value of mineral commodities produced, and the magnitude of state and local taxes. The quantity and value of the flows of mineral materials into and out of the state are measured and their impact assessed in this study.

The study for the State of Colorado can be visualized as a prototype of a large-scale study of a region or the entire United States. The use of data obtained by a comprehensive study of mineral commodity flows will allow formulation of a systems approach to the mineral and energy policy.

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NEW GEOPHYSICAL AND GEOLOGIC DATA ON NORTHWEST EUROPEAN SHELF AND THEIR BEARING ON SEA-FLOOR SPREADING AND OIL AND GAS EXPLORATION

Geologic and geophysical data acquired on the northwest European shelf, mainly resulting from the search for oil and gas, reveal a fundamental system of tensional rifts and horsts which form the framework controlling post-Paleozoic deposition. Deep grabens filled with Mesozoic and Tertiary strata can be traced from the northernmost North Sea through the North Netherlands trough into Holland, to link up with the Rhine and Rhone grabens. Another rift system, west of Britain includes the West Scotland, Hebridean, Irish Sea, Celtic Sea, and Western Approaches basins. Similar thick sedimentary basins occur in the Porcupine Seabight and Rockall troughs. Selected geophysical profiles illustrate the basic rift framework. The rift system is considered to be a response to crustal stresses in the northwest European plate, related to the opening of the southern part of the North Atlantic, which began in the Triassic. The Celtic Sea-Hebridean, Porcupine Seabight and Rockall basins represent abortive attempts to extend the spreading ridge northward.

The tensional rifting and faulting of the northwest European shelf control the distribution and facies of the infilling sediments and the location of several of the large oil and gas fields recently discovered in the northern North Sea.

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STRATIGRAPHIC FRAMEWORK OF ATLANTIC CONTINENTAL MARGIN

No abstract available.

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SUBSURFACE, TEMPERATURE-CONTROLLED ORIGIN OF SAN JOAQUIN VALLEY CRUDE OILS OF CALIFORNIA

Many Tertiary oil basins are convenient for studying the fundamentals of the oil generation process, because the full stratigraphic section from very young to mature source rock commonly is represented, and all stages of the oil generation process can be investigated, except advanced, postmature stages. A study was made of the origin of crude oils in the San Joaquin Valley. Shale cores ranging in age from upper Miocene to Upper Cretaceous were analyzed from depths of 1,000 ft to more than 15,000 ft. Crude oils were analyzed from producing reservoirs ranging in age from Plio-Pleistocene through Late Cretaceous. A gradual change in composition of the shale hydrocarbons was observed from unlike petroleum (immature) in shallow strata, to like petroleum (mature) in deep and warmer strata (diagenesis of the shale organic matter).

Lower Miocene and upper Eocene shales were identified as the major source rocks of the San Joaquin Valley on the basis of relatively high organic content of the shales, shale hydrocarbon maturity, and the great similarity of shale and crude oil hydrocarbons.

In the San Joaquin Valley, as in the Los Angeles and Ventura basins earlier studied, the bulk of petroleum was formed at subsurface temperatures above 100°C (212°F), where the shales are sterile to bacteria. In the San Joaquin Valley, as in the other two basins, petroleum was formed by a nonbiologic chemical process which is strongly temperature-dependent.

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COAL—OUR MOST ABUNDANT ENERGY SOURCE

Coal is this nation's most abundant source of energy. It represents 88% of the proved national fuel reserves now and 74% of all we can ultimately hope to recover. Yet coal now accounts for only about 19% of the nation's energy production and use, whereas the much more limited oil and natural gas are carrying about 78% of the energy load. In the face of an accelerating national energy demand, that fuel mix simply cannot be maintained.

It is essential that the public recognize that trade-offs are necessary between our energy and our environmental goals. We need to strike a workable balance between reasonably environmental restrictions and the total well-being of an energy-based society. In our efforts to merge our energy and environmental goals, the nation must start thinking about coal not so much as part of the problem but as part of the solution.

