upper members, respectively, of the Gros Ventre Formation) contain evidence of shoaling carbonate-clastic associations within a major transgressive sequence.

Death Canyon carbonates accumulated far offshore in relatively shallow water of restricted circulation. The basal portions of the Death Canyon represent subtidal blanket carbonates consisting of burrowed and mottled biomicrites and peloidal biomicrites. Strandline stability resulted in prolonged periods of vertical aggradation of this carbonate platform into progressively shallower water. Evidence for this shoaling includes: (1) increase in abundance of ooids and intraclasts up section; (2) increase in the relative abundance of siliciclastic debris up section; (3) coarsening upward of the siliciclastics; (4) occurrence of cryptalgal structures and large algal stromatolites as well as desiccation features near the top of the Death Canyon. These stromatolites are closely spaced circular mounds from 1 to 3 m (3 to 9 ft) in basal diameter and 0.5 to 2 m (1.6 to 6.6 ft) in height. The mounds consist of a thick inner faintly laminated zone and a thinner outer zone of discrete columns composed of curved laminations. Pits and channels occur on the outer surface and probably represent areas where low-water stage runoff was concentrated.

Carbonate production diminished with the influx of fine-grained siliciclastics near the Death Canyon–Park contact. Although the lower Park is predominantly dark, micaceous shale, it also contains cryptalgal micrites, algal stromatolites, and lenticular beds of feldspathic and arkosic arenites. These deposits all accumulated in shallow water a considerable distance from the Middle Cambrian shoreline. The siliciclastics were derived from nearby source areas that were probably offshore islands of Precambrian crystalline basement. Facies associations indicate deposition of the coarser clastics in subtidal settings.

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Barreirinhas Basin, an Equatorial Atlantic Transform Basin

A regional study of the Barreirinhas Basin, located in the Brazilian equatorial Atlantic margin, revealed that this basin does not fit the classical rifted Atlantic margin model and that it should be interpreted as a transform basin.

Three major stratigraphic sequences, Canarias, Caju, and Humberto de Campos, limited by unconformities, represent the principal evolutionary steps of the basin. The basin evolved from an initial rift phase dominated by tension (early or pre-Aptian?) to a transform phase dominated by lateral motion with tension/compression produced by a wrench system (late Aptian). These events were followed by a more quiet period as final separation (Albian-Cenomanian) and subsequent continental drifting (Upper Cretaceous to Holocene) occurred.

The Aptian sediments (Canarias) were formed by clastics representing fluvial-deltaic and fan delta, slope, and basinal depositional systems. The Albian-Cenomanian sediments (Caju) comprise cyclical deposits of carbonates and shales representing carbonate shelf and slope depositional systems. The Upper Cretaceous to Holocene sediments (Humberto de Campos) are composed of mixed coarse clastics, carbonates, and shales representing fan delta, carbonate platform, and slope-basinal depositional systems.

Structural and isopach maps, based on seismic and well data, allowed the determination of the structural framework and displayed several features not related to a normal rift basin. The structural grain of the basin at the end of the Aptian is formed by a succession of folds arranged in a consistent north-northeast en echelon pattern displaced by normal and strike-slip faults. Also, inversion structures affecting deep sedimentary sections and local shale mobilization associated to fault zones are present in the central and eastern area of the basin. All these features indicate that the area was affected by a right-lateral motion in connection with the separation of African and South American plates. The motion was directly related to the Romanche fracture zone, as shown by the reconstruction of continents at the end of the Aptian.

From east to west, the complexity and magnitude of the wrench tectonics gradually decrease, and in the westernmost area (Plataforma de Ilha de Santana) only horst-and-graben rift tectonics is observed. The stratigraphy, controlled by tectonics, also changes from a thick Aptian section in the east to a thick Upper Cretaceous to Holocene section in the west.

