able to recognize and map much gentler dips in the eastern part of the structure. The result of this is to move the mapped subcrop of the reservoir sands much farther eastward, thus extending the eastern limit of the field considerably.

Based on this 3-D interpretation, three successful oil wells have been drilled. These are located in parts of the field that could not be accurately mapped on the basis of the 2-D seismic data, because of its poor quality. This has increased the estimate of the field's reserves such that Statoil were able to declare the field commercial in late 1980.

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Diatoms in Sediments as Shelf-Slope Indicators

Diatoms, a group of unicellular algae, are limited to the upper 50 to 100 m of the water column, owing to their light requirement. Benthic diatoms, consequently, are restricted to the continental shelf, and primarily the inner shelf, coasts, and estuaries. Planktonic diatoms occur on the shelf (neritic) and in deeper waters (pelagic); certain genera are restricted to one region while others occur in both. Salinity appears to exercise an important control on these distributions, so that a salinity front frequently produces a sharp boundary between populations. The shelf-slope break is usually associated with a sharp salinity gradient, where low-salinity shelf waters encounter a high-salinity oceanic current. The result is that benthic and low-salinity planktonic diatoms characterize shelf sediments, while higher-salinity planktonic diatoms and an absence of benthic diatoms characterize the slope and ocean basin sediments.

A transect across the southeastern Bering shelf and slope, with stations at 25-km intervals, shows a dramatic change in species composition of the sediment assemblages at the 200-m isobath. Shallower samples are dominated by benthic marine species and a group associated with the presence of winter sea ice, while below 200 m the assemblages are dominated by a species common in the North Pacific and the Bering basin. The ratio of this pelagic species to the benthic species shows a high correlation with depth ($r = .85$). Other work in the literature, while not directly addressed to this question, suggests that similar transitions can be found off Peru, west Africa, and in Miocene deposits of the U.S. East Coast.

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Stratigraphy and Intertonguing Between Coal-Bearing Upper Cretaceous Blackhawk Formation and Star Point Sandstone, Central and Southern Parts of Wasatch Plateau Coalfield, Central Utah

Intertonguing of the lowermost part of the coal-bearing Blackhawk Formation and the uppermost part of the marginal marine Star point Sandstone has caused a progressive steplike offset of the Blackhawk coal beds in the central and southern parts of the Wasatch Plateau. The tongues of the Star Point Sandstone are marginal shore deposits representing episodic transgressions of the Upper Cretaceous epeiric seaway. The development of these sandstone tongues affected the geometry, lateral continuity, and thickness of the associated Blackhawk coal beds.

Mapping and exploration of sandstone tongues in the lowermost part of the Blackhawk Formation will help identify the thicker coal beds. Knowledge of their distribution can assist the exploration geologist in mapping the coal-bed geometry. Economic coal beds associated with the marginal marine sandstone tongues trend parallel to the paleoshoreline and may be thicker landward of the sandstone tongues. These coal beds are the primary targets of current drilling programs directed toward exploration and development of Blackhawk coals in the study area.

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Pennsylvanian Aragonite from Southeastern Kansas—Environmental and Diagenetic Implications

Unaltered acicular aragonite cements have been found in Pennsylvanian limestones from southeastern Kansas as spherulitic arrays encased in pore-filling spar in intragranular voids. Identical cements are documented in Pleistocene carbonate rocks. Associated early cements in intergranular pores include aragonite botryoids now altered to irregular noemorphic calcite, and bladed calcites inferred to have been precipitated as magnesian calcite. In addition, phylloid algal blades of *Archaeolithophyllum,* now altered to irregular neomorphic calcite mosaics, contain varying concentrations of oriented inclusions of original aragonite. The unaltered aragonite cement was apparently protected from diagenetic alteration by the enclosing calcite spar and organic matter on the skeletal substrate. Individual aragonite relics in the algae probably survived because of enclosure in organic envelopes, a phenomenon observed in Pleistocene examples.

We see two explanations for the precipitation of these metastable carbonate cements in Pennsylvanian seas, both of which raise perplexing questions regarding ancient carbonate deposition. (1) Several authors have suggested a domination of calcite in Paleozoic non-skeletal carbonate deposition; our cements could represent some local departure from that general pattern, or (2) these carbonates document part of a long-term temporal trend in non-skeletal carbonate mineralogy from a domination of calcite in Paleozoic seas to aragonite and magnesian calcite domination in Quaternary seas. However, later calcite domination as evidencd by calcite cements and ooids in the Jurassic and Cretaceous, suggests that if the latter explanation is accepted the postulated trend was neither simple nor unidirectional.

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Stratigraphic Traps in Paleocene Sands in Balder Area, North Sea

The Balder oil field in blocks 25/10 and 11 in the Norwegian sector of the North Sea contains 25° API oil in a Paleocene deep-water sandstone reservoir. The sands were deposited from high concentration, high-energy turbidity currents as a complex of channelized sand lobes which formed a small fan. Depositional topography and subsequent submarine erosion created a geometric closure on the upper surface of the fan. Oil is stratigraphically trapped by this closure. Recognition and definition of this mounded surface on seismic records and the development of a sedimentary model has made it possible to drill successful appraisal wells after disappointing initial drilling results.

