

the oil presents an impenetrable physical barrier that can persist after the oil itself is degraded by bacteria.

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Environmental Significance of Fossil Root Casts from Koobi Fora Formation (Pliocene-Pleistocene), East Turkana, Kenya

Roots and fossil root casts at East Turkana, Kenya, are valuable as paleo-environmental indicators. Roots are preserved within the Koobi Fora Formation as calcified concentric and nodular casts in lithologies independently interpreted as fluviodeltaic or lacustrine-coastal plain. Five common root cast "types" are recognized: (1) horizontal, planar root mats; (2) vertical or vertically branching root structures; (3) horizontal or horizontally branching root structures; (4) diagonally branching root structures; and (5) root clusters or balls. Root mats are usually in blocky or laminated muds. Typically, the mats extend laterally over tens of square meters, although an individual mat will be only about 5 cm thick. They appear to have grown in quiet-water lagoons. Vertical root structures are best developed in coarse-grained sands interpreted as fluvial channel, and secondarily in fine-grained silts believed to be interdistributary overbank deposits. They are uncommon in blocky or laminated lagoonal muds. Comparison of root morphologies among living East Turkana plants supports interpretation of the fossil associations. In arid environments water availability is a dominant factor in root morphology. Plants growing along intermittent streams or flood plains must frequently rely on perched water bodies or underground seepage, and therefore send out long vertical tap roots to take advantage of this limiting resource. Plants living within shallow reed swamps have no such requirement, as their roots are nearly continually immersed in ground water; during floods the plant stalk itself is subaqueous. The roots of these plants tend to extend laterally in thin mats over much of the lagoon.

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Nearshore Glacial-Marine Sedimentation; Preliminary Modeling Based on Pliocene-Pleistocene Deposits of Puget Lowlands

Environmental interpretations based on combined sedimentologic and micropaleontologic analyses together with field relations have enabled preliminary modeling of processes of nearshore glacial-marine sedimentation in the Puget Sound region (Washington and British Columbia). Although these processes are active today in the Arctic and Antarctic, ice cover makes direct observations of them difficult. Therefore, uplifted Pliocene-Pleistocene deposits were examined, using various criteria for the recognition of similar deposits in the ancient record.

Forty-six whole or partial sections from the Puget Lowlands have been measured, described, and sampled, and over 200 samples have been analyzed for foraminiferal content. These data, in conjunction with detailed textural (settling tube) analyses and available radiocar-

bon dates from the area, have enabled the delineation of sedimentary environments and their associated facies.

Modeling is based on the interaction of such parameters as thermal regime of the ice sheet, eustatic sea-level fluctuations, circulation patterns as delineated by the microfaunas, and changes in bathymetry resulting from isostatic loading and rebound and from regional tectonics. Thermal regime of the ice appears to be the major controlling factor, determining both the kinds of sediments deposited and the extent to which marine processes are able to act on them. Microfaunas show strong evidence of the mixing of a restricted shallow-water ice-shelf fauna with mid-shelf and outer-shelf forms which must be explained by any subsequent models. Glaciotectonic structures appear to be an important consideration for interpreting these sequences and may possibly be used to explain some of the present problems with regional stratigraphic correlations.

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Isotope Geochemistry of Natural Gas in Illinois Basin

Natural gas samples collected throughout the western half of the Illinois basin were analyzed chemically and isotopically to determine the origin and history of the gases. The samples were obtained from a variety of sources including groundwaters (fresh water and brines), cores, oil wells, and gas wells. Samples from shallow (50 to 500 ft; 15 to 150 m) groundwaters contain methane of bacterial origin; the  $\delta C^{13}$  values for methane from these waters are generally in the range of  $-65$  to  $-90$  parts per thousand. Samples from relatively deep (1,500 to 3,000 ft; 450 to 900 m) gas and oil accumulations contain thermogenic methane having  $\delta C^{13}$  values in the range of  $-46$  to  $-56$  parts per thousand. Gas accumulations that have isotopic compositions intermediate between those of the deep thermogenic gases and the shallow bacterial gases may be the result of mixing of gases from these two sources. There is also a general trend of increasing  $\delta C^{13}$  values southward, however, presumably reflecting increasing maturity of the source rocks in that direction as indicated by increasing coal rank. Therefore, some of the gases with  $\delta C^{13}$  values in the range of  $-56$  to  $-65$  parts per thousand may be "low grade" thermogenic gases. Additional  $C^{13}/C^{12}$  analyses and some D/H analyses are in progress to help resolve this question.

Most of the gas wells are on the margins of the basin. Gases from these wells are isotopically similar to solution gases from oil wells in the center of the basin, but often are depleted in the heavier hydrocarbons, some consisting almost entirely of methane. This chemical difference is believed to be at least partly a result of fractionation during migration of the gas toward the basin margins. Other available data are being assimilated to test this hypothesis.

