explained by a relatively simple progradational cyclic model without invoking major sea level fluctuations.

A typical cycle contains 3 major components: (1) shelf-bar stones; and (3) interbar siltstones. **Shelf-bar sandstones, 1 to 6 m (3 to 20 ft) thick, are typically overlain by carbonate grainstone/packstone facies 1.5 to 6 m (5 to 20 ft) thick, which are** grainstone/packstone facies, 1 to 6 m (3 to 20 ft) thick, which are in turn overlain by siltstones, 1 to 6 m (3 to 20 ft) thick, thus completing the cycle, 4 to 18 m (13 to 59 ft) total thickness.

Shelf-bar sandstones in the Holder Formation (Virgilian) are lenticular concavo-convex sand bodies, 2.5 to 6 m (8 to 20 ft) thick, with flat depositional bases. Average grain-size (4 ϕ - 0 ϕ) and maximum clast size (12 mm, 0.5 in.) increases upward. Seaward dipping (W - NW) accretion foresets, up to 0.6 m (2 ft) thick, and bimodal trough cross-stratification, 10 to 30 cm (4 to 12 in.) thick, characterize lower sandstone facies. Hummocky cross stratification, 7 to 9 cm (2.8 to 3.5 in.) thick, 1.2 to 2.5 m (3.9 to 8 ft) wavelength, is common along accretion foreset surfaces and the tops of many of these sets are rippled and burrowed. Syndepositional deformation structures are common. Missourian and Virgilian shelf-bar sandstones were rapidly deposited by storm-induced currents and were modified by fair-weather tidal oscillatory flow and biological processes.

In contrast with Virgilian shelf-bar sandstones, Wolfcampian bars are thinner, 1.5 to 2 m (5 to 6.5 ft) thick, coarser grained, and locally have erosional bases. Bimodal through cross-stratification is well-developed at the expense of seaward dipping accretion foresets which if present, are poorly developed. Hummocky cross-stratification and burrows are rarely present, whereas ripples and syndepositional deformation structures are common. Average grain size coarsens-upward crudely. These Wolfcampian shelf-bars were deposited in shallow water subject to strong tidal currents, which winnowed finer sediments, produced distinct bimodality in sedimentary structures, and prevented the bars from achieving significant depositional relief.

Carbonate units, 1 to 5 m (3 to 16 ft) thick, decrease in micrite and increase in abundance of allochems upward in the vertical sequence. Sedimentary structures are similar to those of the associated siliciclastic shelf-bars, indicating a change in sediment-supply without significant change in hydrodynamic conditions. Carbonate units are thinner, 1 to 2 m (3 to 6.5 ft), become less important volumetrically in Wolfcampian sediments as compared with those in Virgilian rocks.

The spectrum of high energy siliciclastic shelf-bar sandstones, and the presence of fan-deltaic and fluvial deposits in overlying sediments (Wolfcampian) suggests that the shelf adjacent to the Pedernal uplift continuously prograded into the Orogrande basin. Shifting clastic influx along depositional strike caused drastic local changes in shoreline configuration, longshore currents, and subsequent clastic and carbonate sediment distribution patterns.

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Conodont Paleoecology of Lower Triassic Thaynes Formation

The Lower Triassic (Smithian) Thaynes Formation represents a broad spectrum of paleoenvironments. Samples arranged along a generalized depth-salinity environmental gradient from tidal flats to a relatively deep, commonly dysaerobic, basin yielded a conodont fauna of 30 form elements. Association and similarity analysis were used to group the conodont elements into eight conodont entities, reflecting both biologic association (multielement apparatuses) and ecologic association (biofacies). Simple chi-square tests and discriminant analyses, using the eight conodont entities, and indicate presence of three distinctive conodont biofacies related to the generalized environmental gradient. The restricted inner shelf biotope was characterized by a conodont fauna dominated by *Parachirognathus*. The outer shelf biotope was distinguished by a diverse conodont fauna including the distinctive form *Furnishius*. The biotope farthest offshore consists of a low diversity conodont fauna composed primarily of species of *Neogondolella*. Some early Triassic conodonts such as *Neospathodus* and *Ellisonia triassica* are ubiquitous, and provide the foundation for a inter-basinal conodont zonation. Early Triassic conodont biotopes can be arranged along a generalized environmental gradient that probably reflects changes in hydrographic factors (e.g., salinity, temperature, and energy) which affected the distribution of conodonts.