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Geophysical Characterization of Lithology—Application to Subtle Traps

Traps for oil or gas consist of a geologic material whose physical properties may differ from those above and around it. In its first half century, geophysical exploration by the reflection seismic technique was used to delineate the boundaries between subsurface materials of different properties. The technique could not discriminate between the properties on either side of those boundaries. If geologic information from nearby wells or from outcrop was absent, the wildcatter drilled blindly through trap boundaries in the hope of finding the right kind of material.

Technology has advanced sufficiently that it is now possible to determine from seismic data at least one physical property of subsurface materials. That property is seismic velocity. Because seismic velocity generally decreases with increased porosity and because gas under pressure further decreases that velocity, it is now possible to define some non-structural traps and to identify some hydrocarbon accumulations.

Seismic velocity measurements displayed on computer-plotted cross sections in color, graphically identify a variety of subtle traps in many parts of the world. When applied to 3-D survey data the velocity methods can yield enough information to define all the boundaries of a hydrocarbon accumulation. The characteristic seismic velocites in a 3-dimensional subsurface block can most graphically be displayed as a motion picture depicting passage through the earth in selected directions.

New seismic techniques under investigation should make possible the simultaneous determination of additional physical properties so that even more subtle traps can be found.

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Porosity and Textural Characteristics of Eolian Stratification

An analysis of experimentally formed eolian stratification has shown that processes of deposition are the major factors controlling the primary porosity and texture in the avalanche, grainfall, and ripple-produced types. Avalanche stratification generally exhibits the highest primary porosity (avg 47%) because of loose packing and grain arrangements that occur as a mass of sand shears downslope. Wind ripple-produced stratification has the lowest primary porosity (avg 39%) due to the relatively close packing and the presence of finer grained sublayers developed near the base of each inversely graded ripple stratum during ripple migration. Primary porosity of grainfall stratification (avg 43%) is usually intermediate between that of avalanche and ripple-produced deposits because the packing is between the avalanche and ripple produced types.

Avalanching forms the high-angle, porous, lee-slope stratification commonly observed in eolian deposits. Ripple-produced stratification is formed in two principal localities—on the low-angle windward slope where potential for preservation is poor, and on the lower part of the lee slope where preservation potential is excellent. The ripple deposits, produced by winds moving across the lee slope, form the tangential foreset-to-bottomset stratification common to eolian dunes. The relatively low porosity observed in these deposits is due to the stratification being composed of ripple-produced deposits. Grainfall stratification has a poor preservation potential because of redeposition by avalanching on the upper part of the lee slope. Grainfall on the lower lee slope usually occurs on a rippled surface, and these grains are incorporated into the ripple-produced stratification being formed at that site.

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Bahama Platform Slopes: Carbonate Diagenesis Within and Below Thermocline

Sediments on Bahamian slopes, reef rubble, gully sands, and periplatform carbonate ooze, consist of calcite, magnesian calcite, and aragonite. When not continuously buried by new material, these sediments harden to limestone crusts, 10 cm to several meters thick, on the sea floor. The pathways of sea floor diagenesis vary with depth. (1) Reef wall and talus slope (50 to 400 m) are pervasively cemented by micritic magnesian calcite; botryoidal aragonite fills the large voids. There is no evidence of selective dissolution; primary and diagenetic minerals coexist. (2) On the gullied slopes between 500 and 1,300 m most sediment lithifies to calcite limestone or chalk, with 3 to 7 mol % $MgCO_3$; however, about 20% of the samples are micritic magnesian calcite limestones of 8 to 14% $MgCO_3$. (3) On the gullied slopes from 1,300 to at least 2,500 m, calcite limestones with 2 to 4 mol % $MgCO_3$ prevail.

The downslope trend from aragonite and magnesian calcite to calcite is explained by the decrease in water temperature and carbonate saturation. The magnesian-calcite limestones between 500 and 1,300 m do not follow this trend even though their oxygen isotopes indicate formation in cold bottom water. Micritic ooids of magnesian calcite with globigerinids as nuclei and coccoliths in the cortex are associated with the limestone crusts and obviously form in this current-swept deep-water environment. This suggests that magnesian calcite precipitates from a pore fluid close to, and derived from, sea water. The microenvironment may be controlled by micro-organisms or by inorganic precipitation of calcium carbonate that increases the Mg:Ca ratio in the pore fluid, thus raising the magnesian content of the precipitating calcite.

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Estimate of Displacement in Major Zone of Tear-Thrusting in Fold and Thrust Belt, Southwest Montana

The most pronounced deflection of the marginal fold and thrust belt in Montana occurs in the northern Tobacco Root