stance is another matter. A challenge is presented when both geology and seismic expression entail subtlety. These problems are encountered frequently and often are treated with great success. Detection of fracture porosity in carbonate rocks is an example.

Bounds and nature of seismic visibility and detectability are developed for families of lithologies of exploration interest. Geometric considerations are examined in the context of subsurface definition. Tools and techniques currently available for treating seismic data for the subtle trap are described, and uses for these tools and methods are given. In reconciling geologic and geophysical views toward the subtle trap, a more complete definition of the concept and a still larger family of exploration targets are provided.

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Carbonate Submarine Fan Facies Along a Paleozoic Prograding Continental Margin, Western United States

Mass-transport deposits, though common in carbonate basins, normally occur as widespread sheets or debris wedges, as in the Devonian of Canada and elsewhere, or in modern interplatform troughs of the Bahamas.

Reexamination of a seaward-prograding Cambrian and Ordovician continental margin section in central Nevada reveals a 150-m thick interval whose facies resemble current models of submarine-fan deposition. The upper 100 m of sediment is assigned to an inner-fan setting and is characterized by submarine slides and several entrenched channels 10 m deep and 500 m wide. The channels are filled with disorganized boulder-bearing conglomerates but are not arranged in any well-defined thinning- and fining-upward sequences. Stratigraphically below this interval are thinning- and fining-upward organized, pebble to cobble-bearing channelized conglomerates, 30 to 50 m thick. These channels are 1 to 5 m deep, 20 to 100 m wide, and rapidly coalesce laterally and vertically. The conglomerates grade laterally into and are interbedded with thin and discontinuously bedded ripple-laminated and graded calcarenites, similar to detrital overbank-levee and interchannel deposits. These sedimentary units probably represent a system of braided channels in a mid-fan position. Below the braided channels are 10 to 20 m of thickening- and coarsening-upward cycles of virtually nonchanneled beds; beds in the cycles are composed of calcarenites exhibiting Bouma divisions. These carbonate sand sequences are interpreted to represent prograding outer-fan lobes.

The recognition of carbonate submarine-fan sequences raises several questions. (1) What sedimentologic and tectonic conditions are conducive to fan development in carbonate provinces? (2) Do these conditions resemble those for clastic-fan development, or do carbonate provinces have unique requirements? By recognizing carbonate submarine fans and the geologic conditions that control their sediment dispersal patterns, areas of maximum sediment accumulation may be predicted as an aid in exploring for petroleum reservoirs of deeper water carbonate environments.

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Distribution of Recent Deep-Sea Benthonic Foraminifera from Southwest Indian Ocean

Deep-sea benthonic foraminifera from the Crozet, Madagascar, and Mascarene Basins of the southwest Indian Ocean were studied (9-45°S, 45-80°E) to determine faunal-water mass relations. Principal component analysis of the faunal data reveals distinct trends related to depth and bottom-water potential temperature. Principal component 1 represents an average of all the faunal data. Negative values of principal component 2 reflect the importance of *Epistominella umbonifera* and are found generally south of 35°S latitude in the Crozet Basin and on the flanks of the Madagascar, Southwest Indian, and Southeast Indian Ridges. These negative values are associated with bottom-water potential temperatures ranging from -0.1 to 1.2°C with the high relative values (≤ -0.4) associated with potential temperatures $\leq$0.8°C. Positive values of principal component 2 reflect the importance of *Planulina wuellerstorfi*, rare species ($\leq$ 3%), *Globocassidulina subglobosa,* and *Astrononion echolsi,* and are found on the Central Indian and Madagascar Ridges where bottom-water potential temperatures are 0.4 to 1.2°C. High relative values of principal component 2 ($\geq$ 0.4) are found with potential temperatures of 1.2°C. High negative values of principal component 3 reflect the importance of *G. subglobosa* and high positive values reflect the importance of *Epistominella exigua, P. wuellerstorfi,* and *Pullenia bulloides.*

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Uranium Mineralization in Eocene Point-Bar Deposit, South Texas

