account for the sudden appearance of pelagic facies which follow platform disintegration.

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CRETACEOUS SEDIMENT DISPERSAL PATTERNS IN THE METHOW-PASAYTEN GRABEN, NORTH CASCADES, WASHINGTON

Analysis of paleocurrent trends, thickness variations, and lithologic intervals recorded to Cretaceous clastic sediments of the Methow-Pasayten graben indicates a dominantly eastern source through most of the Cretaceous, but with a Late Cretaceous interval of westerly derived sediments.

Neocomian black shales, volcanic sandstones, and conglomerates of Barksdale's Buck Mountain Formation and the Upper Jurassic Dewdney Creek Group of Coates were derived from the east. These sediments are overlain unconformably by arkosic Aptian sediments of Barksdale's Goat Creek, Panther Creek, and Harts Pass Formations, and Coates' Hauterivian to lower Albian Jackass Mountain Group, all apparently derived from the crystalline rocks of the Okanogan Highlands on the east. These Late Jurassic, Neocomian, and Aptian sequences of volcanic rocks, volcanic sediments, and arkosic sediments record the destruction of the volcanic cover and erosion into the Okanogan Highlands crystalline rocks. In sharp contrast, the unconformably overlying chert-grain sandstones and chert-pebble conglomerates of Barksdale's Upper Cretaceous Virginian Ridge Formation contain paleocurrent structures and variations in clast size and formation thickness which indicate derivation from a western source. The most probable source terrain is the Paleozoic Hozomeen Group of the Cascade core.

Unconformities and chert sandstones and conglomerates correlate with the mid-Cretaceous deformational episode of Misch in the North Cascades. These sediments could reflect tectonic uplift during thrusting or rapid isostatic rebound following mid-Cretaceous deformation and metamorphism.

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DIRECT DETECTION OF HYDROCARBONS

Because of the gas shortage in the United States, it is necessary to increase the nation's gas reserves. It is possible to utilize a very highly refined seismic technique for the direct detection of gaseous hydrocarbons in aquifers. This refinement is based on the increase in reflection coefficient caused by the addition or the replacement of the liquid in the pore space of an aquifer by the gas and an accompanying decrease in both the velocity and density of the aquifer. Refined data-acquisition techniques, including binary-gain amplifiers, accurately record the size of the reflections. Improved data-processing techniques with floating point processing, which preserves the amplitude of the reflections, make it possible to display a seismic section that the interpreter can use to find subsurface locations where the reflection coefficient is increased in amplitude ("hot spots"). Because this technique depends on the uniformity of source and surface conditions, it is particularly suitable for offshore areas and should come into extensive use in future offshore-gas exploration in the United States. This technique probably was responsible in part for the very high prices paid for some of the blocks in the recent offshore Louisiana sale.

Like almost all seismic techniques, it is not unambiguous and there are phenomena which can be confused with the increase in amplitude due to the presence of gas. This increase in amplitude can be caused by focusing, lithologic changes, phases of reflections caused by multiples, and nonuniformity of source and surface. It is important that the acquisition and processing be done carefully so that the interpreter is presented with a high-quality section for interpretation. This interpretation requires a more careful treatment than in the past.

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TAR SANDS DEVELOPMENT

Tar sands (also known as oil sands and bituminous sands) are sand deposits which are impregnated with dense viscous petroleum. Ultimate world reserves of bitumen in tar sands are about equal to ultimate reserves of crude oil in the United States. However, the only tar-sand deposit of present commercial importance is in the Athabasca area of Alberta, Canada. The pioneer venture to produce synthetic crude oil from tar sands began in 1967, operated by Great Canadian Oil Sands Limited (GCOS).

Tar sand is mined and transported to a processing plant where the bitumen is extracted, after which the sand is discharged into a tailings pond. At 10 weight percent bitumen saturation, two tons of processed tar sand produces 1 bbl of bitumen. Because tar sand is a relatively low-value ore, mining and transportation costs must be minimized. A key economic factor to be considered is the removal of overburden. The overburden ratio at GCOS (that is, the thickness of overburden which must be removed to expose a unit thickness of tar sands) is approximately 0.4.

The fact that large tar sands reserves are readily available in a friendly, stable country, and further that the material shipped is almost pollution free, should lend impetus to development.

