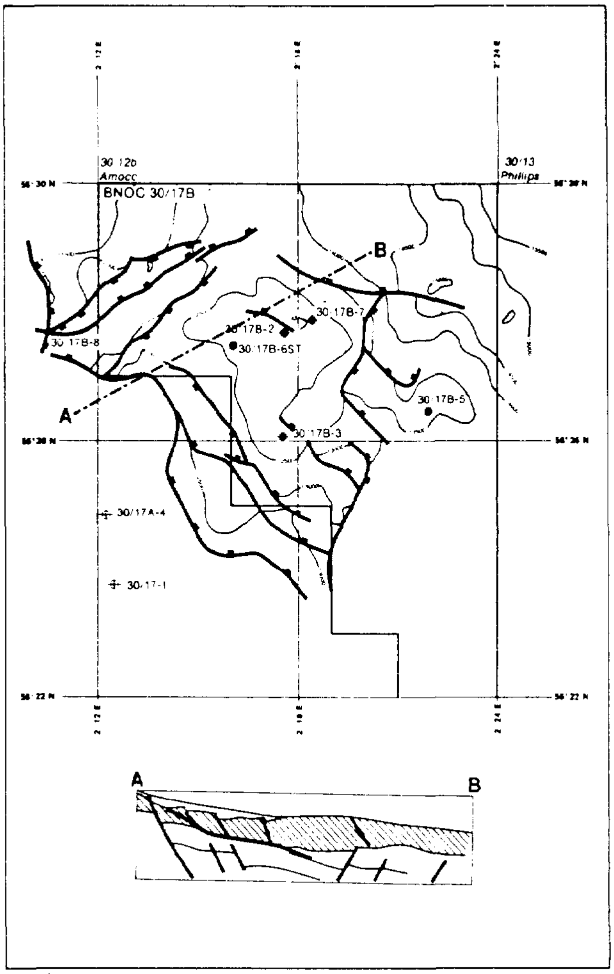
Palinspastic sections were constructed to honor the seismic and well data, and were tested iteratively using new techniques for balancing structural sections in extensional regimes. Cross-sectional area and bed length balance clearly demonstrate the presence of both shallow and deep fault detachments and eliminate models involving tectonic inversion or halokinesis. The deep basement faults form the main regional terrace system and sole-out in the crust at about 15 km (9 mi). A second shallower set of faults defines a listric slide and detachment at the top Permian. The listric shape of the detachment accounts for the lower boundary of the Triassic-Jurassic high. Seismic remapping has substantiated this model and demonstrates the decoupling of the basement and shallow listric fault sets. In plan, the shallower faults are arcuate with pull-apart lows on the downthrown side that show synsedimentary growth of the Upper Jurassic clays. Compaction buckling and uplift of the Jurassic section toward the toe of the slide form positive structural features that are oil-productive. The faults along the margins of the structures have a significant strike slip component where they parallel the structural dip.

The development of this growth fault model for the Clyde field has assisted in understanding the seismic mapping and in establishing a predictive model for the field geology. In particular, the recognition of Jurassic growth and strike slip components on the faults has significance in terms of variations in reservoir quality and possible reservoir discontinuities resulting from fault seals.



Of regional interest is the possibility of further growth fault plays within the North Sea basin. This contrasts with the classical development of growth faults on a continental margin. The distinctive geometry of large growth faults can generate structural highs that are offset from the basement and overlying base Cretaceous structure. This model, along with the lensoid cross section above a simpler basement and distinctive seismic expression of shallow dipping faults, is being used to identify other potential plays that may be analogous to the Clyde field.

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Close Encounters of Reefal Carbonates and Siliciclastics

Siliciclastic depositional environments are not normally favorable for the growth of reef-building organisms because of high turbidity, reduced salinity, or unfavorable substrate. Yet there are numerous examples, both living and fossil, of close associations, even intermixing, of the two kinds of deposits.

