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Former Evaporites Within English Zechstein First Cycle Carbonates

The Upper Permian Cadeby Formation was deposited on the western margin of the Zechstein evaporite basin. The formation comprises two carbonate members which were nearly entirely dolomitized during early diagenesis. Recent meteoric dissolution in the shallow subsurface precludes the presence of evaporites within the carbonates at outcrop, but both direct and indirect evidence indicates the existence of former displacive and replacive evaporites.

Direct evidence of former evaporites is present in the form of both pseudomorphs and casts. In the lower member, textural preservation of internal fabrics within some anhydrite nodules was produced by calcitization of both anhydrite cleavage flakes and possible small chevron halite crystals. Where no replacement preceded dissolution, cauliflower-shaped molds 2 to 3 cm (.78 to 1.18 in.) in diameter evidence the former presence of anhydrite nodules in lower member lagoon wackestones and mudstones. Anhydrite nodule development distorted bedding laminae, indicating displacive growth within soft sediments. Halite hopper casts surround some former nodules. Lack of evidence of subaerial exposure or intertidal sedimentation suggests both sediment deposition and anhydrite nodule growth were subaqueous; evaporites forming when lagoon waters became restricted and progressively hypersaline.

Further direct evidence of interbedded evaporites is shown by fabrics of vertically oriented calcite crystals with scattered pseudomorphs of gypsum crystal margins. Ghosts of foraminifera, only visible under cathodoluminescence, and numerous dolomite inclusions are present within the calcite. The vertical orientation suggests relict gypsum precipitates on the sediment surface. These calcitized gypsum horizons are underlain by skeletal lime wackestones and packstones and overlain by irregular dolomite mudstones with casts of displacive gypsum rosettes, indicating subaqueous evaporite growth within sediment during periodic hypersaline conditions.

In the upper member, indirect evidence of former bedded evaporites overlying the Cadeby Formation is provided by an irregular bed of dedolomite (calcitized dolomite). The dedolomite transects facies boundaries, being found in supratidal carbonates with incipient tepee structures, intertidal and subtidal cryptalgal laminate boundstones, and ooid grainstone shoals. Dedolomite thickness varies from 0.5 to 2.5 m (1.5 to 8 ft) within individual outcrops. Dedolomitization was due to the action of fluids with high Ca^{2+}/Mg^{2+} ratios, created by dissolution of the overlying Hayton Evaporite Formation, with dedolomite thickness dependent on local differences in the permeability of the preexisting dolomites. Petrographically, these dedolomites contrast with ferroan dedolomites elsewhere in the Cadeby Formation and not spatially associated with evaporites.

The presence of former replacive evaporites is shown by irregular vugs which crosscut sedimentary laminations. Such vugs are more numerous in the upper member. Petrography indicates this replacement occurred before final compaction of the carbonates and was possibly related to diagenetic changes within the overlying anhydrite formation.

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Stratigraphy, Depositional History, and Reservoir Potential of Cretaceous and Early Tertiary Rocks of Lower Cook Inlet, Alaska

Depositional relations within strata of Cretaceous age in the lower Cook Inlet area have been clarified by recent drilling and high quality seismic data. Lower Cretaceous (Neocomian) strata are preserved along the Cook Inlet basin axis and are correlated with the Herendeen Formation of Port Moeller and the Nelchina beds in the Matanuska Valley. The Kaguyak Formation of Cape Douglas is expanded to include strata which range in age from Albian through Maestrichtian. Three members are proposed, which are (in ascending order) the Unnamed Albian-Cenomanian, the Middle Member, and the Saddle Mountain Member. Depositional relations within the Kaguyak Formation were strongly controlled by tectonic events and resultant basin configuration.

The Unnamed Albian-Cenomanian Member (up to 1,400 ft [425 m] thick) is composed of carbonaceous sandstone and shale. It is correlated with similar-age deposits in the Matanuska Valley and the Mt. Katmai area, and represents shallow to marginal marine deposition. The Middle Member is up to 4,400 ft (1,350 m) thick and consists of a southeastward-thickening wedge which is predominantly marine siltstone and claystone. Sandstone is significant only at Kaguyak Bay where proprietary studies indicate submarine fan deposition, and in the Socal Anchor Point well where a similar environment is likely. Middle Member strata lap-up on and over-top a topographic shelf, which began to develop at about Turonian time and was a prominent feature in the area east of the Iniskin Peninsula by Campanian time.

Significant shallowing at the beginning of Maestrichtian time was accompanied by an outpouring of coarse clastics of the Saddle Mountain Member. Up to 2,000 ft (600 m) of mostly nonmarine sandstone, siltstone, and conglomerate extends seaward (southeastward) to the shelf edge. We suggest that this shelf edge was the paleolimit of Saddle Mountain Member deposition and that marine reworking and washing fluvially supplied sand along this shelf edge provided the only Cretaceous sandstone with reservoir potential in this area.

Overlying and possibly continuous with the Saddle Mountain Member is a Paleocene sequence of sandstone and conglomerate, about 600 ft (185 m) thick in the COST well. This interval is seismically and lithologically distinct from the underlying Cretaceous and overlying West Foreland Formation rocks and is named the Silver Salmon Formation. This formation showed the best reservoir properties of the Tertiary rocks in lower Cook Inlet.

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Plate Tectonics Control of Global Patterns of Detrital and Carbonate Sedimentation

Global patterns of continental drainage to the oceans have changed markedly over the last 200 m.y. in response to plate tectonic processes; most of the earth's major rivers now enter the sea on passive continental margins which did not exist in the early Mesozoic. This reorganization of drainage has strongly influenced the distributions of marine detrital and carbonate facies.