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YAKUTAT GROUP, AN UPPER MESOZOIC FLYSCH AND MÉLANGE SEQUENCE IN SOUTHERN ALASKA

The Yakutat Group, part of a belt of highly deformed late Mesozoic rocks deposited in deep water and extending for more than 1,600 km along the Gulf of Alaska margin, underlies an area 200 km long by 15-30 km wide of the Saint Elias Mountains foothills and adjacent coastal plain. Bedded rocks of the Yakutat Group are dominantly Cretaceous graywacke and pelite with local pebble-cobble conglomerate and sparse pods of oolitic chert-nodule limestone. Interspersed with the bedded rocks are mélanges composed of large blocks of competent rocks up to several kilometers in size engulfed in a pervasively sheared matrix of pelite or tuffaceous pelite. These clasts include externally derived or exotic greenstone, marble, metagraywacke, metachert, and diorite that are at least in part of Triassic(?) and Middle Jurassic age. Following deposition, the Yakutat was subjected to (1) pre-late Eocene compressive folding and thrusting, (2) regional zeolite to low greenschist-facies metamorphism with emplacement of early Tertiary granitic plutons, and (3) disruption by large-scale dextral shearing.

Available data suggest that the Yakutat was deposited in an oceanic trench associated with a volcano-plutonic arc. Large exotic clasts were presumably incorporated in the mélange by tectonic disruption and submarine sliding of older rocks exposed along the inner wall of the trench. A source for the sediments and exotic clasts does not exist in contiguous parts of the Saint Elias Mountains. The most probable provenance lies roughly 240 km southeast in the Chichagof-Baranof-Admiralty Islands area of southeastern Alaska. Large-scale post-middle Eocene dextral slip on the Fairweather fault is postulated to explain separation of the Yakutat Group from its source area.

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FLYSCH DEPOSITS OF ANTLER FORELAND BASIN, WESTERN UNITED STATES

In Late Devonian and Mississippian times, well-bedded, shallow- to deep-water marine, flysch-like mudstone, siltstone, sandstone, conglomerate, and minor impure limestone were deposited in a subsiding, elongate, structural foreland basin (exogeosyncline) on the continental shelf (Cordilleran miogeocline) east of the Antler orogenic continental margin. The terrigenous detritus was derived from a rising cordillera composed of Devonian and older oceanic rocks that during the Antler orogeny was first deformed and subsequently obducted eastward onto the outer carbonate shelf as the Roberts Mountains allochthon. Significant amounts of westerly derived detritus in Upper Devonian deposits reflect early Antler orogenic activity along the continental margin. Recurring uplift of the cordillera followed Antler obduction, as shown by chert detritus, derived from the allochthon, in Lower and Upper Mississippian deposits. In Late Mississippian time, clastic sediments filled the foreland basin and spread eastward across the carbonate shelf onto the craton. Volume of detritus diminished in latest Mississippian to Early Pennsylvanian time, as evidenced by widespread carbonate deposition in the Pennsylvanian.

Locally in the early Late Devonian and regionally in the late Late Devonian and Mississippian, western detritus came as a steady influx of mostly clay, silt, and sand debris, and as an irregular influx of conglomeratic debris. Many units exhibit turbidite features—graded bedding, convolute laminae, and sole marks. Some fine-clastic units contain indigenous ichnofossils and displaced fossil invertebrates, fish remains, and terrestrial plant debris; few limestones contain indigenous fossil invertebrates. The sequence and thickness of rocks vary areally, indicating irregular bottom relief which produced a complex system of sediment traps and environments.

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SOLUBILITY OF PETROLEUM IN WATER AS FUNCTION OF TEMPERATURE AND SALINITY AND ITS SIGNIFICANCE IN PRIMARY PETROLEUM MIGRATION

The aqueous solubilities of individual hydrocarbons, petroleums, and petroleum fractions increase with increasing temperatures. The rate of solubility increase is uniform from room temperature to about 100°C, after which the rate of increase rises markedly. At temperatures above 150°C, solubilities are high enough to account for the transfer of significant quantities of dissolved hydrocarbons in geologic systems.

Salinities of 350,000 ppm NaCl concentration reduce the aqueous solubilities of individual gasoline-range hydrocarbons to 5-7% of their solubilities in fresh water. A temperature drop from 150 to 25°C reduces the aqueous solubility of a whole petroleum by a factor of 4.5-20.5. Thus, the pronounced decrease in solubility of petroleums at higher salinities and lower temperatures encountered at shallow depths readily serves to release dissolved hydrocarbons during the upward movement of subsurface waters.