In the Red Sea (Gulf of Aqaba), Holocene coral reefs develop on the seaward margins of inactive alluvial fans of gravel. In the nearshore zones of Brazil (Abrolhos Bank), Mexico (Vera Cruz), and the northern Great Barrier Reef, there are reefs surrounded by siliciclastic sands and silty clays; locally some of this noncarbonate fraction occurs as internal sediment within the reefal frame. In the lagoonal areas of both the Belize (Central America) and Great Barrier Reef tracts, the positions and the geometries of some reefs were probably determined by the local relief (channel banks, bars, deltaic lobes) of the underlying siliciclastic foundations.

Throughout the Phanerozoic, there is a wide spectrum of interaction between reefal carbonates and siliciclastics. Reddish or greenish argillaceous internal sediments are common in some Triassic and Devonian reefs of western Europe. In the Phanerozoic of North America, there are numerous examples of reefs encased in shales or siltstones. In the Triassic of Europe and the Yukon (Canada), reefal carbonates are surrounded by and locally interfinger with volcaniclastics. In the Pennsylvanian, Permian, and Jurassic of North American and in the Permian of Japan, reefal carbonates are juxtaposed with deltaic and associated siliciclastics.

At least two factors relating to exploration emerge from this review of the connections between reefal carbonates and siliciclastics. One is the effect of local relief on the underlying siliciclastics in determining the locations and forms of reefs. The other concerns the combined source and seal provided by fine-grained, peri-reefal siliciclastics.

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Upper Eocene North American Microtektite Layer: Associated Radiolarian Extinctions, Climatic Change, and Iridium Anomaly

Tektites are glass objects believed by many authors to have been formed by meteorite (or cometary) impact. The areas on the earth's surface where tektites are found are called strewn fields. Thus, tektites found in Texas and Georgia belong to the North American strewn field. Microtektites (< 1-mm diameter tektites) have been found in upper Eocene sediments from one piston core and in cores from nine Deep Sea Drilling Project sites in the Caribbean Sea, Gulf of Mexico, equatorial Pacific, and eastern Indian Ocean. Based on their fission-track age (34.6 ± 4.2 m.y.), geologic age, geographic location, and chemistry, these microtektites are thought to be part of the North American strewn field. The North American tektites have fission-track, K-Ar, and ^{40}Ar-^{39}Ar ages of ~ 34 m.y. The North American microtektite layer occurs in the *Thyrsocyrtis bromia* radiolarian Zone, the P15 foraminiferal Zone, and the *Discoaster barbadiensis* calcareous nannoplankton Zone. At each site, the layer is associated with the last appearance of several species of Radiolaria (e.g., *Thyrsocyrtis bromia, t. tetracantha, t. rhizodon, Calocyclas turris*). Previously published oxygen isotope data indicate a drop in temperature at about this time, which may be related to the tektite event and may have been responsible for the radiolarian extinctions. An iridium anomaly has recently been found associated with the microtektite layer that supports an impact origin for the tektites. The extent of the strewn field and the calculated mass of microtektite material ($\sim 10^{12}$ kg) indicate that the North American tektite event was a relatively large event.

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Late Cretaceous Multicolored Shales and Phosphatic Sedimentary Rocks in Egypt

Upper Cretaceous transitional fluvial to marine variegated shale (upper Nubia Formation) and the fully marine Duwi (phosphate) Formation occur as thin, widespread, shallow-marine deposits in an east-west-trending belt spanning the lower-middle latitudes of Egypt. These deposits consist of a heterogeneous suite of hemipelagic and shallow-water carbonate rocks that lie near the base of a generally transgressive marine sequence that was deposited on the fringes of the Arabo-Nubian craton in Cenomanian-Maestrichtian time. On a larger scale, the phosphoritic rocks in Egypt represent but a small portion of a laterally extensive Middle Eastern-North African phosphogenic province of Upper Cretaceous–Lower Tertiary age that accounts for accumulation of minable marine phosphate in excess of 70 billion tons.