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ORIGIN OF LATE CENOZOIC BASINS IN SOUTHERN CALIFORNIA

Several sedimentary basins in southern California, within and south of the Transverse Ranges, display a history suggestive of a rhombochasmic origin. Beginning in the early Miocene, segments of the continental margin at the soft and splintered border between the Pacific and Americas plates were apparently fragmented so that basins originated as irregular pull-aparts. Basin walls were formed by both transform faults and by crustal stretching and dip-slip faulting. Deep basin floors grew as a complex of volcanic rocks and sediments. As basins enlarged, high-standing blocks are pictured as separating laterally from terranes that were originally adjacent. Older rocks exposed around margins therefore cannot be extrapolated to depth within the basins.

Support for such a speculative model comes from accumulating understanding of the Salton trough. This narrow graben is being pulled apart obliquely, with faults of the San Andreas system serving as transforms. With widening, the walls sag and stretch, and margins are inundated by sedimentation that occurs simultaneously with deformation and volcanism in the basin floor. The Los Angeles basin apparently started to form as a rhombic hole in the middle Miocene, with basin-floor volcanism accompanied and followed by voluminous sedimentation. The Miocene "Topanga basin" in the western Santa Monica Mountains contains vast thicknesses of volcanic and sedimentary rocks that were laid down adjacent to high ground, from which sediments and huge detachment slabs were carried into a spreading hole. Other basins that perhaps reveal stages in the history of crustal stretching, culminating in pull-aparts and rhombochasms, are parts of Ventura basin, Ridge basin, and several offshore depressions, including the Santa Barbara Channel.

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MARINE MINERAL RESOURCE ECONOMICS

Analysis of future demand projections to the year 2,000 for 88 mineral commodities indicates that estimated land resources in the U.S. will not meet the demand for 31 of these, and world resources are inadequate for 20 of them.

Apparent mineral resources in the marine environment are in most cases equal to, or greater than, those of terrestrial occur-

rence. Marine minerals will in many instances provide a suitable alternative to terrestrial minerals, and their use will allow more time for technological development of a permanent, nondepletionary resource base.

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BIOGEOGRAPHIC SIGNIFICANCE OF EARLY CRETACEOUS FORAMINIFERA FROM BUDDEN CANYON FORMATION, NORTHWESTERN SACRAMENTO VALLEY, CALIFORNIA

A foraminiferal fauna of 189 species and varieties has been recovered from strata of Barremian-early Cenomanian age in the Chickabally Member of the Budden Canyon Formation. Calcareous perforate species, typified by the lagenids and rotaliids and, to a smaller degree, by the rotaliporids and buliminids, and among the arenaceous groups by the lituolids and valvulinids, constitute the major elements of the fauna.

The Foraminifera show close affinities with contemporaneous, medium-depth faunas widely distributed in the lower and middle latitudes of the northern hemisphere. Many lagenid and rotaliid species in particular appear to be conspecific with forms described from Europe and Trinidad. Common genera recorded for the first time from the Pacific Coast include *Falsoguttulina, Pseudosigmoilina, Reinholdella,* and *Spiroplectinata.* However, a persistent endemic element also can be recognized in the Chickabally assemblages, especially in arenaceous forms, the buliminids and the rotaliids. Resemblance of this microfauna to the marginal and neritic assemblages of the Gulf Coast and Alaska is less marked, and very little relation to the specialized brackish-water and quiet shallow-marine assemblages of the western interior is apparent. Regional correlations demonstrate that, during the late Early Cretaceous, benthonic Foraminifera favoring an offshore, medium-depth, muddy-bottom milieu were extant from Europe through North Africa, the Caribbean, and western North America, their distribution being facilitated by widespread tropical conditions and interconnected seaways.