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Dominant Distributions and Niches of Polycystine Radiolarians in Modern Oceans

Approximately 400 to 500 relatively common polycystine radiolarian "species" live in the modern oceans. About 200 species live in shallow (0 to 200 m; 0 to 656 ft), temperate and tropical waters (the "upper warm water sphere"); 40 to 50 in high latitude (poleward of subtropical and polar convergences) shallow waters; 150 to 200 in deep (greater than 200 m; 656 ft) waters, most of which appear to be tropical submergent (shallow in high latitudes and diving as tropical submergent or tropical avoidant forms); and about 40 to 50 eurybathyal forms. In general, spumellarian "family groups" of the warm water sphere (surface to subsurface) include the beloids, collosphaerids, saturnulids, artiscids, phacodiscids, spongasterids, dictyocoryids, spongurids, pylonids, lithellids (loosely coiled), and stylodictids; with the spongotrochids, spongopylids, tholonids, lithellids (tightly coiled), and orosphaerids being dominantly intermediate and deep water (cold water sphere) forms. In general, nassellarian family group of the warm water sphere and transition-central waters include the lophophaenids; sethoperids, sethophormids (complex), carpocanids, eucyrtidids, pterocoryids, cannobotryids, spyroids, and artostrobids (not robust). Plectopyramids, artostrobids (robust), sethoperids, sethophormids (simple), and theocalyptrids dominate in either the transition-central (lower warm water sphere) or cold water sphere.

Polycystine radiolarian species and family level groups appear to fit into four basic broad "nutrition niches:" nannoherbivore-carnivore; bacterivore; detritivore, in association with symbiotic algae; and, perhaps an osmotrophic niche. At the family level these groups dominate the following oceanic habitats: nannoherbivore-carnivore the broad shallow warm water sphere, with algal symbiotes dominating the subtropical anticyclonic gyres, eastern equatorial, and shelf subregions; bacterivores in subsurface and deeper (nutricline and deeper); and, detritivores and perhaps osmotrophs the deep ocean.

A positive relationship exists between the degree of eutrophism in the epipelagic region, and underlying mesopelagic and deeper radiolarian standing crops. Radiolarians are usually sparse in waters overlying the continental shelves. However, those radiolarians harboring symbiotic algae (collosphaerids, artiscids, spyroids, spongasterids, dictyocoryids, etc) are more tolerant of shelf waters. Radiolarians harboring symbiotic algae are also dominant in the oligotrophic subtropical anticyclonic gyres and the eutrophic eastern tropical regions. Acantharian and diatom bloom conditions exclude polycystine radiolarians from these bloom areas (many nearshore areas and the photic zones poleward of polar convergences).

These modern day dominant patterns of radiolarian distribution appear to have been initiated in the early Neogene and related to the development of the Neogene (and modern) water mass regimes at that time. One of the major radiolarian zoogeographic anomalies, since the initiation of the Neogene water mass regimes and their contained radiolarian faunas, has been the isolation of relict radiolarian species in the warm water sphere of the North Atlantic. This oceanographic realm has been semi-isolated from the world ocean for about the last 3 to 3.5 m.y. and contains a relict (and expatriated) radiolarian fauna. Of special interest in the relict fauna are the presence of the species *Lamprocyrtis heteroporos*, *Didymocyrtis penultimus*, *D. avitus*, and *Spongaster pentas*—all, until recently, thought to be extinct.

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Regional Aspects of Diagenesis in Niagaran Pinnacle Reefs, Northwest Michigan: Evidence for Differential Fluid Migration

The Middle Silurian pinnacle reef system of northwest Michigan consists of a narrow, northeast-southwest-trending band of isolated reefs encased in thick Upper Silurian evaporites. All reefs display a similar pattern of diagenetic evolution: neomorphism of metastable carbonate components followed by precipitation of a closure cement; modification of porosity by a combination of cementation, solution and dolomitization; and emplacement of hydrocarbons and stylolitization. The exact sequence of diagenetic events and the resulting texture of the carbonate rock vary considerably from reef to reef, but several regional trends can be identified.