Phosphorites, porcelanites/cherts, organic carbon-rich shales, glauconitic sandstones, and bioclastic and fine-grained carbonate rocks variously reflect major hemipelagic and shallow-water carbonate sedimentation. Biosiliceous hemipelagic deposits, now diagenetically altered to porcelanite and chert, reflect low energy depositional conditions that were periodically interrupted by high energy, possibly storm-induced currents and/or downslope redeposition. Both dark shales and porcelanites locally contain abundant organic matter and are commonly finely laminated. These strata probably reflect conditions of high biologic productivity and periodic anoxia in the water column. Porcelanites and black shales are phosphatic, containing phosphatic grains identical, morphologically and chemically, to those found in associated phosphorites, and are probably the source from which the phosphorites were derived. Several lines of evidence suggest that the phosphorites of the Duwi Formation are clastic sedimentary deposits that have accumulated through mechanical winnowing, reworking, and concentration of preexisting phosphatic fine-grained sediment.

The organic carbon-rich shales of the Duwi Formation appear to be quite laterally extensive and may, depending on thermal maturity, represent potential hydrocarbon source rocks in other portions of the region (e.g., Western Desert, Gulf of Suez), where they are more deeply buried.

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Storm Deposits (Tempestites) in Ordovician Cratonic Carbonates (Arbuckle Group, South-Central Oklahoma)

The Early Ordovician Kindblade Formation (Arbuckle Group), exposed in the Arbuckle Mountains of south-central Oklahoma, is a shallow marine epicontinental carbonate sequence that contains numerous storm deposits. Similar deposits also occur in other Arbukle Group units, although not as abundantly as in the Kindblade Formation. The storm deposits (tempestites) are of two types, proximal and distal; the latter dominates in terms of both number and aggregate thickness. Distal tempestites consist of a fining upward sequence, 5 to 50 cm (2 to 20 in.) thick, that overlies an eroded hardground or firmground. The sequence consists of a lag lithoclastic grainstone that grades up into a laminated peloidal grainstone and then into mudstone. Firmgrounds are characterized by hummocky, sharp, and erosional contacts (relief 2 to 7 cm, 0.75 to 2.75 in.) with grainstone-filled erosive pockets. Hardgrounds are characterized by sharp hummocky-to-convolute surfaces (relief < 4 cm, 1.5 in.), which are mineralized and bored. Primary sedimentary features such as laminations, burrows, and allochems are truncated at the surfaces, and borings are filled with unsorted lithoclasts. The lithoclasts at the base of the sequence are bored, generally well rounded, discoid in shape, and consist of mudstone, peloidal packstone, and oolitic grainstone. Infiltration fabrics within the lithoclastic grainstone include cement-filled shelter voids beneath large clasts and internal sediment perched on the upper surfaces of lithoclasts. The overlying peloidal grainstones contain ripple cross-laminations, plane-laminations, and hummocky cross-stratification as well as rare escape burrows. The overlying mudstone is sparsely fossiliferous and bioturbated with burrows either selectively dolomitized or infilled with lithoclastic grainstone. Although there are many examples of the ideal sequence described above, complex composite or amalgamated beds are also common.

Proximal tempestites consist of coarse lithoclastic flat pebble conglomerate beds approximately 1 m (3.25 ft) thick that are interbedded with ooid grainstone and overlie mudstone. The contact between the units is sharp and erosional. The lithoclasts are of variable composition and may be up to 20 cm (7.75 in.) in diameter.

The two types of tempestites occur in crude cycles, which consist of distal deposits overlain by proximal tempestites and ooid grainstones. The cycles are interpreted as shallowing-upward progradational sequences. The abundance of the storm deposits in the section, approximately one every 20 cm (7.75 in.), indicates that hundreds of storm-induced events are recorded in the Kindblade Formation. The tempestites represent rare catastrophic events, while the hardgrounds-firmgrounds are discontinuity surfaces that represent gaps in the sequence.

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Skeletal Fine Structure of Polycystine Radiolaria

The skeletons of most living Polycycstina are covered with a veneer of very fine, particulate opal that imparts a smooth finish to specimens viewed by the scanning electron microscope. In contrast, the opaline skeletal surfaces of Polycystina preserved in Miocene and older sediments have slightly "etched" appearances, with small dissolution pits presumably representing the removal of the finer particulate opal and revealing a substratum of opaline microspherules approximately 1 to 3 μ in diameter. The cross-sectional surfaces of broken spine bars on the vast majority of specimens have a somewhat conchoidal fracture, but otherwise they are smooth and give no indication of internal