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Depositional Patterns in Point Lookout Sandstone, Northwest San Juan Basin, New Mexico

The Point Lookout Formation, which is well exposed along the northwest margin of the San Juan basin in northwestern New Mexico, includes nearshore sediments deposited during a regression of the Late Cretaceous epicontinental sea in earliest Montanan time. The unit is composed of sandstone and siltstone with sand percentage increasing up-section. Principal outcrop lithofacies include a lower interbedded, highly bioturbated, very fine sandstone and shale that represents the transition from inner-shelf to shoreface environments. The middle part of the unit gradationally overlies the lowermost lithofacies and represents a complex depositional history in the nearshore zone. These progradational units are thickly bedded and coarsen upward. This simple sequence is interrupted by the occurrence of hummocky stratified storm deposits and by broad surfaces of nondepositional scouring in the lower shoreface. A medium-grained upward-fining sandstone lithofacies that caps the entire formation has an erosional base and large-scale lateral accretionary bedsets.

Measured sections from the outcrop of the Point Lookout closely correspond with electric-log patterns from subsurface data east of the outcrop belt. The mapped distribution of SP-pattern facies (representing sandstone textural characteristics) depicts the primary depositional elements of the progradations. Correlation of genetically related sand packages permits the evaluation of changing sedimentation patterns through time. Seven regressive events (time-stratigraphic units) are recognized based on subsurface identification of the transgressive boundaries that rise stratigraphically away from the basin and obliquely traverse lithofacies boundaries. Each unit is composed of three depositional phases (progradation, transgression, and aggradation) that occur in regular succession.

Discrete distributary and interdistributary areas were maintained in the initial depositional phases throughout the history of the Point Lookout. In the broad areas between depositional axes the shoreline prograded by the seaward accretion of beach ridges until sediment sources became insufficient to maintain the shoreface advance. Transgressive reworking of the seaward part of the unit followed and dominated the arrangement of net-sandstone thicks by redistributing the sands into a strike-alignment. Each time-stratigraphic sedimentary unit is therefore the product of a progradational-transgressive depositional couplet. Whereas periodic transgressions were mainly erosive, they did cause the formation of coalesced shallow-shelf bars analogous to estuarine-shoal retreat massifs found on the modern continental margin of the Mid-Atlantic Bight.

During periods of shoreline stability following transgression a channeled estuarine system developed landward of the retrograded shoreline trend. During this tide-dominated aggradational phase, channels migrated over the back-barrier area and produced the relatively coarser sand facies capping the Point Lookout in the study area. After the estuarine system was infilled, coastal plain facies were established in the former back-barrier zone and progradation was renewed. With the repetition of this depositional pattern through time, the coastal plain advanced in a step-wise fashion.

As a consequence of the progradational-transgressive cyclicity, a significant degree of stratigraphic rise was attained during the Point Lookout regression. Each time-stratigraphic coastal sand body acts as a discrete reservoir that interfingers landward with impermeable sediments of the coastal plain facies. Given the necessary present-day structural configuration, major stratigraphic rises corresponding to aggradational phases can act as updip migration boundaries to gas derived from the center of a basin.

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Radiolarian Preservation in Geologic Sequences

The following observations were noted during fieldwork in Tethyan regions.

1. Radiolarians are often preserved where organic matter is abundant, generally in reduced environments or microenvironments resulting from transgression or confined basins. Such an anaerobic environment preserves silica from dissolution.

2. Radiolarian localities are commonly restricted to small basins (e.g., the Gulf of California).

3. In limestones, radiolarians are commonly restricted to small "nests" preserved in pyrite. This restriction may be a result of their sedimentation within fecal pellets, reducing microenvironments.

4. Preservation is generally better in rocks rich in clays (clayey limestones, nonglassy cherts). The clays may produce a double effect: (a) to form protective varnish all around the shell, (b) to slow the opal-A to opal-CT transformation so the structure of the opal-CT is better organized and much less subject to subsequent dissolution.

