strata; 4) rapidly changing shoreline sandstone trends from one time-stratigraphic unit to another; 5) abundance of stream deposits over deposits of other environments of coastal plain; 6) biological criteria in marine strata, especially lack of fossils (absence of pelagic calcareous foraminifera); arenaceous benthonic forms tend to dominate; 7) persistence of above criteria in vertical stratigraphic sequence indicating semi-permanency of drainage systems responsible for deltaic deposits.

In Upper Cretaceous strata, topset strata are characterized by lenticular sandstone, siltstone, claystone, shale, and coal. Depending on the nature of the river load and the energy of the basin, the foreset strata may be interbedded siltstone and shale, or large sheets of sandstone forming a partial aureole around the nose of the delta. Bottomset strata are shale or interbedded shale and siltstone with minor amounts of sandstone.

The Upper Cretaceous (Campanian and Maestrichtian) of southern Wyoming and northern Colorado illustrates deltaic sedimentation and its influence on oil accumulation. Localized deltaic loading caused penecontemporaneous differential deformation of the subsiding basin floor. Incipient structural highs between the more rapidly subsiding delta areas controlled early migration of petroleum in stratigraphic traps. Where subsequent geologic history has favored preservation of these early traps, large petroleum accumulations have been discovered.

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Illinois Basin: Depositional or Post-Depositional?

Pre-Pennsylvanian stratigraphic and tectonic patterns of the Illinois Basin region are revealed through analysis and segregation of the Sauk (Late Cambrian-Early Ordovician), Creek (Middle and Late Ordovician), Tutelo (Silurian-Late Devonian), Piankasha (intra-Devonian), and Tamaroa (latest Devonian-Mississippian) sequences. To relate the Illinois Basin to its regional setting, these pre-Pennsylvanian (pre-Absaroka) unconformity-bounded successions are delineated from Wisconsin to Tennessee and from Ontario to Oklahoma. Abundant Absaroka strata of the Illinois and other major basins involved are excluded because the regional identity of an adequate number of intra-Pennsylvanian stratigraphic datum surfaces is uncertain.

Approximate basin limits are customarily outlined by the outcrop of the base of the Absaroka sequence in Illinois, western Indiana, and northwestern Kentucky. Original interregional continuity of most units comprising the five pre-Absaroka sequences, and the differential degradation patterns beneath each and beneath the Absaroka, deny inception of basin development until at least Pennsylvanian time. For example, the Creek sequence of the basin is neither depositionally nor preservationally thicker than that to the west in Iowa or to the north in southeastern Wisconsin; but it is both depositionally and preservationally thinner than that to the east and south in Indiana, Kentucky, and Tennessee. Except for areas of its later erosional removal, such as the Cincinnati Arch and the Nashville and Ozark Domes, the Tutelo sequence is at least as well preserved in areas adjacent to the Illinois Basin as it is within. The Piankasha and Tamaroa sequences thicken depositionally from north to south across the basin.

Although these patterns do not date the actual onset of basin formation, they nevertheless demonstrate that the long-prevailing hypothesis that the Illinois Basin was persistently negative during most of Paleozoic time is invalid, and that subsidence was post-depositional at least with respect to its pre-Absaroka content.

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Depositional and Stratigraphic Features of Littoral Algal Bioherms and Basin Facies

The Devonian Nubrigyn Reef Complex, Australia, consists of a littoral and a sublittoral facies. The former is composed of numerous abruptly intertongued lithologies: impure algal detritus, andesite pebble lenses, Devonian erosional remnants of andesite lava flows, and over 300 pure algal atoll-like bioherms (some fringing the andesite hills) and biostromes with lagoonal codiaceae-calcarenite. Numerous depositional and diagenetic features are suggestive of a turbulent intertidal environment.

The sublittoral deposits consist of uniformly-bedded detrital algal limestones with interbedded claystones. Most of the former are graded and are believed to be turbidites. There are scattered, thick, lens-like