An Eocene point-bar deposit was exposed by open-pit mining near Conoco's uranium mill in Karnes County, Texas. Two oxidation cells within the 1-mi-wide point bar are closely associated with the sedimentary facies. One oxidation cell with a subtle color difference was wedge shaped, confined by the steeply dipping accretion sets of the point bar. Color differences between oxidized and unoxidized sediments are very subtle. The front of oxidation was in basal point-bar sediments immediately below a sandy channel fill sequence. This sequence contains the second or upper oxidation cell, which is tube shaped and is only 50 ft (15 m) wide and about 20 ft (6 m) thick. Abundant clay galls within the sandy channel fill prevented the encroachment of oxidation along lateral boundaries of this oxidation cell and, therefore, controlled the distribution of local crenulations in the front. Trough cross-bedding and ripples indicate a south to southwesterly paleocurrent direction within the point bar. The orientation of the upper oxidation cell suggests that oxidizing fluids flowed in an easterly direction. Therefore, mineralization developed substantially later than sediment deposition, after uplift and a change in ground-water flow direction.

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Contrasting Facies in Upper Mesozoic Strata of Pacific Northwest

Upper Jurassic to Lower Cretaceous sedimentary rocks in the San Juan Islands, Washington, can be grouped into two facies that are represented elsewhere along the Pacific margin from southeastern Alaska to California. The eastern facies comprises well-stratified volcaniclastic turbidites depositionally overlying mafic to felsic volcanic rocks resting on a mafic-ultramafic igneous basement. Sedimentary breccias derived from the basement and pelagic radiolarian argillites are locally interbedded with basal sandstones. This facies was deposited in part on the remnants of a Middle to Late Jurassic volcanic arc. It is laterally equivalent to the Nooksack Group and underlying Wells Creek volcanic rocks, and correlative with strata in the Methow trough. Overall, the stratigraphic sequence and basement rocks are remarkably similar to the basal Great Valley sequence and underlying rocks in the California Coast Ranges. The western facies consists of thinly bedded to massive volcaniclastic sandstones complexly interbedded with ocean-floor (MORB) basalts, basaltic tuffs, ribbon chert, and polymict pebbly mudstone. Clastic rocks contain rare fragments of amphibolite, blueschist, and upper Paleozoic limestone in addition to voluminous volcaniclastic debris. This clastic eugeosynclinal association is a deposition unit rather than a melange formed by offscraping or accretion. In contrast to the eastern facies, basaltic rocks and pelagic cherts are distributed throughout the section and are interspersed with terrigenous clastic rocks. Coeval, lithologically comparable sequences are the Kelp Bay group (southeastern Alaska), the Pacific Rim complex (western Vancouver Island), and probably the Yolla Bolly terrane in the easternmost Franciscan. The western and eastern facies in northwestern Washington are presently separated by middle Cretaceous thrust faults.

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Tertiary Deformation in Western Spitsbergen

During Cretaceous time, before the opening of the northernmost Atlantic Ocean, western Spitsbergen lay oppostie northeastern Greenland. With the opening of the Norwegian Greenland Sea during early Tertiary time, Spitsbergen slid past northeastern Greenland along a transform fault zone. This strike-slip displacement was accompanied by a strong transpression of the adjacent rocks, causing uplift of crustal blocks in a narrow belt along the western coast of Spitsbergen. Eastward from this coast, three structural zones can be recognized; (1) a 30-km-wide coastal zone of Hecla Hoek strata (upper Precambrian-lower Paleozoic) which was strongly deformed during the Caledonian orogeny and uplifted during early Tertiary time; (2) a 10-km-wide disturbed zone of Devonian-Cretaceous strata with some sills; tilted, folded, and faulted during early Tertiary time; and (3) an interior zone of flat-lying Tertiary sedimentary beds. Most Hecla Hoek structures are probably pre-Devonian, but a prominent westward-dipping foliation may be Tertiary in age. The beds of the disturbed zone display an impressive variety of folds and faults related to uplift, tilting, and slippage between beds; one cliff shows a sequence with large recumbent folds resting in fault contact upon an unfolded sequence. Other structures, however, are related to eastward thrusting of the massive Hecla Hoek rocks onto the younger beds. A graben in the coastal zone, with nearly horizontal Tertiary beds, probably reflects a new tectonic regime (transtension) that formed after Spitsbergen had moved clear of Greenland.