5. Radiolarians in limestones are generally calcitized. However, in rich limestones where silica is not concentrated in nodules but is "diffuse," radiolarians remain preserved in silica. This results from clays which limit (a) the opal-A to opal-CT transformation which occurs in a fluid state and (b) the migration of the silica fluid.

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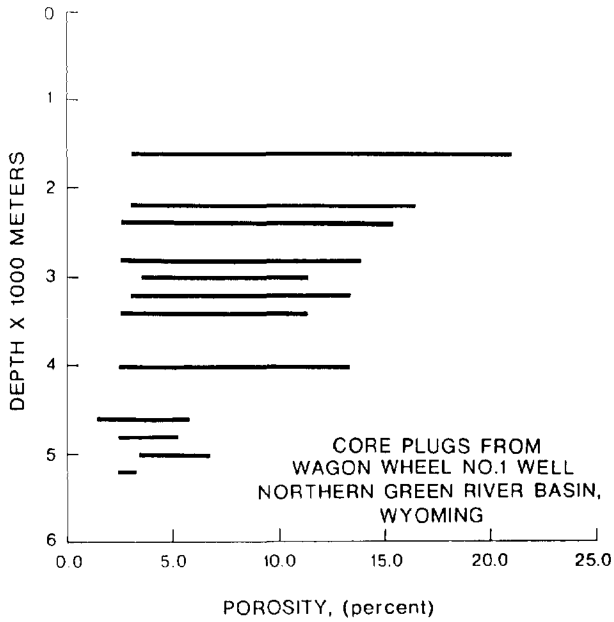
Diagenesis of Nonmarine Rocks and Gas Entrapment in Northern Green River Basin, Wyoming

More than 5,000 m (16,404 ft) of Upper Cretaceous and Tertiary nonmarine rocks have accumulated in the northern Green River basin. At depths below 3,000 m (9,842 ft), they contain large reserves of natural gas in low-permeability, overpressured sandstones and siltstones. Isotopic, petrographic, and mineralogic studies of cores from seven wells reveal that an intricate sequence of diagenetic events has acted upon mineralogically immature sediments to produce the observed low permeabilities. In large portions of the basin, this low permeability impedes the leakage of pore fluids, including gas. Gas accumulates in sandstones because it is generated from humic matter at a rate that exceeds its ability to escape. Gas entrapment due to low permeability is demonstrated by overpressuring. The overpressuring results from a combination of overburden removal and generation of fluids by organic matter maturation.



In the central part of the basin, normal hydrostatic pressures exist down to about 2,500 m (8,200 ft). Sandstone porosities in this zone range from 10 to 15% and permeabilities usually exceed 10 md. Below this depth, sandstones have greatly reduced porosities and permeabilities and become increasingly overpressured. At depths of about 3,500 m (11,483 ft), overpresssuring and gas accumulation are associated with sandstones that have average porosities of about 7% and in-situ permeabilities of approximately 0.005 md. This transition is not marked by a depositional boundary.

Porosity reduction, which is assumed to be paralleled by permeability loss, proceeds by some combination of three principal processes: (1) precipitation of calcite or silica cements early in the burial history; (2) porosity loss through grain deformation and compaction; and (3) the filling and coating of residual and secondary pores by illite, chlorite, microcrystalline quartz, or ferroan carbonates.

A wide range of porosities is present in each depth interval, but maximum sandstone porosity follows a relentless course of destruction with depth. Only locally has the magnitude of grain and cement dissolution been great enough to reverse the porosity-depth trend. Zones of conventional reservoir porosity and permeability have not been recognized in areas of overpressuring and gas accumulation, nor are they to be expected. Because the gas is diagenetically entrapped, the search for economic accumulations should, paradoxically, be limited to sandstones of low porosity and permeability.

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Acritarchs from Ponta Grossa Formation and Their Stratigraphic Significance—Devonian of Parana Basin

The Devonian fossil record in the Parana basin of Brazil is