Analysis of changes in continental topography related to the breakup of Pangaea suggest that throughout much of the Mesozoic, drainage systems were dominated by a pole-to-pole divide directing detrital sediment away from the sites of future continental rifting. This phase was followed by rifting and formation of narrow oceans with uplifted margins. As the margins subsided by thermal relaxation, massive amounts of detrital sediment were delivered from the continental interiors onto the young passive margins. In time, river drainage became increasingly focused, concentrating detrital sediment supply at the mouths of a few large rivers. Very large supplies of detrital sediment require large, high uplifts such as those caused by subduction of young, hot ocean crust or by continental collision.

Large sediment supplies also require drainage basins with relatively constant slope; so that sediment erosion, throughput, and delivery to the ocean margin are efficient. The result is rapid sedimentation of deltaic complexes containing an abundance of organic carbon. During most of earth history, there are no large, high uplifts, and carbonate rocks become more important in the continental margins.

In contrast to the point inputs of detrital sediments, the supply of carbonate has been from the oceanic reservoir and is diffuse. Carbonate deposition dominates the continental shelves in all warm regions where the detrital sediment input is not extremely large. Carbonate shelves become cemented, resisting erosion, so they build up until the shelf edge approximates highstands of sea level. Detrital shelves become adjusted to lowstands of sea level with the shelf breaks typically many tens of meters below the low sea level.

The clastic-carbonate shelf-slope-rise system operates to promote bypassing of detrital materials into deep water in the subtropics and tropics, with sharp facies contrasts. In higher latitudes, carbonate may be a significant proportion of the continental margin material, but facies changes are usually much more gradual.

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Application of Database Management to Biostratigraphy

The nature of biostratigraphic data presents major problems that are not considered by most computerized database-management systems. These problems include the variety of ways that paleontologists record data, the reluctance of many paleontologists to use the computer, the need to change the database to reflect the current state of biostratigraphy, and the need to separate the paleontologic information from interpretive and nonpaleontologic information. With regard to the first problem, the level of paleontologic measurement (e.g., presence-absence, qualitative assessments of abundance, or counts) should be retained for each sample; yet the system should be designed so that data with varying levels of measurement can be reduced to their lowest form allowing comparisons among samples with different levels of measurement. For example, in a series of wells to be correlated, a combination of presence-absence information, qualitative assessments, and counts of fossils may be present. In this example, one wants the opportunity to automatically reduce all data to presence-absence form and correlate the wells.

The second problem presented to the management of biostratigraphic data is the reluctance of paleontologists to utilize the computer. To minimize this problem, the database-management software must be designed to run as efficiently and simply as possible so each user feels that the system was designed specifically for him. In addition, the design of the system should be flexible enough so that the user can request minor modifications in the system to meet his own needs.

With regard to the final problem, paleontologic data must be separated from both interpretative (e.g., zonal and age assignments) and nonpaleontologic (e.g., formational assignments) information. It is highly desirable to assign quality factors to the data, so that high-quality data is distinguishable from data produced in a quick-and-dirty fashion.

Many of these problems have been resolved using an efficient, relational database-management system designed for a variety of paleontologic and related data linked with a series of biostratigraphic applications programs. The internal structure of the database as well as the applications programs are hidden from the user, who only sees a series of panels that allow easy, efficient execution of the entire package. This package expedites report writing, analysis of data from a single well, regional synthesis of data from many wells and outcrops, and integration of biostratigraphic data with other types of geologic information.

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Ocean Margin Drilling Project Data Synthesis off Eastern North America: 28 to 36 Degrees North Latitude

An atlas of geological and geophysical maps has been compiled for the east coast of the North American continent covering an area from well onshore to the ocean crust, and from 28 to 36° N as part of the Ocean Margin Drilling Project.

Included in the atlas are maps of the depth to continental and oceanic basement, depth to the top of Lower and Middle Jurassic (reflectors J_M/J_2 and J_S/J_2), to the top of Jurassic (reflectors J/J_1), to the top of Neocomian (reflector Beta), to the top of Cretaceous (reflector A*), to the top of Paleogene (reflector A_u), and to the top of lower Miocene (reflector X). Isopach maps between these reflectors and between them and the seafloor are also included. Contours are two-way travel time with a contour interval of 0.25 to 1 sec.

The atlas also contains a tectonic map of basement, a pre-Quaternary geologic map, and lithofacies maps for six time slices.

There are geophysical maps of magnetic and gravity anomalies and compressional wave velocities in sediments and basement.

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Evolution of Sedimentary Basins

Simple extensional models that involve stretching by listric faulting in the brittle upper crust and plastic flow in the lower lithosphere have been shown to account for the subsidence history of various sedimentary basins, continental shelves, and the Central graben in the North Sea. The case where extension thins the crust by a different amount from the subcrustal lithosphere has been considered by several authors, but their treatment of two-layer extension is overly complicated and partly incomplete. In this paper, we present a simplified analysis of the two-layer extensional model for the elementary case in which extension is instantaneous, the crust is thinned by a different amount from the subcrustal lithosphere, the effects of radioactivity and dike intrusion are ignored, and local isostatic compensation is assumed at all times. We show how the thinning parameters can be obtained from the subsidence data through the use of a simple and powerful method of data analysis. We show that conservation of mass during a process of non-uniform extension implies that much greater thicknesses of sediment can be deposited in a young basin than in the case of uniform extension of both crust and subcrustal lithosphere. Further, we show that such an extensional process produces significant uplift of the flanks of a graben and that, as a result of erosion of the uplifted areas, the effective area of the basin can be increased as much as 25 to 30%, depending on the rate of erosion, compared to the area that