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Allochthonous Carbonate Rocks in Toe-of-Slope Deposits (Permian, Guadalupian), Guadalupe Mountains, West Texas

Channelized allochthonous carbonate toe-of-slope deposits, equivalent to the Goat Seep Dolomite, and possibly the Getaway Bank, are well exposed along the west face of the Guadalupe Mountains. There are five rock types present: (1) fine rudite conglomerate, (2) carbonate megabreccia, (3) oolitic packstone/grainstone, (4) wavy-laminate wackestone, and (5) thin-bedded sandstone/siltstone. The rudites ($\sim < 1.0$ m thick) appear to have been deposited by laminar debris flows, as evidenced by clasts aligned parallel to bedding, a non-erosive base, and the presence of a rigid plug. In contrast, the megabreccias (> 2 m thick) may have been deposited by turbulent debris flows, based on their erosional bases and lack of aligned clasts. The other rock types are interpreted to have been deposited by fluid density flows and turbidity flows.

The carbonate rocks in the toe-of-slope strata occur in lens-shaped deposits (0.5 km wide $\times$ 30 to 50 m deep) that are surrounded by sandstone and siltstone. The lenses are interpreted as basinward-trending channels that have been filled with shelf- and shelf-edge derived sediments deposited at the base of a carbonate buildup. The channels are typically filled with megabreccia at the base, consisting largely of shelf-edge debris, which is overlain by finer rudites and/or oolitic packstone/grainstone, consisting largely of shelf-derived debris. It is interpreted that the megabreccias were derived from large slumps or slides near the shelf-edge and that the shelf-derived sediments were later carried across the shelf-edge and were deposited in the toe-of-slope as separate, finer units.

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Climatic and Structural Controls of Stacked Algal Lime Mud Mound Development in Oquirrh Group (Pennsylvanian and Permian), Deep Creek Mountains, Southeastern Idaho

Oquirrh Group rocks comprise the uppermost of a series of allochthons exposed in southern Idaho. The basal unit of the Oquirrh Group, the West Canyon Limestone (Atokan), is composed largely of lime mudstone and fossiliferous lime wackestone with the exception of a coarse quartzarenite and lime mudstone clast debris flow that originated from syndepositional faulting. Overlying this unit are unnamed cyclic back-mound siltstones, sandstones, cherts, and fossiliferous wackestones and packstones that thicken southward from 270 to an estimated 1,000 m of noncyclic strata of similar lithologies. Cyclic, thinly stacked algal lime mud mounds are inferred to have developed in Desmoinesian time. In Virgilian time, syndepositional faulting controlled the development of thickly stacked (700 m) algal, lime-mud mounds. To the north and west, cyclic back-mound lithofacies consist of siltstone, sandstone, chert, lime mudstone, and fossiliferous wackestone and packstone. Similar but noncyclic fore-mound lithofacies are greatly thickened southward suggesting that syndepositional faulting controlled sedimentation.

In Wolfcampian time, cyclic, stacked bryozoan algal lime mud mounds (300 m thick) developed. Thin tabular lime mud mounds developed in cyclic back-mound lithofacies. Similar fore-mound lithofacies thickened in a southerly direction. As many as 50 cycles developed in Middle Pennsylvanian to Lower Permian rocks. Eustatic sea level changes caused by late Paleozoic glaciation controlled cyclic sedimentation.

Syndepositional faulting in Atokan, Desmoinesian, and Virgilian times also had the effect of keeping the northern and eastern parts of the study area in the marine photic zone. This area may have constituted a paleohorst within the Oquirrh basin in Pennsylvanian and Permian times.

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Source Rock Potential of Basinal Carbonate Muds, Bahamas