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### Sources of Liability for Geologic Hazards

The range of liability for damage from geologic hazards has a basis in common law and consequently is explicit in most states as such or as modified by statute.

The range of liability extends from absolute through phases of contingent to limited or no liability. In general, absolute liability in civil cases is imposed for acts which are ultrahazardous, inherently dangerous, or public nuisances. Contingent liability exists where an act or omission is intentional or the result of a breach of a duty which leads to a foreseeable damage. Liability is limited or there is no liability where the damage resulted from an act of God, where there were supervening acts of others or where no legal injury occurred. For each potential attachment of liability, there is a defense or range of defenses. In addition, persons who speak out in a defamatory manner may incur liability for that speech unless protected by privilege or on constitutional grounds.

The legal basis for liability for damage from geologic hazards is in tort and property law (including water law) where traditionally the different degrees of liability have been imposed for differing damages to land and the use of land. Loss of vertical support, flooding, and pollution are commonly absolute liability or intentional torts. Damage from landslides and mixed geologic situations commonly fall under the rules of negligence and one would expect the same to apply to damage to man-made structures from earth movements. Interferences with groundwater supplies may result in civil liability depending on one of the four major theories of groundwater law.

Professional geologists in public practice or those who involve themselves in public debate without adequate preparation are likely target defendants where damages result from projects which incorporate their recommendations, where they fail to act when there was a duty to do so, and where their unwarranted alarms cause expensive delays.

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### Exploitation of Very Low-Grade Uranium Deposits

Where once there was great optimism about the economic exploitation of very low-grade uranium deposits (0.002 to 0.010%  $U_3O_8$ ) such as occur in the Chattanooga Shale and the Conway Granite, there now is almost equivalent pessimism. A 1978 National Research Council report "rules out" shales and granites as future uranium sources, because of the "enormous" mining and processing costs required and because the environmental impacts of the "many huge operations" that would be needed are not likely to be acceptable. Such a conclusion appears premature. Gold is won at an after-tax profit from deep-mined refractory ores in which it is found in concentrations as low as 3 ppm (0.0003%), much lower than the low end of the range cited for uranium in shales and granites; the price-grade relations for gold suggest that 0.006%  $U_3O_8$  rock could become ore at a price well below \$150/lb. The energy balance appears positive even for once-through LWR

burning; with breeders, it would be strongly positive. To meet the projected 1980 United States annual requirement of 19,000 short tons of  $U_3O_8$  from a single mine in rock containing 0.006%  $U_3O_8$  at 70% recovery would require moving a minimum of 1.24 million short tons of rock a day—a large amount, but easily within the ability of present technology (5 or 6 large copper pits would be the equivalent), and possibly not unacceptable in a time of energy scarcity. The major constraint on potential uranium supply remains political, rather than geological or technological.

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### Generation of Debris Flows and Turbidity-Current Flows from Submarine Slides

Relatively few data have been published that demonstrate that sediment gravity flows can be generated from slides and slumps. Such evidence can be found in a north-trending, seaward-prograding, continental-slope sequence which existed in central Nevada during the early Paleozoic. Translational slides on this slope are up to 400 m wide and 10 m thick. These slides moved semi-lithified, black, thin-bedded, hemipelagic limestone. Once the slide was in motion its transformation into mass flows began at its base and thin margins. Probably the rupture strength of these parts of the slide was exceeded and movement by plastico-viscous flow resulted because of a variety of factors which includes strain, mechanical shock, and incorporation of water. The development of clasts in the basal shear zone and thin margins of the slides resulted from overfolds and nearly horizontal beds within the slides which gradually separated into thin tabular fragments. Clast development progressed as the slide continued to move downslope until the base and margins of the slide attained a completely conglomeratic texture. The clasts at this stage assumed a random or subparallel orientation supported by a carbonate mudstone matrix.

Conglomeratic debris-flow deposits generated by these slides occur in channels up to 400 m wide and 12 m thick. Field data suggest that a downslope transition occurs from debris flow to turbidity-current flow. Many of the conglomeratic turbidity-current flows on the lower slope probably originated as debris flows which in turn were generated from slides higher on the slope. These turbidity-flow deposits occur in channels up to 100 m wide and 2 m thick and contain clasts identical to those in the debris-flow deposits.

A further genetic link may exist between these slides and the slide-generated mass-flow deposits. The mechanics of flow and the resulting fabric and sedimentary structures in the mass-flow deposits were influenced by the nature of the clasts generated by the slides. Preliminary data suggest that the size, shape, and original orientation of the slide-derived clasts were strongly controlled by the bedding characteristics, degree of induration, and style of deformation of the slides.

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