Other investigators have shown that 15-20% water, by volume, remains in Gulf Coast argillaceous sediments at depths below 14,000-18,000 ft. This quantity of water is sufficient to account for the primary migration of petroleum from source rocks by molecular solution.

Faults are believed to provide the pathways for vertical movement of water and dissolved hydrocarbons from great depth. Eventually the fluids are focused into sands when the fault becomes impermeable to further fluid movement. Field examples are present in the Gulf Coast and Los Angeles basin. This mechanism is restricted to argillaceous basins containing high concentrations of expandable mixed-layer clays that are buried to a minimal depth of 20,000 ft. It does not apply to carbonates or argillaceous limestones in which primary migration can occur at much shallower depths.

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PETROLOGY AND SEDIMENTOLOGY OF *OPHIOMORPHA NODOSA* AND MODERN CALLIANASID BURROWS

The trace fossil, *Ophiomorpha nodosa* Lundgren, callianasid burrows, and other similar decapod domichnia exhibit petrographically distinct wall structures that are formed by the mandibular activities of the decapods during construction of their tubular domiciles. These decapod burrows are lined with one or two layers of aggregated sand pellets, 1-10 mm in diameter. The pellets, in turn, are composed of radially oriented, 0.025-0.5-mm subspherical masses of sand grains in a fine-grained, organo-clay matrix.

Callianasid decapods live and construct ophiomorphid burrows in a wide range of marine and brackish-water environments, including estuaries, bays, lagoons, tidal pools and creeks, beaches, shallow-littoral deposits, and in sediments at least 1.5 km offshore at depths of at least 12 m. Ophiomorphid burrows of *Callianasa major* and *C. atlanticus* average only about 5 burrows/sq m in the high-energy, open-marine shore zones and increase to an average of 20 burrows/sq m in 10 m of water, 1 km offshore. The highest concentrations of actively used ophiomorphid burrows, up to 450/sq m, are in the protected, low-energy, tidal pools of the bay and lagoon shores. Contrary to previous reports, callianasid burrows and their ancient equivalents, *Ophiomorpha nodosa* Lundgren, are not indicators of the high-energy, open-marine littoral zone.

Callianasa major and *C. atlanticus* burrows extend down, vertically, to depths of 4.7 m below the sediment surface, where they branch laterally as interconnected, horizontal gallery systems of wide extent. Identical configurations of *Ophiomorpha nodosa* Lundgren are present in the Gulf Coastal Plain Mesozoic and Cenozoic sediments.

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SEQUENTIAL ANALYSIS OF TURBIDITE BASINS IN NORTH-CENTRAL APENNINES

The Miocene Marnoso-arenacei and Laga Formations form two of the largest outcropping turbidite units of the north-central Apennines, where extensive exposures make facies analysis feasible. Following a more general model proposed by Mutti and Ricci Lucchi (which utilizes bed geometry), sedimentary structures and texture, facies association (slope, submarine fan, basin plain) and sedimentary facies (conglomeratic sandstones, sandstones, sandstones with shale interbeds, shales with sandstone interbeds, chaotic deposits, hemipelagic pelites) were recognized. The value of sequential analysis for comparing stratigraphic subunits within a submarine fan system, and particularly for differentiating between inner fan, mid-fan, outer fan, and basin-plain environments, is emphasized. Recurrent patterns of sedimentation (megasequences or megarhythms, 10-100 m thick) are composed of sets of thick, mostly arenaceous, massive, graded, or crudely laminated layers, with alternate finer grained beds, which are thinly laminated in the lower part. Two main types of "ordered" megasequences are recognized: (A) positive, or thinning upward, interpreted as filling of fan valleys or channels; and (B) negative, or thickening upward, considered to be prograding outer fans along nonchanneled distributaries. Three monotonous, or random, sequences composed of finer grained sediments are also present: (C) slope deposits (thin layers, with a sandstone/shale ratio less than 1); (D) interdistributary fan deposits (thin to medium layers, sand/shale ratio less than 1; and (E) basin-plain deposits (medium to thin layers, with sporadic isolated thick turbidite units, sandstone/shale ratio greater than 1). The vertical association of these subunits, and especially those of the A and B megasequences, show both similarities and differences in the sedimentary history and tectonic control of the Miocene basins. Further application of these criteria to other turbidite basins probably will aid in predicting the location and geometry of sandstone bodies.

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