There is an obvious change in reef mineralogy *across* the reef trend, from predominantly calcitic reefs basinward to predominantly dolomitic reefs near the shelf. There appears to be a corresponding increase in $\delta^{13}C$ and $\delta^{18}O$ isotopic ratios shelfward, both in matrix limestone, according to Sears and Lucia in 1979, and in the neomorphic replacement of former marine cements. A change in the mineralogy of closure cements is observed *along* the reef trend, from calcite-pyrite in the southwest to pyrite or dolomite-quartz in the northeast. Oil emplacement also varies along the reef trend. Sparry dolomite and pyrite mineralization are associated with bitumen in the southwest parts of the reef trend, whereas leaching appears to accompany or just predate oil entry in the northeast. Finally, the dominant pore-filling phases in each reef vary in an irregular fashion throughout the trend from calcite and halite in some reefs to anhydrite and laminated dolomite in others.

These variations on a diagenetic theme appear to be related only to the presence or absence of diagenetic fluids in the reef's history, not to the lithology involved. Differential migration of fluids, caused by different hydrostatic heads on each fluid or migration through different pathways, would account for the diversity of diagenetic sequences in the pinnacle reef system. Careful petrographic and chemical analysis of each individual reef is needed to identify the local diagenetic history, and these local histories must be correlated in order to infer the larger picture of basin development.

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Freshwater Carbonate Cements

Freshwater carbonate cements in nonmarine sediments form in a diverse assemblage of settings, including fluvial, lacustrine, pedologic, spring, and spelean environments, giving rise to a plethora of textures and structures. Many deposits exhibit both phreatic and vadose zone textures. Cement mineralogy and composition vary considerably from deposit to deposit, as well as within individual deposits, depending on water chemistry and environmental setting. Similarly, cement habits range from highly acicular to nearly equant. The wide variety of textures, mineralogies, and compositions exhibited by both cement and associated sediments suggests that freshwater carbonate precipitation may involve complex processes. A survey of our present knowledge indicates that such cements are most commonly composed of low magnesian calcite as crystals with rhombohedral terminations. Among those features which appear to be unique to freshwater carbonate cements are crystals displaying trigonal prisms, rhombohedrons ornamented with parallel sharp spikes, and crystals with thorn-shaped vacuoles. Although variation in crystal habit may be influenced by either magnesium or total cation or anion concentrations in the precipitating fluid, the concentration of solutes does not appear to be the sole controlling factor. Growth rate, influenced by a variety of parameters, such as P_{CO_2}, may be the most important factor in predicting crystal habits in freshwater carbonate cements.

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Surface Gamma Logs: A Helpful Correlation Tool

Gamma logs of measured surface sections provide an excellent correlation tool in wildcat areas where well control is sparse and outcrops are abundant. Gamma logs of measured surface sections can be correlated with gamma logs of any nearby wells that have penetrated the same strata. Subtle changes in lithology that may have been missed during routine section measuring are detected by surface gamma measurements. Furthermore, gamma measurements over covered intervals may give clues to the nature of the buried lithology.

A portable scintillation counter is used to take gamma measurements. These measurements are recorded along with lithologic descriptions. Five-foot-intervals provide the best results.

Surface gamma logs are successfully used in correlating members of the Jurassic Twin Creek Limestone from wells in the northern Utah Overthrust to outcrops in north-central Utah. They are also useful in correlating upper Paleozoic rocks in the Basin and Range province.

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Channel-Levee-Overbank Sequence in Paleocene Submarine Canyon Fill, Point Lobos, California

Vertical sequences characterized by upward decreases in the grain size and bed thickness of turbidites are commonly attributed to laterally migrating channel-levee-overbank systems. A probable Paleocene example of such a sequence is superbly exposed at Pebbly Beach, Point Lobos, California. Contact relations indicate that the Paleocene deposits fill a steep-walled sinuous valley carved into underlying granodiorite of Late Cretaceous age. The few fossils found in the Paleocene rocks indicate deposition in water depths of 100 m (328 ft) or more and suggest that the sediment accumulated in a submarine canyon. Although most of these Paleocene deposits are conglomeratic, the upper part of the section exposed at Pebbly Beach consists of a 30-m (98-ft) thick fining-upward sequence from conglomerate through sandstone to mudstone. About 10 m (33 ft) of predominantly thick-bedded sandstone grades upward through a transitional sequence of about 2 m (6 ft) of thin-bedded sandstone into