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ROLE OF STORMS IN DEVELOPMENT OF ANCIENT MARINE RIDGE AND SWALE SYSTEM

Upper Jurassic (Oxfordian) sediments of Montana and Wyoming were deposited on a broad, shallow-marine shelf. Facies relations demonstrate that much of this shelf was characterized by a series of sand ridges separated by muddy swales. Ridges attain a thickness of about 12 m, an axial length of at least several kilometers, and a width measured perpendicular to crest less than 1 km. The crests of individual ridges are not parallel with one another or with the paleoshoreline. Analyses of directional features reveal multidirectional current vectors within individual ridges. The vertical sequence of internal sedimentary structures reveals that the ridges were constructed in distinct episodes, during which current flow was at least in the upper low-flow regime. Each episode is represented in the rocks by a unique style, scale, and vector of cross stratification. Storms are considered to be the main process responsible for the buildup of ridges, individual storms being responsible for each of the sedimentation units of which the ridges are composed. As sand supply, storm intensity, and wind direction varied from storm to storm, so the style, scale, and vectors of the resultant cross stratification varied. Fair-weather processes were minor factors in the development of the ridge and swale system.

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GLOBAL LOOK AT HIGH PRESSURES

Formation pressures higher than hydrostatic have been found in all parts of thw world during oil and gas drilling operations. The present paper analyzes the worldwide distribution of these high pressures. Data used include wells from western Europe, Hungary, Poland, Rumania, Russia, the Middle East, the Indian subcontinent, Australia, New Guinea, New Zealand, Japan, the Arctic, the African West Coast, the Red Sea, South America, and the United States. A statistical analysis to define the main geologic characteristics of high-pressure reservoirs was carried out using data from wells penetrating more than 5,000 reservoirs in the Gulf of Mexico, Santa Barbara Channel, and the Anadarko, Permian, and Uinta basins. The probability of finding high pressures in a given depth range for each of these basins has been established.

The main mechanisms responsible for the creation of these high pressures are concluded to be (1) gravitational compaction, (2) the montmorillonite-illite transformation, (3) wax seals, and (4) tectonic compression. Although in certain instances one of the mechanisms predominates, in most places a combination of them is responsible for the high pressures. Modeling of the geologic processes that have created a basin allows us to recognize in advance the type of pressures to be found there.

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SEDIMENTATION ASSOCIATED WITH TECTONISM OF ANCESTRAL ROCKY MOUNTAINS

During the Pennsylvanian and Early Permian, block-faulted tectonism created mountain ranges (Ancestral Rocky Mountains) as much as 5,000-10,000 ft in elevation in Colorado and adjacent areas. These mountain ranges and associated basins profoundly affected sedimentation; thick sequences (up to 20,000 ft) of Pennsylvanian and Permian strata, with abrupt facies changes and thickness variations, were deposited adjacent to the uplifted mountain blocks.

Early Pennsylvanian tectonic activity developed the general outlines of the north- to northwest-trending Front Range, Apishapa, Uncompahgre, Pathfinder, and Sawatch uplifts. Up to 2,000 ft of nonmarine, alluvial and coastal-plain deposits (Kerber, Sharpsdale, Flechado, and Fountain Formations) accumulated locally in narrow facies bands adjacent to these uplifts, but generally marine shale and carbonate deposition (Morgan, Belden, Casper, and Minnelusa Formations) prevailed.

During the Desmoinesian, 5,000- to 9,000-ft displacements occurred on many faults that bounded the mountain-block uplifts. Narrow bands of thick, coarse-grained arkosic detritus (Minturn, Maroon, Fountain, Sangre de Cristo, Alamitos, Cutler) surround all of the major uplifts; these arid-climate alluvial-fan and coastal-plain deposits change facies abruptly to marine carbonates (Hermosa, Morgan), evaporites (Paradox, Eagle Valley), and shales within short distances from the mountain uplifts.

During the Late Pennsylvanian and Early Permian, the area of alluvial sedimentation expanded onto the mountainous areas and laterally from them, and filled the adjacent basins with up to 3,000 ft of red, arkosic sandstone and shale (Fountain, Maroon, Sangre de Cristo, and Cutler). Local relief of the Ancestral Rocky Mountains became subdued by Guadalupian time, and erosion of low-lying land area or marine deposition (Lykins, Park City, Kaibab) prevailed.

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PALEOBATHYMETRY BY FISH OTOLITHS

Four distinct faunal zones are present in otolith assemblages of bottom muds from the eastern Gulf of Mexico, between depths of 300 and 2,000 ft. At least 2 more zones can be projected on the basis of the literature and known water-circulation patterns in the Gulf, and the outer limit of workable faunas may be far out on the abyssal plain. Within the documented depth range, surprising precision is obtained by mea-